593

THE SUPERSONIC TRANSPORT

HEARINGS

BEFORE THE

SUBCOMMITTEE ON PRIORITIES AND ECONOMY IN GOVERNMENT

OF THE

JOINT ECONOMIC COMMITTEE CONGRESS OF THE UNITED STATES

NINETY-SECOND CONGRESS

SECOND SESSION

DECEMBER 27 AND 28, 1972

Printed for the use of the Joint Economic Committee

U.S. GOVERNMENT PRINTING OFFICE

90-912 O WASHINGTON : 1973

For sale by the Superintendent of Documents
U.S. Government Printing Office, Washington, D.C. 20402
Price $2.10 domestic postpaid or $1.75 GPO Bookstore
Stock Number 5270-01743

JOINT ECONOMIC COMMITTEE

(Created pursuant to sec. 5(a) of Public Law 304, 79th Cong.)

WILLIAM PROXMIRE, Wisconsin, *Chairman*
WRIGHT PATMAN, Texas, *Vice Chairman*

SENATE	HOUSE OF REPRESENTATIVES
JOHN SPARKMAN, Alabama	RICHARD BOLLING, Missouri
J. W. FULBRIGHT, Arkansas	HALE BOGGS, Louisiana
ABRAHAM RIBICOFF, Connecticut	HENRY S. REUSS, Wisconsin
HUBERT H. HUMPHREY, Minnesota	MARTHA W. GRIFFITHS, Michigan
LLOYD M. BENTSEN, Jr., Texas	WILLIAM S. MOORHEAD, Pennsylvania
JACOB K. JAVITS, New York	WILLIAM B. WIDNALL, New Jersey
JACK MILLER, Iowa	BARBER B. CONABLE, Jr., New York
CHARLES H. PERCY, Illinois	CLARENCE J. BROWN, Ohio
JAMES B. PEARSON, Kansas	BEN B. BLACKBURN, Georgia

JOHN R. STARK, *Executive Director*
LOUGHLIN F. MCHUGH, *Senior Economist*

ECONOMISTS

WILLIAM A. COX
JERRY J. JASINOWSKI
L. DOUGLAS LEE
LUCY A. FALCONE
JOHN R. KARLIK
COURTENAY M. SLATER
ROSS F. HAMACHEK
RICHARD F. KAUFMAN

MINORITY

LESLIE J. BANDER
GEORGE D. KRUMBHAAR, Jr. (Counsel)
WALTER B. LAESSIG (Counsel)

SUBCOMMITTEE ON PRIORITIES AND ECONOMY IN GOVERNMENT

WILLIAM PROXMIRE, Wisconsin, *Chairman*

SENATE	HOUSE OF REPRESENTATIVES
JOHN SPARKMAN, Alabama	WRIGHT PATMAN, Texas
HUBERT H. HUMPHREY, Minnesota	MARTHA W. GRIFFITHS, Michigan
CHARLES H. PERCY, Illinois	WILLIAM S. MOORHEAD, Pennsylvania
JAMES B. PEARSON, Kansas	BARBER B. CONABLE, Jr., New York
	CLARENCE J. BROWN, Ohio

CONTENTS

WITNESSES AND STATEMENTS

WEDNESDAY, DECEMBER 27, 1972

	Page
Proxmire, Hon. William, chairman of the Subcommittee on Priorities and Economy in Government: Opening statement	1
Lundberg, Bo, aviation consultant, Stockholm, Sweden	5
Capron, William M., associate dean, John Fitzgerald Kennedy School of Government, Harvard University	72

THURSDAY, DECEMBER 28, 1972

Proxmire, Hon. William, chairman of the Subcommittee on Priorities and Economy in Government: Opening statement	87
Wilson, Andrew, aviation correspondent, the London Observer	88
Johnston, Harold S., professor of chemistry, University of California, Berkeley, Calif	99
Soucie, Gary A., president, Environmental Policy Center, Washington, D.C	136
Brower, David R., president, Friends of the Earth	149

SUBMISSIONS FOR THE RECORD

WEDNESDAY, DECEMBER 27, 1972

Lundberg, Bo:
- Prepared statement 10

Proxmire, Hon. William:
- Statement of Hon. Secor D. Browne, Chairman, Civil Aeronautics Board 2
- Letter from Milton Friedman, professor, Department of Economics, University of Chicago, dated December 11, 1972, to Chairman Proxmire regarding the building of an SST in the United States 80

THURSDAY, DECEMBER 28, 1972

Brower, David R.:
- Articles:
  - "Concorde Sales Details Secret 'In Public Interest,'" from the Daily Telegraph, London, December 22, 1972 150
  - "Anglo-U.S. Talks in Concorde," from the Daily Telegraph, London, December 22, 1972 151
  - "Watt's New in Motive Power," from Your Environment, vol. III, No. 3, autumn, 1972 151
  - "Summary of Proposed Aerospace Reconstruction Finance Corporation," from Coalition Against the SST 159
  - "Aerospace Industry To Lobby for Aid Bill," from the Washington Post, December 21, 1972 159
- Letter from Richard Wiggs, secretary, the Anti-Concorde Project, dated October 14, 1972, to Senator Alan Cranston regarding Senator Cranston's amendment to the Environmental Control Act requiring SST's to conform to airport noise levels prescribed for subsonic aircraft 160
- Full-page advertisement entitled "Concorde—1962–1972: Is It Already Obsolete?" from the Times, London, December 4, 1972 ..... Fold in
- Response to Chairman Proxmire's request to submit calculations on the fuel consumption of the SST 163

Page

Johnston, Harold S.:
Prepared statement ... 102
Proxmire, Hon. William:
Article entitled "Try, Try Again—Die-Hard Supporters of Supersonic Airliner Plot To Revive Project: Officials of Boeing, FAA Say They Have Nixon's Backing, Foresee Victory This Time; Aiming for Next Generation," from the Wall Street Journal, November 1, 1972 ... 132
Soucie, Gary A.:
Article entitled "Public Interest Science—The Governmental and Public Advisory Activities of Scientists Have Great Political Impact," from Science magazine, September 29, 1972 ... 140

APPENDIX

Letters and articles submitted for the record in the context of the discussion on the SST ... 173

THE SUPERSONIC TRANSPORT

WEDNESDAY, DECEMBER 27, 1972

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON PRIORITIES AND
ECONOMY IN GOVERNMENT OF THE
JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 5302, Dirksen Senate Office Building, Hon. William Proxmire (chairman of the subcommittee) presiding.

Present: Senator Proxmire and Representative Reuss.

Also present: William A. Cox and Courtenay M. Slater, economists; George D. Krumbhaar, Jr., and Walter B. Laessig, minority counsels.

OPENING STATEMENT OF CHAIRMAN PROXMIRE

Chairman PROXMIRE. The subcommittee will come to order.

This morning the Subcommittee on Priorities and Economy in Government continues its overall evaluation of Federal transportation policy. Our purpose today and tomorrow is to assess Federal Government support for development of a supersonic transport, commonly known as the SST.

Last year, Congress voted not to fund further construction of two prototype SST aircraft. However, the SST remains a matter of continuing congressional concern, and several agencies, including the Department of Transportation, and the National Aeronautics and Space Agency, have ongoing SST research programs at the present time.

Recent press reports have also indicated that revival of Federal assistance for the SST, in some form, is under consideration by the administration, and that the cost would be in the neighborhood of $5.5 billion. That is more than three times as much as it was expected that the SST would cost the Government when it was killed last time.

While I have been assured that none of this assistance is included in the budget for fiscal year 1974, we are concerned that such a commitment may ultimately be made, and that the drain on Federal resources could be substantial.

The subcommittee will also want to discuss the progress of the British-French Concorde and its impact on a potential American SST program. Also, the Russian TU-144 which is very similar, I understand, to the British-French Concorde and is also a commercial plane being offered for sale in the world markets.

As we open these hearings, the question probably uppermost in many minds is, what plans does the administration have to revive the SST?

Earlier this year, Presidential Adviser John Erlichman reportedly stated in a preelection talk in Seattle that "the SST is not dead," and that SST planning or startup money might be included in the budget in the near future.

FAA Administrator John Shaffer predicted a move to revive the SST in the first year of President Nixon's second term, and CAB Chairman Secor Browne has publicly advocated the establishment of a Civil Aviation Production Financing Authority to undergird the development of the SST. At least in part that would be its purpose.

To shed some light on the administration's official intentions, the subcommittee invited the Secretary of Transportation, the Chairman of the Civil Aeronautics Board, and the Administrator of the FAA to testify at these hearings.

All three accepted, the CAB Chairman in person, and the DOT Secretary and the FAA Administrator agreeing to send designates. And the committee looked forward to enlightenment on the administration's intentions with regard to resumption of the SST program.

It is, therefore, with deep regret that I announce today that none of these three witnesses, nor any Government witness will appear at these hearings. The CAB Chairman, Secor Browne, spoke to me in person late last week and pleaded that he had "longstanding family commitment" and would not be able to make the hearings. The Department of Transportation and the FAA informed me via messenger yesterday morning that their agencies are, and I quote, "in transition" and they would not be able to appear.

What is the administration trying to hide? If there is nothing in the works, or nothing planned, why won't the administration witnesses come before the committee and say so? If the matter is under study and no conclusions have yet been reached, let them come before the committee and say that. But to accept the committee's invitation, and then to renege on the invitation can only leave the committee, and the public, to speculate about what revival plans the administration may have in mind.

Is it to be an outright subsidy, along the lines of the SST program which was terminated last year?

The Wall Street Journal recently put the costs of such an outright subsidy at $5.5 billion.

Or is it to be in the form of a loan guarantee, along the lines of last year's Lockheed bailout?

CAB Chairman Browne has suggested in a number of speeches the establishment of an Civil Aviation Production Financing Authority, and Commissioner Browne has submitted a written statement to the committee outlining his proposal. That statement, incidentally, will be made part of the record.

(The statement follows:)

STATEMENT OF HON. SECOR D. BROWNE, CHAIRMAN, CIVIL AERONAUTICS BOARD

Mr. Chairman, you have asked for my views in helping the Committee to assess "Federal Government support for development of a supersonic transport." In meeting your request, I first have to say that what follows are my personal views, and not necessarily those of my colleagues on the Board. Second, I must say that I have no knowledge whatever of any plans to revive the SST or to develop a new program based on Federal funding.

I have said before that Congressional disapproval of the SST program was a mistake, in my opinion. But that is spilt milk. What was done is done. Certainly, the plane which was voted down could not be resurrected without tremendous new expense. The design and engineering team, the jigs and tooling, the network of subcontractors and suppliers—all are dispersed and engaged—if engaged—in other purusits. The Government team, I am told in the magazine *Government Executive*, perhaps could be reassembled, but I doubt that the private team could be. The SST in the Boeing version we knew is, for all practical purposes, dead.

I do support the on-going programs of research into supersonic flight dynamics and the atmospheric effects of supersonic aircraft. The knowledge gained from such programs is valuable in itself, no matter what way it leads. Such knowledge might, if it were favorable, help in creating an acceptable aircraft in the future.

I continue to believe that in the long run an American SST is going to be needed. Of course, SST's built by the British/French consortium and by the Soviets are coming. Even if from the standpoint of civil transport economics one does not particularly admire the Concorde, it will be followed by even better aircraft. They will not be stopped by holding a finger in the air.

I have just returned from a visit to England and France. The most striking impression I got was the strong sense of broad national pride in the Concorde, coupled with the unanimity within both Governments. At official levels there was absolute determination that the Concorde would succeed.

I believe that unless an American SST is developed, the role of world leadership in civil aircraft, which the United States has so long enjoyed, will irrevocably be lost to the Europeans. The Concorde—not to mention the TU–144—is only the most spectacular demonstration of the European effort to seize leadership across-the-board in civil aviation development. The Europeans will offer a whole family of attractive, commercially profitable aircraft—from SST's and air buses to short-haul, short takeoff-and-land vehicles—and our airlines, in the absence of something better, will eventually buy them. Exports of civil aircraft have been the *only* consistently positive contributor to our international export balance. When one considers that fact, the potential impact of having to import our major civil aircraft should give economists nightmares.

It need not—and probably will not—come to that. An American-made SST, benefiting from the advanced design made possible by continuing the research programs now underway, is certainly feasible and—I think—desirable. The economics of such an aircraft undoubtedly would be better—because they would have to be better—and this would be in keeping with the tradition of American civil aircraft. However, the means by which an American SST can be built are by no means clear.

I have advocated a Civil Aviation Production Financing Authority operating through the method of loan guarantees to help finance major new civil aircraft development in this country. I would like to make clear that my proposal is *not* a stalking horse for an SST. I advanced this idea because I believe that the production costs for *any* new type of major civil aircraft are going to exceed what the manufacturer, the airlines, and the private capital market will provide without some form of Federal assistance. Some have criticized my proposal for not including more of the developmental, as well as the strictly production, costs. This may be merely a matter of definition. In any event, my proposal was to start some thinking now about the very real problem of the future—after the 747, DC–10, and L–1011, what? The problem covers all types of major new aircraft. Something like my proposal is essential whether or not we have an SST.

Whatever happens to my proposal, I would hope that some method for financing the future development of an SST could be found which would not place a Government design or procurement team in charge. On hindsight, a closer relationship between the manufacturer and the airlines—eliminating the Government as a technical project manager—might have been more efficient than what we had. I say this without intending any criticism of those on the Government team of the now-dead SST project. Certainly the great civil aircraft of the past were tailored closely to the specific needs of the airlines without government intervention. This development technique, patterned on actual needs, is one of the great secrets of past American achievements in civil aircraft, and I would like to see it continue.

While all these ideas are being debated, Mr. Chairman, it seems that nothing very definite is emerging at this point.

Thank you.

Chairman PROXMIRE. I regret to announce further that our invitations to representatives of two aircraft manufacturers and two

U.S. airlines also were declined. We invited T. A. Wilson, chairman of the Boeing Co.; Sanford McDonald, president of McDonnell-Douglas; Edward Carlson, president of United Air Lines, and NaJeeb Halaby, former president of Pan American World Airways. As a result of their declinations, we have, unfortunately, no one to present the picture as seen by the potential builders or purchasers of an SST. Their views would have been most useful.

Now, before I introduce Mr. Lundberg, let me say that I think that the differences on the SST are very clear. It is not a matter of whether we eventually should have or will have a supersonic transport. Some of those who favor the SST, including the Vice President of the United States, have indicated that is inevitable, and they may well be right. I am inclined to agree that that is correct; we will have an SST some day—I hope we do.

I have just completed 600 miles of a 1,200-mile walk around my State. Walking 3 miles an hour, it takes 200 hours to walk 600 miles and that is about 3 weeks, and you can appreciate, of course, the enormous value of being able to move faster. Automobiles have helped us to annihilate distances, and now we have the jet planes. This means, of course, that one of the great difficulties and obstacles that mankind has confronted in overcoming distance has been mastered by the speed of transportation. The world has become more closely knit, more interdependent and, I hope, eventually more peaceful because of the speed of transportation. It does represent progress, and very important progress.

But there are two fundamental problems that have to be solved before we proceed with an SST. I think the administration recognizes this to a considerable extent.

One is that there are environmental problems that have to be met. We have to meet the noise problem. This doesn't mean we can't meet it, I think we can and will, but it will take time, it will take resources—and I am not talking about the sonic boom at the moment, I am talking about sideline noise, which is intense.

We also have a witness who will testify on another very vital element, perhaps the critical element, that made the difference in beating the SST last time, and that, of course, is the depletion of the ozone, the increase of radioactivity on earth that might be caused by a great deal of supersonic traffic. That has to be answered one way or another before we approve or permit the SST.

In addition to solving the environmental problems, we have the problem of whether or not the Federal Government should subsidize the supersonic transport. After all, our advance so far, which has led the world in subsonic jets and in commercial aircraft, has been based on commercial development, aided very greatly, it is true, by breakthroughs in military aircraft, which have been sponsored by the Government. But we have supersonic military aircraft now, have had them for years, and the fallout from that research and production experience should be just as helpful to commercial breakthrough on an SST.

So I think that the difference really between some of the witnesses who will appear today, on the one hand, and the administration on the other, is a difference over the importance of making sure that we have solved the environmental problem, and the importance of confining the SST development, immediate SST development at least, to the commercial sector rather than to the public sector. There may be recognition on the part of all that it might very well be desirable as well as exciting and glamorous to have a supersonic transport.

Now, I have already spoken too long, Mr. Lundberg, and I am delighted to introduce you. We are honored that you have come before us.

Mr. Lundberg is an independent aviation consultant from Stockholm, Sweden. Mr. Lundberg was Director General of the Aeronautical Research Institute of Sweden for 20 years, and has written numerous scientific and technical papers on aircraft performance, design, and economics, and is highly esteemed in the aeronautic and scientific community. He is an honorary fellow of the American Institute of Aeronautics and Astronautics and a fellow of the Royal Aeronautical Society; is that correct?

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. All right, sir, will you proceed. As you know, in spite of the long introduction that I made this morning explaining the absence of some of the witnesses, we would appreciate it if you would confine your remarks to 10 minutes. We will notify you when the 10 minutes are up and then you can bring your remarks to a close.

Go right ahead, Mr. Lundberg.

STATEMENT OF BO LUNDBERG, AVIATION CONSULTANT, STOCKHOLM, SWEDEN

Mr. LUNDBERG. Thank you, Mr. Chairman.

It is, indeed, a great honor for me to have been invited to be a witness at these hearings, and to submit also a prepared statement.

The time available for preparing the prepared statement, after I had received the invitation a fortnight ago, would normally have been quite ample. It was, however, a bit short in this case because it occurred to me that I should do my utmost to finish, in a matter of 10 days instead of several months as planned, an improved version of the new method I had developed last summer for an accurate assessment of the relation between the operation economics of SST's and subsonic jets. I just managed to conclude my prepared statement, incorporating this new analysis, with the good help of four rapidly mobilized assistants, but it was simply not possible to make the prepared statement a self-contained document. Instead, I had to attach, as an integral part of the prepared statement, my previous report of August this year, to the Eighth International Congress of the Aeronautical Sciences in Amsterdam, in which I had developed the basic method just referred to. And there are also three more enclosures in this big document that you have received.

Naturally, I should now concentrate on the new method for the assessment of SST economics and the rather sensational findings obtained, because these I regard as decisively important for both of the two questions at stake; namely, the advisability of Federal Government support for a new U.S. SST program, and the impact on Concorde of such a program. But before dealing with operation economics, let me dwell a few minutes on what I call "the lesson of the past" in the prepared statement.

At the end of the 1950's, the British, French, and U.S. aircraft industries and Governments were faced with a question similar to the one that is at stake today in the United States; namely, the advisability of launching SST programs with the support of public money.

After years of intense studies at the end of the 1950's, I most emphatically warned against any development of commercial SST's, my main reasons being:

One, the sonic boom over land and sea; two, the insufficient flight safety of SST's; three, the risks, due to solar flare radiation, of damage to the fetus of fertile female SST passengers and stewardesses; four, my conviction—based on thorough studies although not as complete as of today—that for fundamental reasons it is impossible to design an SST that is not grossly uneconomic in operation; five, the extremely, not to say fundamentally, important fact that, after the introduction of the very fast and convenient subsonic jets, there is no longer any great need for or benefit from further big increases in flight speed.

Six, the fact that the market for SST's would be appallingly small, because of passengers' marginal need for being shot at ballistic speed and the high SST fare surcharge that the high operation costs would necessitate.

Seven, the fact that the resulting small SST production series would tend also to make the manufacture of such aircraft grossly uneconomic, if it is not subsidized; and, eight, the tremendous investment in research and development for every new SST design from public money that most certainly could be better spent on greatly needed advances in aviation of other kinds, such as flight safety and V/STOL development.

Excuse me, please, Mr. Chairman, for mentioning myself here, but this seems unavoidable in order to bring out clearly the significant fact that all these arguments and warnings against SST—which today, I think, are almost generally accepted as correct—were sounded from the fall of 1960 to the end of 1962 in about a dozen scientific reports and popular articles, and at four major international congresses, including the big IATA SST Conference in April 1961. Thus the warnings were clearly and repeatedly sounded before the ominous British-French decision of November 29, 1962, to develop the Concorde.

Over and above these efforts of mine, warnings that should have been far more effective than the voice of a lonely Swede were sounded by IATA, but, unfortunately, at a late stage—not until the middle of 1962. I refer to the following three "commandments" in IATA's farsighted "Ten imperative design objectives" for SST's. I quote:

> Economic operations at supersonic speed must (in spite of the sonic boom) be practicable over inhabited areas at any time of the day or night.
>
> No increase in the level of engine noise (at takeoff and landing) can be tolerated in the SSTs. In fact, engine noise from the SST must be lower than that of subsonic jets operating at present in order to permit round-the-clock operations.
>
> SST seat-mile costs must be equal to or better than—I repeat or better than—those of subsonic jets of comparable size and range operating at the time of its introduction.

Those were the three most important commandments, and I submit that, if it had been understood before November 1962 that none of these three IATA commandments could be met—which I had tried in vain to explain—no one in his right senses would have recommended the development of the Concorde. But all the warnings and the commendable advice of IATA were not sufficient to halt the SST.

The starting signal was given in November 1962.

The No. 1 lesson of the past is obviously then that the economic and political interests behind the SST had by that time already reached such a tremendous strength that not even very strong and unrefuted arguments against the SST could change the course of events.

We all know what has happened thereafter. In the prepared statement I have given further accounts of the implications of the supersonic threat as it stands today and tomorrow—I refer particularly to enclosure B of the prepared statement—and, moreover, what should be done about it.

In the latter respect I am convinced that the main condition for success in stopping a most detrimental development is that all people concerned be made to understand by all conceivable means the facts (*a*) that Concorde will be grossly uneconomic in operating, and (*b*) even more important for the new U.S. SST issue, that it is not possible ever to design an economic SST. If we do not succeed in these enlightment efforts, nothing has been learned from the lesson of the past. The Concorde mistake will be repeated, perhaps on a 10-fold scale, by a new SST project.

So let me now show a few slides to give you a hint of the method I have developed for comparing the relative operation economics of SST's and competing subsonics, with the hope that this will motivate you to study my prepared statement. Can I have slide 1, please. Slide 1 shows equation No. 5 in the prepared statement and its enclosure A.[1]

In common methods for calculating operating costs and returns on investment for subsonic and supersonic transport aircraft, a great number of parameters are included which are all given estimated absolute values. In the new method the idea is that only ratios between significant economic parameters are applied in the various equations for evaluating the economics of Concorde (or, for example, of a U.S. SST) in relation to a typical subsonic aircraft, such as Boeing 747. Because the parameters involved in this method have to be directly matched one by one, this relative method gives greater accuracy and less scope for biased assumptions than does the commonly applied absolute method, in which the economics of SST's and subsonics are calculated separately and compared afterward.

For example, the equation in this slide for the ratio C_s/C between the seat mile costs of SST's and subsonics is expressed as a function of ratios between all the significant cost items, such as the depreciation period A_s/A, the purchase price per seat ratio, P_s/P, and the productivity ration M_s/M, that is the ratio between the total great-circle mileage flown per year by an SST and, for example, by a 747. Because this parameter P_s/P, that is, the price per seat ratio, appears in several cost items, it is particularly important. Furthermore you will see that in this equation I have expressions for the ratios, SST to subsonic, of the costs of maintenance, insurance, fuel burnt, crew,

[1] See pp. 17 and 23.

cabin attendants and food, and that is about everything that counts.

Slide 2 please. Slide 2 shows figure 2 of enclosure A of the prepared statement.[1]

This is a most important slide showing the possible scheduling of Concorde over the Atlantic. You have here the clock or local time in New York and in Paris, where the local time is 6 hours ahead of the time in New York.

The Concorde advocates state that it is possible to make four single flights over the Atlantic in 24 hours (numbered here one to four). That is not so. Four flights in 24 hours would give an altogether insufficient time per day for inspection and maintenance over the time required just for the turnarounds; that is, for filling the aircraft with fuel and passengers. It is important to observe that a considerable amount of time is required for maintenance, repairs, and inspections and those times are proportional to the number of flights. This implies that, the faster the aircraft, the greater the number of flights it can make, and thus the time needed for maintenance and inspection is a greater burden to the fast SST. So I state, and no one has refuted me, that the best one can expect for any lengthy period is to make two crossings every second day and four on the days between, implying an average of only three crossings in 24 hours, compared with the two that are normally made by subsonic aircraft.

So the SST/subsonic production ratio is merely 1.5 at best.[2]

Slide 3 please. Slide 3 shows figure 3 of enclosure A to the prepared statement.[3]

Chairman PROXMIRE. Mr. Lundberg, that was 10 minutes. If you could summarize the remarks and give us your conclusion we would appreciate it.

Mr. LUNDBERG. I have just one more slide and then I will bring it to a stop. This slide shows the ratio between the seat-mile costs for SST's and subsonics as function of the productivity ratio, M_s/M, and the price per seat ratio, P_s/P. For a P_s/P of six to eight, which applies for Concorde/747, the SST will have a 2.5 to 3 times higher seat-mile cost.

Slide 4 please.

And the next and last slide, which shows figure 1 of the prepared statement,[4] is a little too complicated to explain in just a few seconds, so may I please continue for a few moments, Mr. Chairman?

---

[1] See p. 28.

[2] Even if there are no sonic-boom restrictions. For the sea-limited SST M_s/M can at best be about 1.25. See prepared statement.

[3] See p. 29.

[4] See p. 24.

This slide shows, on the scale to the right, the loss per year and per Concorde that will be suffered in relation to equal return on investment in 747's. Without explaining the diagram in detail which I understand I have not time to do—it is explained in the prepared statement—you will see here that with the currently assumed Concorde seating of 108 first-class passengers, operation of the Concorde will result in a loss per aircraft of some $17 million per year. Furthermore, if one tries to improve the situation by a so-called "stretched" Concorde, that is, a bigger plane, one could slightly improve the deficit factor, but because it is a larger aircraft calling for a greater investment, the deficit or loss will be much greater. In the example in the slide (for a doubled empty weight of the SST) it would be almost twice as high; that is, nearly $30 million per year per SST.

Let me now just make a few concluding remarks, which are summarized on the first page of the prepared statement. My most important conclusion is that it is impossible ever to design an economic SST, the main reasons for this being fundamental and inevitable. Briefly, they are the wave drag, which also causes the sonic boom; the aerodynamic heating at supersonic speed; the compromise solutions required to enable the SST to fly both subsonic and supersonic; the high SST flight altitude; and the airport noise of SST's, a problem that cannot be licked without much greater weight penalties than for subsonics. These factors together result above all in an exceedingly high purchase price per seat for Concorde, about eight times as high a price per seat than for a 747.

I shall not go into more details here, except to point out that the exceptional drawback of the SST to be almost forbidden to fly over land at the speed it is designed for implies a very serious economic constraint. Even the Wright brothers in 1903 could fly over land at the speed their plane was designed for.

To sum up, the reason why I now advise against a new U.S. SST program is that, even if the social "diseconomics," such as the sonic boom to people at sea, could be neglected, the SST can never pay its own way.

With regard finally to the significance of Concorde for a U.S. SST program, the only impact that I can see that the grossly uneconomic Concorde could possibly have is that of a deterrent example.

Thank you.

(The prepared statement, with attached enclosures, of Mr. Lundberg follows:)

Prepared Statement of Bo Lundberg

THE NEW U.S. SST ISSUE

STATEMENT

Pertaining to Federal Government Support for the Development of a U.S. SST, and. the Progress of the Concorde and its Impact on a Potential American SST Program.

by

Bo Lundberg

Presented at the Hearings of the Joint Economic Committee of the U.S. Congress on December 27-28, 1972.

SUMMARY

1. It is not possible - on the basis of current supersonic technology or foreseeable advances - to design an SST which is economically viable in competition with contemporary subsonics.

2. The main reasons for this are fundamental and inevitable: (1) the wave drag (causing the exceptionally poor lift/drag ratio of SSTs), (2) the aerodynamic heating at supersonic speed, (3) the compromise solutions required for enabling the SST to fly in two widely different aerodynamic environments, subsonic and supersonic, (4) the much higher SST flight altitude necessitating heavier fuselage skin, and (5) the fact that the weight penalties for compliance with the same airport noise standards as for subsonics (a self-evident requirement) are much greater for SSTs.

3. These basic facts result in a much smaller payload/empty weight ratio of the SST in relation to subsonics, and a much higher price/empty weight ratio, the latter also being caused (unless great subsidies are applied) by the high research and development costs, and the small production series of SSTs. This in turn results in a much higher price/payload ratio for the SST, the most important single "mathematical" reason why SSTs are bound to be grossly uneconomic.

4. The exceptional drawback of the SST to be almost totally forbidden to fly over land at the speed it is designed for is a further serious economic constraint, not experienced before in the history of aviation.

5. For these reasons I advise against a new U.S. SST program even if the "social diseconomics", e.g. the effects of sonic boom to people at sea, could be neglected.

6. Airlines operating Concorde will suffer a yearly loss of at least $ 10 million per aircraft in relation to the return on equal investment in subsonic jets.

7. The impact of the Concorde on a U.S. SST program is therefore that of a deterrent example.

Foreword

It is a great honour for me to have been invited - by letter of December 8, 1972, from Senator William Proxmire, Chairman, Subcommittee on Priorities and Economy in Government - to appear at these hearings and to submit a written Statement.

In the short time available it has not been possible for me to prepare my Statement as thoroughly as the great significance of the issue at stake would warrant. Fortunately, however, I a few months ago made a rather comprehensive analysis of, I think, most aspects pertaining to the general question of the justification of civil supersonic transports. In that analysis the decisively significant questions, the need for and the operation economics of SSTs, were dealt with in considerable detail. This Report,

"Economic and Social Aspects of Commercial Aviation at Supersonic Speeds",

was presented at the Eighth Congress of the International Council of the Aeronautical Sciences in Amsterdam, August 28 - September 2, 1972, ICAS Paper No. 72-51. As the ICAS Report in my opinion provides adequate answers to many of the questions under consideration by the Joint Economic Committee I have made it an integral part, Enclosure A, of this Statement. I therefore recommend that Enclosure A be thoroughly studied by all who wish to form an opinion about the advisability of launching a second U.S. SST program. Furthermore, the following even more recent documents are also made part of my Statement:

Enclosure B: "The Need for Reconsidering the SST Issue. Shall we Drift into the Supersonic Age by Accident?", BL Memo 25, presented at the International Congress of Communications, Genoa, October 8 - 13, 1972.

Enclosure C: "Concorde Economics", BL Memo 26, November 28, 1972. This Memo is almost identical with an article of November 12 with the same title and approved by Flight International (London) for publication probaly on December 28, 1972.

Enclosure D: "CONCORDE, sold on incorrect pretences?", Letter of December 11, 1972, to the Editor of The Times (London) in response to some of the articles in the special Concorde issue of The Times of November 28, 1972 (Ref. 1). (As of December 21 the Letter has not yet been published.)

Together with the Enclosures this Statement is thus intended to be a rather complete and up-to-date survey of all significant aspects that have bearing on the SST issue. Over and above this I have in Chapter 2 presented an improved analysis of the decisively important problem of the operation economics of current SSTs, and of SSTs conceivable in the future, in competition with contemporary subsonic jets.

1. The Lesson of the Past

At the end of the 1950s, when the possibility of designing a civil supersonic transport was under lively discussion, I made a study of the need, and possible demand, for a further big leap in the flight speed of commercial aircraft (over the speed of near-sonic jets), of the technical and economic feasibility of SSTs, and of those of their environmental effects that were foreseeable at that time. I soon arrived at the conclusion that introduction of civil supersonic flight would be a grave mistake, with most serious consequences for air passengers, for airlines, for the aircraft industry, and, not least, for the governments that would have to subsidize or finance the SST enterprises. In a way I felt disappointed by these negative results of my studies; as a former aircraft designer I could well understand the tremendous thrill and challenge of producing also civil aircraft that could fly twice or three times faster than the speed of sound. At times I almost even had a feeling of being illoyal to my aeronautical profession by opposing, as strongly as I possibly could, what was generally regarded as "the next logical step" in civil aviation which was believed to mean tremendous benefits to air passengers and great aeronautical advances.

The main reasons for my conviction that any type of SST is a mistake were, and still are:

1. The very basis for the alleged great benefits of SSTs is unfounded and indeed incorrect: This basis is the belief that, because "history has shown" that increased speed in civil aviation up to now has always been very attractive to passengers and greatly boosted aviation, this experience will necessarily apply also for high supersonic speeds. This whole "extrapolation" conjecture is wrong:

(a) With the short to moderate flight times afforded by the near-sonic jets the time on board can no longer be regarded as a serious "loss" to the passenger that one must continue to cut down almost at any cost. By and large the passenger can, of course, enjoy a meal or some relaxation about as well in the air as on the ground.

(b) The long and boring ground times to and from the airports are more dominating the shorter the flight times (and they now tend to increase appreciably due to the hijacking checks). SST passengers are likely to ask why so tremendous efforts and costs are spent in order to shorten the only reasonably pleasant portion of the whole door-to-door journey.

(c) For most passengers it takes several DAYS (for many up to a WEEK) to adjust, especially with respect to sleep, to the usually quite different local time at the destination so as to be fit for work or tourism. They will therefore often find it rather pointless to "gain" a few HOURS by an SST, in particular if this has to be paid for by a considerable SST surcharge.

2. The SST sonic boom was deemed to be quite unacceptable over inhabited land by at least a factor of 3 to 5 (at the relatively low nominal booms of 1.0 psf in cruise and 1.5 psf in climb foreseen around 1961) considering that avoidance of sleep disturbance, at night and in daytime, to "light sleepers" and sick and old people must be regarded as decisive for the acceptable boom intensity. That this must be the "critical" criterion was in my opinion quite clear because of the enormous vastness of the boom carpets making escape, and noncoverage of hospitals, etc. virtually impossible. Sleep disturbance was estimated to begin at about 0.3 psf (or even less). I furthermore judged the acceptable boom limit for people at sea as markedly higher, but that it still would be greatly exceeded by the expected SST climb boom of 1.5 psf. I made urgent pleas for carrying out night boom tests over land and special over-sea boom tests before any decisions were made on substantial investments in SST research and development.

3. On the basis of general observations by experts on cosmic radiation I

warned (in 1960-61) that occurrences of severe solar flares would impose unadvisably high risks for fertile female SST occupants because of the high sensitivity of the foetus to ionizing radiation. Alternatively the SST pilot would have to dive to subsonic flight altitudes (implying increased flight risks) but this would have to be done also at a relatively high proportion of "false alarms" (discontinued increase in dose rate) which would adversely affect punctuality and economy. A third alternative would be an unacceptably high number of cancelled SST flights during solar active years. (These warnings were in essence made also by ICRP in 1966, Encl. A, Ref. 54.)

4. On the basis of particularly thorough studies (a) of the increase in productivity of SSTs over subsonics (notoriously widely exaggerated but in fact rather modest), (b) of the by necessity high purchase cost per ton payload of SSTs (because of the complexity and small production series, etc.) and (c) of the continuous rapid improvements in the much simpler subsonic technology, I concluded that the operation cost of SSTs would be much higher than for competing subsonics, and also that the gap would probably continuously increase.

5. Because, *inter alia*, of the fact that the high operation cost would require a substantial SST fare surcharge and that the market for SSTs(i.e. the number built) would therefore be quite limited, I furthermore concluded that the production cost per SST would be so high that it was doubtful, to put it mildly, whether the SSTs could be sold at a profit unless the manufacture were greatly subsidized.

6. Finally, I emphasized that there could be no justification for accepting a higher airport noise by SSTs than that of comparable contemporary subsonic aircraft.

All these warnings were sounded in technical reports as well as in mass media between the fall of 1960 and November 1962, e.g. Refs. 2-9. I attached particular significance to the opportunities I had to present reports and explain and defend verbally my findings at the big IATA SST Conference in April 1961 (Ref. 4) and at ICAS III in August 1962 (Ref. 9).

Fortunately, I was not alone in my criticism of the SST. Some prominent aviation leaders, in particular the famous British aviation pioneer, the late Lord Brabazon of Tara, also expressed serious doubts about the SST in the 1960s (Ref. 10).

A still greater reason for optimism that irrevocable decisions to introduce civil supersonic flight could at least be postponed was caused by the following three "commandments" in IATA's far-sighted "Ten imperative design objectives" for SSTs issued in the middle of 1962 (Encl. A, Ref. 11):

(a) "SST seat mile costs must be equal to or better than those of subsonic jets of comparable size and range operating at the time of its introduction."

(b) "Economic operations at supersonic speed must (in spite of the sonic boom) be practicable over inhabited areas at any time of the day or night."

(c) "No increase in the level of engine noise can be tolerated. In fact, engine noise from the SST must be lower than that of subsonic jets operating at present in order to permit round-the-clock operations."

But all these efforts, warnings and advice were not sufficient to halt the SST. The ominous British/French contract to develop the Concorde was signed on November 29, 1962, and this resulted in an acceleration of the U.S. SST development efforts.

The number one "lesson of the past" is, obviously, that the economic and political interests (including the by itself understandable employment aspect) behind the SST projects had already at that time reached such a strength that not even very strong, widespread and unrefuted arguments against civil supersonic aviation could change the course of events.

This did not mean, however, that the enlightenment campaign, intensely continued also after November 1962, has been altogether in vain. It contributed to the conduction of several sonic boom tests and, still more important, to a slowly but steadily growing opposition against the SST. In this context I wish in particular to pay tribute to the enormous and to a great extent independent contributions that were made by Mr. Richard Wiggs, England, and by Dr. William Shurcliff, USA, in order to enlighten the general public especially about the serious environmental effects of SSTs; Wiggs founded the Anti-Concorde Project in 1966 and Shurcliff the Citizens League against the Sonic Boom in 1967. It is not possible here to mention all the many other people who have unselfishly and devotedly contributed to reveal the adverse implications of the SST (including several outstanding economists in the USA and experts on atmospheric chemistry warning against the risks of serious ozone depletion in the stratosphere that might be caused by SST exhausts). The most noteworthy result of all these efforts was that the U.S. Congress terminated the Boeing SST project by voting against further funding of the development in March 1971.

Most deplorable, however, the Concorde enterprise was not terminated in spite of the fact that all the many serious reasons that "killed" the U.S. SST are equally applicable to the Concorde. The reasons why the British and French Governments still "are determined to make the greatest success possible from Concorde" (Ref. 1) are apparently the tremendous amounts of money already spent on research and development, and the likewise vast sums advanced or promised for the manufacture of some 24 Concordes.

It thus appears that the economic and political forces behind the Concorde are stronger than ever, and the "supersonic threat" has now become even more serious as a result of the ambitions in many influential quarters in the U.S. to launch a second SST development program.

In Enclosure B I have discussed the current dilemma and threat in considerable detail. The serious consequences of continued SST developments are outlined and counter actions are proposed. The main conditions for success are that the enlightenment campaign is made still more intense and universal, and it should, in my opinion, be concentrated on the operation economics of SSTs.

2. Operation Economics of SSTs

"There is no point in technological marvels if they do not make commercial and social sense. Nobody disputes that Concorde is technically marvellous. --- But Concorde will not sell in any quantity, and it will certainly not become established as a standard form of transportation if it does not meet the profit test."

No doubt everyone must agree with these statements, referring to Concorde, made in one of the articles in The Times (Ref. 1) and also that the "profit test" is equally applicable for any new type of SSTs, e.g. a new U.S. SST project. Basically, the "profit test" ought to refer only to the operation economics of the SST, thus disregarding not only any "social sense" aspects of the SST but also its "production economics" considering that SST-sponsoring governments might wish to write off the whole or part of the R&D costs, and possibly also loans for some of the manufacturing costs (e.g. for tooling), in order to enable the SST to be sold at an attractive price.

I submit that in order to comply with the "profit test" operation of an SST should yield the same return on investment per year as is obtained by equal capital investment in competing contemporary subsonic jets.

In my ICAS paper I derived a general equation for the deficit, or "loss", that operation of an SST might incur in relation to the condition just defined, but the main part of the analysis of SST economics was based on another concept (a function of the SST fare surcharge required to yield equal return on investment) which is probably somewhat too abstract for easy understanding by laymen. The following analyses are therefore based on the simpler concept of the deficit in terms of dollars per year per SST, as compared to the return on investment obtained by subsonics, this loss-in-dollar concept being believed to be very revealing and informative.

In commonly used methods for calculating operating costs and returns on investment for subsonic and supersonic transport aircraft a great number of parameters are included which are all given estimated absolute values. In the new method described in the ICAS paper the basic idea is that only ratios between significant economic parameters are applied in the various equations for evaluating the economics of Concorde in relation to a typical subsonic "comparison aircraft", Boeing 747. Because the parameters involved have to be directly matched, this "relative method" gives greater accuracy and less scope for subjective or biased assumptions than does the commonly applied "absolute method" where the economics of SSTs and subsonics are calculated separately.

The yearly return on investment resulting from operation of one aircraft, subsonic or SST, is defined as the difference between revenue and costs divided by the purchase price, including spares, thus

$$R = (M\ S\ L\ F_n\ D - M_f\ S\ C)/I \qquad (1)$$

R = Yearly return on investment

M = Great-circle aircraft mileage per year, i.e. the sum of great-circle distancesflown between city pairs

M_f = Actual aircraft mileage flown per year

S = Number of "effective" seats, including "cargo" seats (see below)

L = Load factor, i.e. proportion occupied seats

F_n = Nominal (non-discount) fare rate, cents per seat mile

D = Fare decrease factor (= 1 - discount)

C = Total operation cost, cents per seat mile

I = Aircraft purchase price including spares

Usually M_f is noticeably greater than M; for subsonics mainly due to navigational reasons and for SSTs mainly due to overland sonic-boom restrictions. In the following it is conservatively (favouring the SST) assumed that $M_f = M$. Hence, in general

$$R = M\ S\ C(D\ L\ F_n/C - 1)/I \tag{1a}$$

M S C = Total yearly operating cost per aircraft

For an all economy-class subsonic aircraft is obtained

$$R = M\ S\ C(D\ L\ F_{ne}/C - 1)/I \tag{1b}$$

and for an SST

$$R_s = M_s\ S_s\ C_s(D_s\ L_s\ F_{ns}/C_s - 1)/I_s \tag{1c}$$

where index s denotes SST, and

F_{ne} = Nominal subsonic economy-class fare rate, cents per seat mile.

The yearly deficit in SST operation, in relation to the aforementioned "operation profit test" as regards equal return on investment and based on the investment in one SST, I_s, is obviously

$$Z = R\ I_s - R_s\ I_s \tag{2}$$

$$Z = M\ S\ C\ \frac{W_{es}}{W_e} \cdot \delta \tag{3}$$

$$\delta = \frac{x_s}{x}\left[\left(\frac{D\ L\ F_{ne}}{C} - 1\right)\frac{P_s}{P} - \frac{M_s}{M}\cdot\frac{D\ L\ F_{ne}}{C}\cdot\frac{N}{D/D_s} + \frac{M_s}{M}\cdot\frac{C_s}{C}\right] \tag{4}$$

δ = "Deficit Factor"

W_e = Operating weight empty

$x = S/W_e$ = Number of "effective" seats per unit empty weight

$P = I/S$ = Aircraft purchase price per "effective" seat, including spares

$N = \frac{F_{ns}}{F_{ne}} \cdot \frac{L_s}{L}$ = "Obtained Surcharge Number" (see Encl. A)

In eq (4) the following four ratios are particularly significant:

$x_s/x = \frac{S_s/W_{es}}{S/W_e}$ = The ratio between the number of "effective" seats to empty weight ratios

P_s/P = Ratio between the price per seat ratios

M_s/M = Ratio between the great-circle mileages per year, the "Productivity Ratio"

C_s/C = Operation cost ratio

For C_s/C the following equation is used in the ICAS paper:

$$C_s/C = \underset{\text{Const.}}{0.54} + \underset{\text{Depreciation}}{\frac{0.11}{A_s/A} \cdot \frac{P_s/P}{M_s/M}} + \underset{\text{Maintenance}}{0.09\, k_m\, P_s/P} + \underset{\text{Insurance}}{0.03\, k_i\, P_s/P} + \underset{\text{Burnt fuel}}{0.10 k_b\, B_s/B} +$$

$$+ \underset{\text{Crew}}{0.05\, k_c\, S/S_s} + \underset{\text{Cabin attendants}}{0.04\, k_a} + \underset{\text{Food}}{0.04\, k_f} \qquad (5)$$

The cost item percentages 0.54, 0.11, etc. apply for the Boeing 747 (Encl. A, Ref. 8).

A_s/A = Depreciation period ratio

B_s/B = Ratio of the average amount per year of fuel burnt per "effective" seat mile

S/S_s = Number of "effective" seats ratio, subsonic to supersonic

In eq.(5) P and P_s should not include the cost of spares (possibly except for the depreciation term). P_s/P in eq.(5) will therefore be slightly less than P_s/P in eq. (4) if the cost of spares in relation to the total purchase price is somewhat higher for SSTs than for subsonics. The difference is, however, neglected as it only amounts to about 2 percent for current prices of Concorde and 747 and their spares.

Introducing

$b = x \cdot B$ = Average amount of fuel burnt per unit empty weight and mile,

and combining eq.(4) and (5) gives

$$\delta = \left(\frac{D\,L\,F_{ne}}{C} - 1\right) \frac{P_s}{P} \cdot \frac{x_s}{x} - \frac{D\,L\,F_{ne}}{C} \cdot \frac{N}{D/D_s} \cdot \frac{M_s}{M} \cdot \frac{x_s}{x} + 0.54 \frac{M_s}{M} \cdot \frac{x_s}{x} +$$

$$+ \frac{0.11}{A_s/A} \cdot \frac{P_s}{P} \cdot \frac{x_s}{x} + 0.09\, k_m \cdot \frac{P_s}{P} \cdot \frac{M_s}{M} \cdot \frac{x_s}{x} + 0.03\, k_i \cdot \frac{P_s}{P} \cdot \frac{M_s}{M} \cdot \frac{x_s}{x} +$$

$$+ 0.10\, k_b \cdot \frac{b_s}{b} \cdot \frac{M_s}{M} + 0.05\, k_c \cdot \frac{M_s}{M} \cdot \frac{1}{\frac{1}{W_{es}/W_e}} + 0.04\,(k_a + k_f) \frac{M_s}{M} \cdot \frac{x_s}{x} \qquad (6)$$

As is seen by eq. (6) the ratio between the price per seat ratios, P_s/P, is of dominating significance. In order to facilitate a closer analysis of P_s/P I have found it clarifying to split it up into two separate ratios (as is also done in the ICAS paper) namely

$$P_s/P = \frac{i_s/i}{x_s/x} \qquad (7)$$

where x_s/x was defined above and

$$i_s/i = \frac{I_s/W_{es}}{I/W_e}$$ = The ratio between the purchase price to empty weight ratios.

Eq. (6) might thus be rewritten so as to give δ as a function of i_s/i instead of P_s/P.

Evaluations for Concorde

The most recent purchase prices indicated for the 108-seat, all-first-class Concorde and for the 747 (Ref. 11) together with the empty weights for the two aircraft yield $i_s/i = 3.42$; $x_s/x = 0.42$; and hence $P_s/P = 8.2$. These i_s/i and P_s/P values are furthermore based on the assumption of 440 passenger seats and 105 "cargo" seats in the 747, thus 545 "effective" seats, i.e. the same assumptions as in the ICAS paper. This load carrying capacity for 747s competing with Concordes around 1980 must be regarded as conservative as explained in Encl. C.

As is extensively explained in Encl. A and C the "Productivity Ratio", M_s/M, can at best reach the value 1.25 for the "sea-limited" Concorde. For reasons explained in Encl. C it would finally be most uncautious to assume a value for the depreciation period ratio, A_s/A, higher than 0.8. For the remaining parameters in eq. (6) the "optimistic" set of values indicated in Encl. A (where also "realistic" values are indicated) is assumed, thus $D = 0.71$; $D/D_s = 0.75$; $L = 0.55$; $F_{ne} = 6.5$; $C = 1.7$; $N = 1.4$; $W_{es}/W_e = 0.475$; $b_s/b = 1.8$; $k_m = k_i = k_b = 1.0$; $k_c = 0.6$ and $k_a = k_f = 0.7$.

Using these values eq. (6) takes the following form

$$\delta = (0.638 + 0.12\ M_s/M)(i_s/i) - 2.204\ (M_s/M)(x_s/x) + 0.243\ M_s/M \qquad (8)$$

The Deficit Factor δ can of course also be expressed as function of P_s/P by applying eq. (7).

Eq. (8) is presented in Fig. 1 showing δ as function of x_s/x, i_s/i and P_s/P. The i_s/i (P_s/P) and x_s/x values indicated above for Concorde yield the point "a", thus $\delta = 1.85$. By means of eq. (3) any value of the Deficit Factor δ can be transferred to the yearly deficit in dollars per SST, Z. Applying (as in Encl. A) $M = 2,100,000$ miles, $S = 545$, $C = 1.7$ and $W_{es}/W_e = 0.475$ yields the ordinate scale A to the right of Fig. 1. As the arrow from point "a" indicates, the yearly deficit would be about \$ 17 million per Concorde. In the ICAS paper the deficit was found to be about \$ 10 million on the basis, above all, of earlier, and lower, estimates of the price of the Concorde.

Prospects of Future Generation SSTs

The question whether or not it can be deemed possible to make advances in supersonic technology sufficiently great for producing an economic SST was

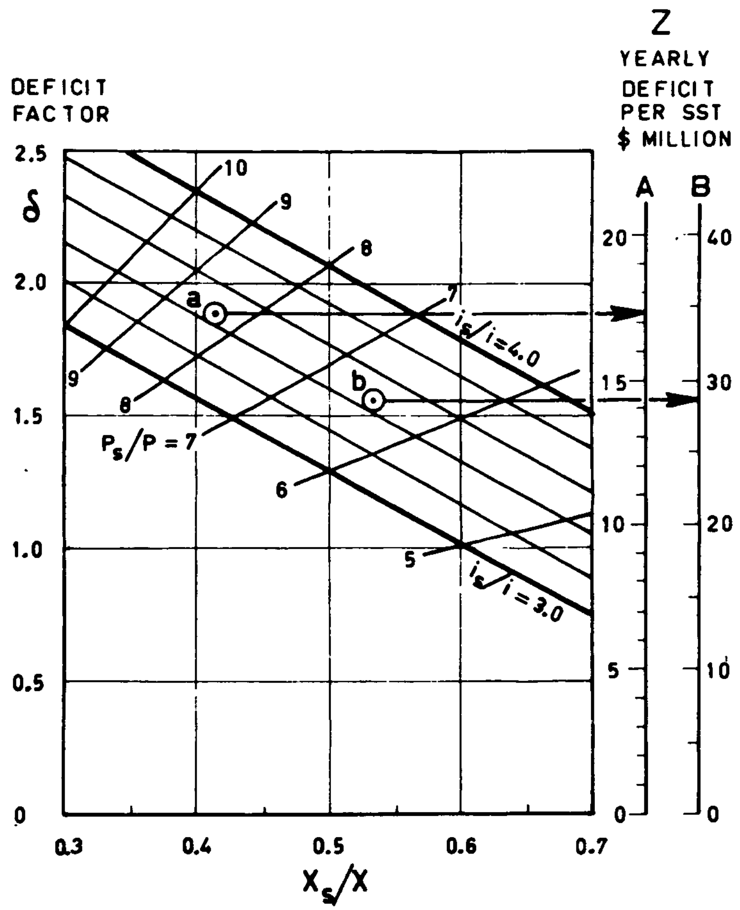


Fig. 1

The "Decifit Factor" δ and the yearly deficit, Z, in dollars, per SST (in particular Concorde) as functions of the three most significant parameters, i.e. the ratio between the payload ratios (x_s/x), the ratio between the purchase price to empty weight ratios (i_s/i) and the ratio between the price per "effective" seat (or per payload) ratios (P_s/P). The "Productivity Ratio", M_s/M, is assumed to 1.25. The relation between Z and δ is given in eq. (3). The scale "A" for Z, and in particular the point "a", corresponds to current SST technology as represented by Concorde. The scale "B" which differs from "A" by a factor of 2, is applicable to, for example, a doubled empty weight ratio, W_{es}/W_e, see eq. (3).

analyzed in considerable detail in the ICAS paper. For this purpose the equations for the relative SST/subsonic economics were combined with fundamental "laws" for aircraft design, in particular the so-called weight-growth factor, and the analyses were also supported by evaluation of preliminary future SST projects. The overall conclusion arrived at was that, even if there are no sonic boom restrictions it is not possible - on the basis of current supersonic technology or foreseeable advances - to design an SST which is economically viable in competition with contemporary subsonics.

Application of the indicated approach on the Deficit Factor concept yields the same negative result. A simple but elucidating example is the following: Let us assume (a) an unchanged relationship between supersonic and subsonic technology, implying, inter alia, a retained i_s/i level, e.g. 3.42 as for point "a", (b) that we wish to improve the relative payload ratio x_s/x by a factor of 1.3, thus attain point "b" in Fig. 1, and (c) that this improvement is brought about merely by enlarging the SST. Fig. 9 in the ICAS paper indicates that the payload capacity of the SST (Concorde) would have to be increased by a factor of at least 2.6 (e.g. 281 seats in a "Concorde successor" instead of 108) for achieving the desired increase in the payload ratio of the SST by a factor of 1.3. Consequently, the empty weight ratio W_{es}/W_e, would have to be increased by a factor of 2. As is shown by the arrow from point "b" to the scale "B" the yearly deficit in dollars in relation to equal investment in competing subsonic aircraft would amount to almost $ 30 million per SST.

At first sight this still more negative result seems surprising. The explanation is, of course, that the investment in an SST with a doubled empty weight is twice as high as for the "original" SST (i_s/i being assumed unchanged).

3. Views on Federal Government Support for the Development of a U.S. SST

In modern society government support is necessary for many different activities judged to be in the public interest. Transportation, and thus commercial aviation, is no doubt one of the fields where such support might be justified with respect to projects or enterprises which, for one reason or another, cannot be better handled by the private sector of the society.

In order for government support to be justified for any new and costly enterprise the economic and social benefits (including the real need for the activity) must clearly outweigh the costs as well as any particular drawbacks, e.g. adverse effects on the environment.

If the adverse environmental effects, or "diseconomics", are appreciable it is necessary not only that the need for the activity is substantial but, even more important, that the operation economics of the enterprise is so good that the "social diseconomics" can be paid for out of the profit.

It seems advisable to launch a new U.S. SST program only if these conditions are expected to be met with a high degree of certainty.

In Chapter 1 of this Statement and, in even greater detail in my ICAS Paper (Encl. A) I have explained why, in my opinion, the need for air passengers to fly at supersonic speed, by and large, is only marginal, but admittedly there can be different opinions about this. With respect to operation economics, however, Chapter 2 clearly confirms the main finding in the ICAS paper that neither current nor greatly improved SST projects conceivable in the future will be able to compete with contemporary subsonic jets without severe losses.

But, over and above the fact that any future SST would thus be grossly uneconomic, it would also cause a number of serious social effects and hazards. These are dealt with in detail in Chapter IV of Encl. A, which I hope will be studied thoroughly. Particular attention is drawn to the disturbance and hazards due to SST sonic booms on people at sea, a problem which so far has been greatly neglected and appears to imply still another serious environmental effect.

In view of all these negative and serious consequences of supersonic transport, and considering also the enormous monetary government investment that completion of a new SST project would require I take the liberty of advising against any Federal support for a new U.S. SST program.

There is in my opinion only one aspect that could possibly be argued in favour of a U.S. SST program, namely the considerable employment that such a program would provide in a great number of the States of the U.S.A. Surely, however, the employment aspect, which is of geographically limited significance, cannot outweigh the sum of all the serious economic and environmental drawbacks of an international scope that supersonic aviation would incur.

4. The Program of Concorde and its Impact on a Potential U.S. SST Program

Airline interest in the Concorde has so far been very insignificant. This is evident from the fact that only the two British and French state-owned airlines have ordered small numbers of the aircraft; BOAC 5 and Air France 4 Concordes. Most of the other previous option-holding airlines seem to be very reluctant to convert their options into firm orders, and some of them have even cancelled their options.

It is my belief that, if the still remaining option-holding airlines (and the airlines of China and Iran which have written "letters of intent" to buy the Concorde) thoroughly study Chapter 2 of this Statement, they will be definitely discouraged from placing firm orders on the Concorde. Chapter 2 confirms beyond doubt the finding in my ICAS paper that operation of Concorde would result in a deficit per year in excess of \$ 10 million per aircraft in relation to the return on equal investment in 747s, or similar wide-bodied jets.

I therefore feel compelled to conclude that the only conceivable impact that the Concorde enterprise could have - or indeed should have - on a potential American SST program is that of a deterrent example.

References

1. The Times, Special Report on Concorde (13 articles), Nov. 28, 1972.

2. Lundberg, Bo. Thoughts on Space and Supersonic Aviation. Address at 13th Int. Air Safety Seminar of Flight Safety Foundation. Nov. 14-18, 1960.

3. Lundberg, Bo. Should Supersonic Airliners be Permitted? New Scientist, Vol. 9, 1961.

4. Lundberg, Bo. Some Special Problems Connected with Supersonic Transport. Prep. for the IATA Conf. on Supersonic Air Transport in Montreal, April 1961. Publ. in Proceedings and as FFA Memo PE-11.

5. Lundberg, Bo. Is Supersonic Aviation Compatible with the Sound Development of Civil Aviation? Lecture to the Cranfield Society, Sept. 1961. Publ. as FFA Memo PE-12, 1962.

6. Lundberg, Bo. Preventive Measures against Intolerable Sonic-Boom Disturbances Caused by Civil Supersonic Aircraft. Presented at the Second International Congress of the "Association Internationale contre le Bruit", AICB, Salzburg, May 1962. Publ. as FFA Memo PE-14.

7. Lundberg, Bo. The Case against the Supersonic Airliner. Flight, April 5 and 19, 1962.

8. Lundberg, Bo. "The Point of No Return" would be Exceeded by the First SST. Address at the 17th Annual Conference of IFALPA in Stockholm, March 27 - April 3, 1962.

9. Lundberg, Bo. Speed and Safety in Civil Aviation. The Third Daniel and Florence Guggenheim Memorial Lecture. Pres. at the Int. Congress of the Aeron. Sciences in Stockholm, Aug. 1962. Publ. in Proceedings and as FFA Reports 94, 95 and 96.

10. Lord Brabazon of Tara. Supersonic Civil Aircraft. House of Lords Official Rep., Vol. 244, No. 7, 1962.

11. Hofton, A. Concorde Returns, Flight, Oct. 12, 1972.

Enclosure A

ICAS PAPER
No. 72 – 51

ECONOMIC AND SOCIAL ASPECTS OF COMMERCIAL AVIATION
AT SUPERSONIC SPEEDS

by

Bo. K. O. Lundberg, Aviation Consultant, former Director General of the
Aeronautical Research Institute of Sweden, Stockholm, Sweden.

The Eighth Congress of the International Council of the Aeronautical Sciences

INTERNATIONAAL CONGRESCENTRUM RAI-AMSTERDAM, THE NETHERLANDS
AUGUST 28 TO SEPTEMBER 2, 1972

Price: 3. Dfl.

ECONOMIC AND SOCIAL ASPECTS ON COMMERCIAL AVIATION AT SUPERSONIC SPEEDS [x]

Bo Lundberg [xx]
Stockholm, Sweden

Abstract

Neither current nor greatly improved SST projects conceivable in the future will be able to compete with subsonic jets in the economy-class market without enormous losses or subsidies, even if no restrictions are imposed on overland flights. Operation at about first-class fares will also be grossly uneconomic, and at such fares SSTs, operating mainly over the oceans, can only take over at most half of the small long-haul oversea first-class market and a quite insignificant portion of the economy-class market. The main reason for the deficient economics is the much higher purchase price per seat. The exceedingly high cost/benefit ratio appears to make the SSTs unjustified even if they had no adverse environmental effects. Minimum requirements for their introduction are (a) that they are forbidden to fly supersonically over land, (b) that they comply with airport noise standards for subsonic aircraft, and (c) that it has been proved that no adverse effects result from sonic booms over sea, cosmic radiation or exhaust emission in the stratosphere.

1. Introduction

For any new and costly technological enterprise of international scope to be justified there must, in the first place, be a great real need for it, i.e. the benefits must be considerable in relation to the cost. Secondly, the operation economics of the enterprise must be beyond doubt. This is particularly important if the activity causes adverse environmental effects because then the profitability must be so good that the social "diseconomics" can be paid for out of the profit. The need for and operation economics of current and future SST projects will therefore be the main subjects of this paper.

The analysis are based on the presumption that civil supersonic flight is not inevitable. The opposite assumption - in particular that the "point of no return" has been reached because some Concorde aircraft have recently been ordered - would be biased and hence unscientific. Surely, an objective judgment of the justification of the SST, the social costs of which might be found either to be totally unacceptable *per se* or to more than outweigh its benefits, can only be made on the basic presumption that mankind has still a free choice to determine whether or not, or on what conditions, this means of transportation should be introduced.

[x] This work was supported by the Swedish Board for Technical Development.

[xx] Aviation Consultant, former Director General of the Aeronautical Research Institute of Sweden.

II. The Need for the SST

All since the outset the SST proponents have maintained that the benefits of flying SSTs instead of subsonic jets would be about equally as great as the tremendous benefits of the transition from the piston aircraft to the jets. In both cases, it is alleged with little variation the "journey time is halved" and historically this causes "a great upsurge in trade" or has "a major positive influence on travelling habits".[1]

From the very beginning of my criticism of the SST I have opposed this allegation of proportionality between benefits and reduction in travel time[2-5] but apparently with no or little effect. Allegations that the travel time is halved and that therefore the SST is "enormously attractive" are still persistently repeated. [6-7] This makes it imperative to analyse these questions in even more detail than before because they are fundamental for the need for the SST.

Firstly, the door-to-door travel time is not halved. It is only reduced by 20 to 35 percent (depending upon trip distance) because of the long ground times. Secondly, and even more important, the human body and soul do not respond to percentage reductions in journey time; what is felt is the absolute travel time in hours! And the time gain by current SSTs would be only 3 to 3 1/2 hours on the longest distances they can fly, some 3,500 miles, see Fig. 1. As this gain is merely half of the 6 to

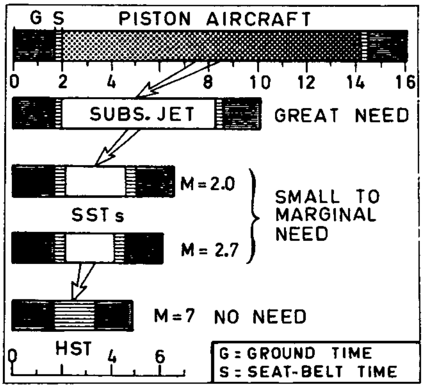


Fig. 1. Illustration of the impairment in "comfort per hour" and the rapidly decreasing time gains with flight speeds exceeding Mach 1.

7 hours saved by the jets over the pistons, the benefit of the SST, measured in hours, is only half of the benefit of the previous large increase in cruise speed.

In reality, however, the SST/subsonic-jet benefit is, in fact, for many additional reasons rather insignificant, even on long flights:

1. It was, of course, the last about 6 hours of a 3,500-mile piston flight of some 13 hours that were the most tiresome because of the long duration, and the unpleasantness and tiring effect was enhanced by the high vibration and noise in the cabin of piston aircraft and, still further, by frequent occasions of bumpy weather at the low cruise altitude of these aircraft. Consequently, the elimination by the jet of these 6 last "piston hours", e.g. over the Atlantic, was an enormous improvement which would have no equivalence whatsoever if SSTs are to replace subsonic jets.

2. Next we should compare the smoothness of flights in SSTs, subsonic jets and piston aircraft. Also in this respect remarkable allegations are still being made. A spokesman for Boeing states:

> "This same load-factor preference for the SST, as compared to subsonic jets, has been used in the economic assessment (for the SST) because we see the same factors present (as for the transition from pistons to jets). Half the flight time, the airplane flying at very high altitude, out of the weather, and a much smoother ride." (8)

Disregarding the fallacy of implied benefits due to percentage reductions in journey time the two further points are also erroneous. Both the subsonic and the SST fly above most of the "weather", providing very smooth rides x, also because they are both relieved from the high vibration and cabin noise in piston aircraft.

3. The fact that subsonic flights, thanks to the jets, have become quiet, smooth and reasonably short in duration can hardly be overemphasized. It means that the time on board is no longer a "loss" to the average passenger - as the SST proponents will have us to believe - because it can be pleasantly used for eating, reading, taking a nap or enjoying a movie, etc., occupations that are considered a plus in life when performed on the ground.

The time gain of a couple of hours by the SST might, of course, nevertheless be attractive to some hurried businessmen, but so is the spaciousness of the wide-bodied jets to the majority of passengers. And quite a few businessmen use the flight for effective work with no interference by phone calls, etc.

The "thrill of flying faster than sound" has been advertised as a plus but many passengers will certainly be more content with the less exciting subsonic speeds.

4. The speed advantage of the SST will also be questioned for a further reason, namely the great difference in local time between the two ends of most longhaul routes, e.g. over the Atlantic where 5 or more one-hour time zones are crossed. Most passengers will undoubtedly find the time gain by the SST of a few HOURS rather pointless as it normally takes several DAYS to adjust to the new local time, in particular as regards sleep, and be fully fit again for work or tourism. As a result the spaciousness and other advantages of the wide-bodied jets will to an increased extent be regarded as a greater plus than the time gain by the SST.

For all these reasons the passengers' SST-or-subsonic choice at equal fares has to a great extent been reduced to a matter of taste.

That this is so was clearly confirmed by the Gallup poll with nearly 200,000 passengers made by TWA. (9) No less than 20 percent "favored the 747" over the SST - and 14 percent "made no choice or answer" - because they considered the jumbo jet "more comfortable", "saw no need of getting to destination any faster", "enjoy longer flight time" or "prefer slower speed". Another set of replies indicated a 747/SST preference split at equal fares of about 40/60.

It should be observed that the time-difference nuisance was apparently not taken into account in this TWA poll. If it had been, the preference splits would likely have been more favorable for the subsonics. The important matter is, however, not the accuracy of the preference splits - all Gallup polls are subjected to uncertainties - but the highly significant revelation that increased speed is no longer taken for granted as the number one consideration.

To sum up, we are facing an entirely new situation. For the first time in the history of aviation there is no longer a great need for a further big increase in speed. SST proponents use to tell me that it is not the need but the demand that is important for the economics of the SST. I disagree. Admittedly, the SST/subsonic preference at equal fares might be as high as, say, 70/30, on some long routes, yielding a considerable demand. But it might also be much lower, say, 30/70. The pendulum could swing either way. The important fact is that whenever the need is insignificant or marginal there is no longer a sound concrete basis for good and reliable economics. It has, in fact, been a terrific gamble - with billions of dollars - to rely, in the prediction for SST economics, on speculative extrapolations of experience in the past that "passengers always flock to the fastest aircraft".

---

x There might be a slight difference in cruise smoothness one way or the other: As the SST flies higher than the subsonic jet its encounters with "weather" (cumulonimbus clouds, clear air gusts, etc.) are probably even more rare but they might instead result in greater accelerations and thus be more upsetting than are such encounters for subsonic passengers. More important, however, the SST will likely be subjected to much greater "weather bumpiness" at low altitudes where turbulence is far more frequent: Because the SST is more sensitive to the increases in fuel consumption and flight time that would be caused by circumnavigating turbulence (e.g. thunderstorms) in the regions of the normal subsonic climb and descent flight paths, SSTs will have to fly through regions of considerable turbulence more often than subsonics.

One thing should be obvious: The need being marginal at equal fares, the demand for the SST can only be great and reliable in the long run if its operation costs are lower than for competing subsonics so that the SST fares can be set below subsonic economy-class fares. This was, in fact, what was expected some 10 to 12 years ago, as ever since 1945 each new generation of aircraft has proved to be significantly cheaper to operate, resulting in continous reductions in fares at constant money value.[10] IATA demanded in one of its "Ten Requirements" for the SST that "SST seat mile costs must be equal to or better than those of subsonic jets...".[11]

III. Operation Economics of the SST

Theoretical Analyses

In commonly used methods for calculating operation costs for subsonic and supersonic transport aircraft a great number of parameters are included which are all given absolute values. A new method for comparing the economics of supersonic and competing subsonic jets was developed in [12]. The basic idea is that it is preferable, because it yields greater reliability and accuracy, to study the ratios between the values of the most significant parameters governing the economics, the SST parameters being related to a representative subsonic "comparison aircraft".

Even though this method is relatively simple it would be impossible to describe it in sufficient detail in a brief paper. Therefore only the highlights of the method will be presented. The reasons for the detailed assumptions are found in [12].

The yearly return on investment resulting from operation of one aircraft, subsonic or SST, is defined as the difference between revenue and costs divided by the purchase price, thus

$$R = (M\,S\,L\,F_n D - M\,S\,C)/I \qquad (1)$$

R = Yearly return on investment

M = Effective aircraft mileage per year computed as the sum of great-circle distances flown between city pairs

S = Number of seats per aircraft, in particular number of "effective" seats, see below

L = Load factor, i.e. proportion occupied seats

F_n = Nominal (non-discount) fare rate, cents per seat mile

D = Fare decrease factor (= 1 - discount)

C = Total operation cost, cents per seat mile

I = Aircraft purchase price

The relative economics for the two kinds of aircraft can be studied in many ways. For reasons that will be explained below the concept "Surcharge Number" appears to be significant. Introducing subscript s for SST the Surcharge Number is in general defined as

$$f \cdot l = \frac{F_{ns}}{F_{ne}} \cdot \frac{L_s}{L} \qquad (2)$$

$f = F_{ns}/F_{ne}$ = Nominal SST fare surcharge ratio

F_{ne} = Nominal subsonic economy-class fare rate

$l = L_s/L$ = Load factor ratio

Two specific Surcharge Number concepts are introduced: The Required Surcharge Number

$$(f \cdot l)_{req} = \left(\frac{F_{ns}}{F_{ne}} \cdot \frac{L_s}{L}\right)_{req} \qquad (2a)$$

and the Obtained Surcharge Number

$$(f \cdot l)_{obt} = \frac{F_{nas}}{F_{ne}} \cdot \frac{L_{s\,obt}}{L} \qquad (2b)$$

F_{nas} = Applied nominal SST fare rate

$L_{s\,obt}$ = SST load factor obtained at F_{nas}

Eqs. (1) and (2b) yield the following equation for the Obtained Return on Investment Ratio:

$$\left(\frac{R_s}{R}\right)_{obt} = \frac{M_s/M}{P_s/P} \cdot \frac{(f \cdot l)_{obt} \cdot y/(D/D_s) - C_s/C}{y - 1} \qquad (3)$$

P = I/S = Aircraft purchase price per seat

P_s/P = Price per seat ratio, in particular on the basis of number of "effective" seats, see below

M_s/M = Effective aircraft mileage ratio, or "productivity ratio", for one seat in the two types of aircraft

$y = D\,F_{ne}L/C$ = Subsonic revenue to operation cost ratio

D/D_s = Fare decrease factor ratio

C_s/C = Operation cost ratio

For a new-technology enterprise involving many uncertainties and hence financial risks (such as the SST) it would be desirable to achieve a higher return on investment than for competing well-established activities (subsonic operations), a minimum requirement being equal return on investment. The concept Required Return on Investment Ratio is therefore introduced. The surcharge number required for achieving a certain $(R_s/R)_{req}$ is derived from eqs. (1) and (2a)

$$(f \cdot l)_{req} = \frac{D/D_s}{y}\left(\left(\frac{R_s}{R}\right)_{req} \cdot \frac{(P_s/P)(y-1)}{M_s/M} + \frac{C_s}{C}\right) \qquad (4)$$

The Required Surcharge Number - see definition eq. (2a) - can be said to be the nominal SST fare surcharge ratio necessary for achieving, at a load factor ratio $L_s/L = 1.0$, the Required Return on Investment Ratio without the (possibly very high) SST surcharge resulting in a change of the load factor ratio.

Obviously, the lower the $(f \cdot 1)_{req}$ the better the SST economics. In general it has to be close to 1.0 for making it possible to apply nominal SST fares about as low as the nominal subsonic economy fares and still achieve the required return on investment.

Whatever the level of $(f \cdot 1)_{req}$, as computed by eq. (4), it should be compared with the Obtained Surcharge Number, $(f \cdot 1)_{obt}$, and in particular with its highest achievable value. To determine this is obviously an optimisation problem as the applied SST fare rate, F_{nas}, has to be set so that the product $F_{nas} \cdot L_{s\ obt}$ is maximum, see eq. (2b). If $(f \cdot 1)_{req} > (f \cdot 1)_{obt}$ SST operation will result in a deficit in relation to $(R_s/R)_{req}$.

One of the main features of this method for assessing SST economics is the way in which the operation cost ratio, C_s/C, is determined. This is done firstly by considering the percentages of the various cost items that contribute to the operation cost, C, for the subsonic comparison aircraft, and, secondly, by multiplying each percentage item cost with a factor indicating the known or estimated increase or decrease for SST operation of the cost of the item in question. The following equation is derived:

$$C_s/C = \underset{\text{Const.}}{0.54} + \underset{\text{Depreciation}}{\frac{0.11}{A_s/A} \cdot \frac{P_s/P}{M_s/M}} + \underset{\text{Maintenance}}{0.09\, k_m\, P_s/P} + \underset{\text{Insurance}}{0.03\, k_i\, P_s/P} + \underset{\text{Burnt fuel}}{0.10\, k_b\, B_s/B} + \underset{\text{Crew}}{0.05\, k_c\, S/S_s} + \underset{\text{Cabin attendants}}{0.04\, k_a} + \underset{\text{Food}}{0.04\, k_f} \quad (5)$$

The cost item percentages 0.54, 0.11, etc. apply for the Boeing 747.[8] Furthermore

A_s/A = Depreciation period ratio

B_s/B = Ratio of the average amount per year of fuel burnt per seat mile

S/S_s = Number of seats ratio, subsonic to supersonic

As is seen C_s/C is above all dependent upon the important parameters P_s/P and M_s/M and this applies also to the Surcharge Number equation (4). Eq. (5) may therefore be written

$$C_s/C = \alpha \frac{P_s/P}{M_s/M} + \beta P_s/P + \gamma \quad (5a)$$

(The expressions for α, β and γ are obtained from eq. (5).)

The price per seat ratio, P_s/P, will be analysed in the following Section.

As regards the effective mileage per aircraft ratio, M_s/M, leading SST proponents [8, 13-16] have alleged that the productivity (per seat) of SSTs is superior to that of subsonics in proportion to the cruise speeds of the two types.

This is incorrect as it neglects (a) that the ratio between average block speed and cruise speed is substantially smaller for the SST than for the subsonic, (b) that each flight is burdened by a turn-around time for reloading and refuelling and (c) that the total maintenance time per year (e.g. for daily inspections and major overhauls) is also roughly proportional to number of flights, not to hours of flight. In particular the aspects (b) and (c) imply that the increase in productivity of an SST due to its increased speed is greatly offset by the increased number of flights (e.g. on a given route) made possible by the speed increase.[4]

The correct expression for the increase in productivity per seat by the SST is, of course, M_s/M, which is much smaller than the ratio between the cruise speeds of the SST and the subsonic jet. I submit that the concept "productive speed" be introduced and defined as

$$V_{prod} = M/(365 \cdot 24) \quad (6)$$

As will be exemplified in the following V_{prod} for SSTs is rather modest and definitely subsonic.

Reverting to the possible deficit in SST operation, this should be related to the Required Return on Investment. Furthermore one should, of course, compute the deficit on the basis of the same magnitude of investment in subsonic aircraft as in SSTs thus preferably on I_s (for one SST). The yearly deficit is obviously

$$Z = \left(\frac{R_s}{R}\right)_{req} \cdot R\, I_s - R_{s\ obt} \cdot I_s \quad (7)$$

Z = Deficit per year and SST related to $(R_s/R)_{req}$

From eqs. (1), (2a), (2b) and (7) is obtained

$$Z = M_s\, S_s\, D_s\, F_{ne}\, L\ \ \Delta(f \cdot 1) \quad (8)$$

$$\Delta(f \cdot 1) = (f \cdot 1)_{req} - (f \cdot 1)_{obt} \quad (9)$$

Eq. (8) is convenient to use when $(f \cdot 1)_{req}$ has been computed on the basis of eq. (4) and $(f \cdot 1)_{obt}$ is estimated according to eq. (2b) for a known applied SST fare surcharge ratio, F_{nas}/F_{ne}, and an estimated resulting load factor ratio, $L_{s\ obt}/L$.

For studying Z as function of the main significant "relative parameters" the following equation, derived from eqs. (1) and (2b), could be used

$$Z = \frac{M\ S\ C}{S/S_s}\left[\left(\frac{R_s}{R}\right)_{req} \cdot (y - 1)\, P_s/P - M_s/M\left(y \cdot \frac{(f \cdot 1)_{obt}}{D/D_s} - \frac{C_s}{C}\right)\right] \quad (10)$$

For the purpose of studying the prospects of improving the operation economics of future generation SSTs it is advantageous to split P_s/P into two significant components:

$$P_s/P = \frac{(I_s/W_{es}) \;/\; (I/W_e)}{(S_s/W_{es}) \;/\; (S/W_e)} = \frac{i_s/i}{x_s/x}$$

$i = I/W_e$ = Purchase price per ton empty weight

i_s/i = Purchase price per ton empty weight ratio

$x = S/W_e$ = Number of "effective" seats per unit empty weight, being proportional to W_p/W_e

W_p/W_e = Payload to empty weight ratio, payload being defined as a full load of "effective" passengers

$$x_s/x = \frac{S_s/W_{es}}{S/W_e} = \frac{W_{ps}/W_{es}}{W_p/W_e}$$ = Ratio between the payload ratios

S and S_s are the numbers of "effective" seats, i.e. the sum of real passenger seats and "cargo seats". The latter concept is introduced in order to account for the extra revenue that is obtained for cargo carried in excess of passenger baggage. Due consideration should be taken to the fact that the revenue per ton cargo is smaller than the revenue per ton passengers.

From eqs. (4) and (5) is obtained

$$(f \cdot l)_{req} = \left(\frac{F_{ns}}{F} \cdot \frac{L_s}{L}\right)_{req} = \frac{D/D_s}{y}\left[\frac{i_s/i}{x_s/x}\left(\frac{K_1}{M_s/M} + K_2\right) + K_3\,\frac{1}{x_s/x} + K_4\right] \quad (11)$$

$$K_1 = \left(\frac{R_s}{R}\right)_{req} \cdot (y - 1) + \frac{0.11}{A_s/A}$$

$$K_2 = 0.09\,k_m + 0.03\,k_i$$

$$K_3 = 0.10\,b_s/b$$

$$K_4 = 0.54 + 0.05\,k_c\,S/S_s + 0.04\,k_a + 0.04\,k_f$$

$b = B \cdot x$

b = Burnt fuel per unit empty weight and mile

Applications, especially to Concorde/747

a. Parameter Values

The assumed values of the various parameters in the equations above are listed below with but a few explanations in some important cases. Detailed reasons for the assumptions are found in [12].

Number of Seats Ratio, S/S_s. Most of the evaluations are based on the 128-seat Concorde and the 440-seat Boeing 747. Whereas the former can take no cargo, the latter can take a substantial load of cargo, corresponding to 105 "cargo seats", assuming that on a weight basis the revenue for cargo is half of that for passengers. The number of "effective" seats in the 747 is thus 545 and S/S_s = 4.25. This corresponds to an appreciably lower maximum payload in lbs for the 747 than is quoted in Jane's [22] because the available cargo compartment volume rather than weight is limiting when having a low density load. Comparing Concorde with the 490-seat 747, i.e. 590 "effective" seats, S/S_s is 4.6. BOAC's all-first-class 104-seat Concorde compared with a 350-seat 747, carrying about 465 "effective" seats yields S/S_s = 4.5.

Price per Seat Ratio, P_s/P. The price for Concorde, except spares, has for some time been estimated at about $ 34 m, which is to be compared with $ 26 m for 747. This yields a range of P_s/P from 5.5 (S/S_s = 4.25) to 6.0 (S/S_s = 4.6). According to Pan Am [17] the 104-seat Concorde would at $ 60 m with spare parts cost "more than twice as much" as a 350-seat 747 thus yielding P_s/P at least 9.0. It could be objected that there are no all-first-class, 350-seat 747 flying today, but what is significant is that it is potentially possible to apply a first-class comfort standard to 747s of this or "stretched" capacity. It seems therefore realistic to extend the possible P_s/P range to 9.0.

Effective Aircraft Mileage Ratio, M_s/M. As follows from the text to Fig. 2 Concorde can hardly average more than 3 single Atlantic flights per 24-hour day during longer service periods if it is to have the same average time per flight available for inspection and maintenance (about 3.5 hours) as a subsonic jet making 2 single flights per day. This means that M_s/M can hardly exceed 1.5 assuming the same total number of service days per year. Because of its greater complexity and the kinetic heating at each flight, etc., the SST will, however, likely require a longer total off-service time per year for major overhauls and repairs and this reduces M_s/M.

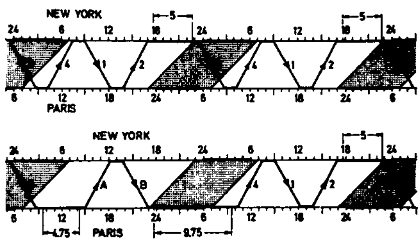


Fig. 2. Assuming 3.25 hrs flight time and 1.5 hrs turn-around time, 4 single flights per 24 hrs allow a daily maintenance time of only 5 hrs, i.e. 1.25 hrs/flight. For a subsonic jet making 2 flights in 24 hrs of 7 hrs each the daily time for maintenance is 7 hrs, i.e. 3.5 hrs/flight. Three daily SST flights yield an average daily maintenance time of 9.75 hrs, i.e. 3.25 hrs/flight.

A still further reduction will be caused by the fact that the subsonic jet often produces a greater mileage per 24-hour day than is obtained by 2 single flights between, for example, New York and Paris, e.g. by longer direct flights, such as Frankfurt to New York, or by "tag-end" flights to or from the coastal cities before or after the flights over the Atlantic. Even if there are no boom restrictions the SST is much inferior as regards this "range flexibility", because short supersonic "tag-end" flights are uneconomic and usually pointless to the passengers.

For these reasons the lower limit for the possible range in M_s/M is in the no-boom-restriction case assumed to 1.25 whereas the upper limit is optimistically set at 1.5. The latter value, however, presupposes a Mach number close to 3.0 and/or extreme measures and costs to reduce overhaul, daily maintenance and turn-around times. Note that the "productive speed" of a Mach 2+ SST averaging for example 2.8 Atlantic crossings per day (which might correspond to $M_s/M = 1.4$) during 320 days/year is only 360 mph.

For the "sea-limited" SST - forbidden to fly supersonically over inhabited land, except, perhaps, over some sparsely populated areas - the achievable Mileage Ratio will be greatly reduced, in particular because of the necessity to circumnavigate islands and mainland areas located on the great circle routes, and also because of the practically non-existent possibilities to supplement the main oversea operations, e.g. over the Atlantic, with supersonic "tag-end" flights, (SST operation at subsonic speed will usually be out of the question for economic reasons). Detailed studies indicate that it will be very difficult for the sea-limited SST to attain $M_s/M = 1.25$ and that a realistic productivity ratio falls rather close to 1.0.

BOAC intends initially "to operate two Concorde services each day from London to New York, three each week on the routes to Sydney and Johannesburg, and two a week across the Soviet Union to Japan". (18) Assuming that these services are all round-trips the great-circle distances flown per week would total 218,000 miles. This is to be achieved by 5 Concordes, but let us conservatively assume that one serves as reserve, thus that the schedule can be carried out by 4 aircraft. A typical mileage per week achievable by 4 subsonic jets (each making for example one New York - Paris roundtrip per day) is of the order 196,000 miles. The Concorde mileage is thus only 10 % better, i.e. $M_s/M = 1.1$. It should be noted, however, that although the BOAC schedule could possibly be improved later on, the corresponding weekly mileage assumed for 4 subsonic jets is probably unduly small. Furthermore, SST operation will likely require a higher proportion reserve aircraft and a longer total off-service time for overhauls. The net effect of all this could well be $M_s/M = 1.0$, or even smaller.

Fare Decrease Factor Ratio, D_s/D. As is well-known considerable discounts are often applied on the nominal subsonic economy-class fares whereas discounts are comparatively rare on first-class services. As the SSTs will be catering largely for business and first-class passengers they would also have rather small revenue reductions due to discounts. A spokesman for the Concorde enterprise (19) has suggested that realistic values would be $D_s = 0.95$ and $D = 0.71$, thus $D/D_s = 0.75$.

Subsonic Revenue to Operation Cost Ratio, y, is obtained on the assumptions $D = 0.71$, $F_{ne} = 6.5$, $L = 0.55$ and $C = 1.7$, yielding $y = 1.5$.

Remaining Parameters. Most of the remaining factors in eq. (5) for C_s/C are assumed to have "optimistic" and "realistic" values, thus A_s/A = 0.9, 0.8; B_s/B = 3.4, 3.6; k_c = 0.6, 0.75; $k_a = k_f$ = 0.7, 0.8. The factors k_m, k_i and k_b are all assumed to have the value 1.0. These assumptions yield α = 0.12, 0.14; β = 0.12 (jointly) and γ = 1.07, 1.12.

b. Evaluations

The Operation Cost Ratio, C_s/C, is shown in Fig. 3 as a function of M_s/M and P_s/P, and the indicated values for α and β. As is seen P_s/P is by far the most important factor for C_s/C which might obtain values roughly from 2.2 up to 3.5 when M_s/M varies from 1.0 to 1.5.

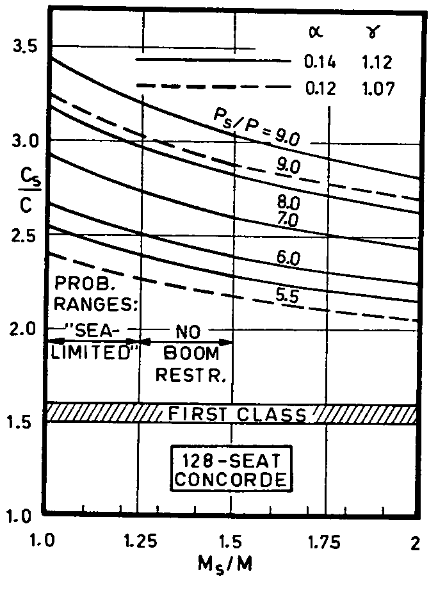


Fig. 3. Operation cost ratio as function of productivity (great-circle mileage) ratio, M_s/M, and price per seat ratio, P_s/P.

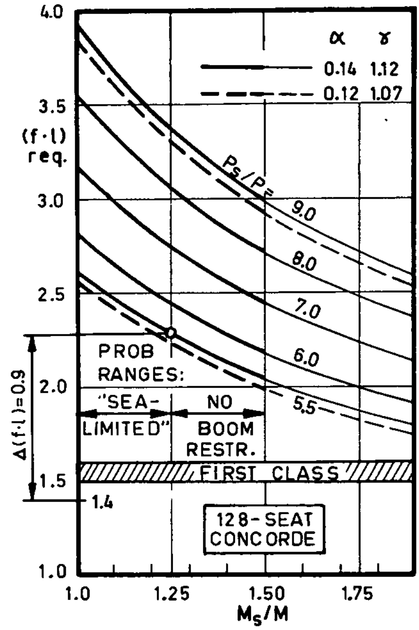


Fig. 4. Required Surcharge Number, $(f \cdot l)_{req}$, as function of productivity ratio and price per seat ratio.

Surcharge Number. In Fig. 4 $(f \cdot l)_{req}$ for $R_s/R = 1.0$, is shown as function of the same parameters as for C_s/C in Fig. 3. P_s/P is obviously the most significant factor, followed next by M_s/M, whereas α and γ have relatively little importance. Within the realistic range of M_s/M (1.0 to 1.5) the Required Surcharge Number varies from 2.0 to 3.9. In view of recent information about the price for Concorde, see above and (7, 23), it seems unrealistic to assume P_s/P lower than 6 to 8 at the time when Concorde is expected to enter service. Thus $(f \cdot l)_{req}$ would have to be of the order 2.5 to 3.5 in the "sea-limited" case. However, even if as low a value as 2.3 is assumed this would apparently far exceed the Obtainable Surcharge Number. It has been indicated (1) that for the 128-seat model the surcharge should preferable be 40 % over the subsonic economy-class fare level. Assuming the same load factor for SST as for subsonic, $(f \cdot l)_{obt}$ would thus be 1.4.

Deficit per year and SST, Z. For the values $\Delta(f \cdot l) = 2.3 - 1.4 = 0.9$, $S_s = 128$, $F_{ne} = 6{,}5$, $D_s = 0.95$, $L = 0.55$, $M_s/M = 1.25$ and assuming $M = 2{,}100{,}000$ miles for the subsonic aircraft (e.g. an average of 7,000 miles per day during 300 days of the year) eq. (8) yields Z = \$ 10.3 million per Concorde and year.

In Fig. 5 the yearly deficit as a function of M_s/M is computed on the basis of eq. (10) for a few selected combinations of the Surcharge Ratio and the Load Factor Ratio, using the realistic set of values for the other parameters. The curve 1.4/1.0 is believed to represent the lowest achievable deficit because an SST surcharge of 40 % probably yields about maximum revenue for the 128-seat Concorde (see above) and because it seems overly optimistic to assume $L_{s\ obt}/L$ significantly above 1.0 for several reasons: Firstly, also SSTs will suffer from seasonal variations, secondly, their inferiority with respect to making "tag-end" flights will tend to reduce the overall load factor and, thirdly, the SST night flights, e.g. over the Atlantic, will be particularly unpopular because the passengers will be practically deprived of sleep for one night (see Fig. 2). The two latter factors are believed to about outweigh the definite advantage with the SST with respect to "schedule flexibility": An SST can, for example, make popular daylight flights from North America to Europe whereas most subsonics fly at night on this route direction.

Let us, however, optimistically assume that the SST/subsonic Load Factor Ratio could be as high as 1.2. Fig. 5 shows that the yearly deficit per 128-seat Concorde would nevertheless be \$ 7 m to \$ 8 m.

The arrows in Fig. 5 illustrate in principle the optimisation problem involved when determining the SST surcharge: If the surcharge is increased from 40 % to 60 % with the hope of increasing $(f \cdot l)_{obt}$ from 1.4 to 1.6 the SST load factor might instead be reduced by 20 % yielding an $(f \cdot l)_{obt}$ of only 1.28 and an increase in the yearly deficit of over one million dollars.

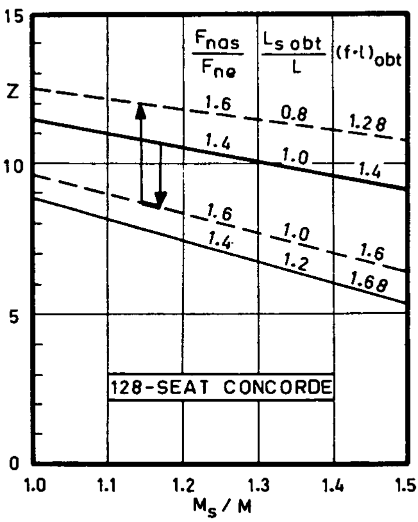


Fig. 5. Yearly deficit in million dollars per 128-seat Concorde (costing \$ 34 m).

Prospects of Future Improvements

a. Second Generation SSTs

It seems now to be widely accepted that Concorde's economics is doubtful, but the magnitude of the deficiency is apparently not recognized. The general belief seems to be that it is a marginal case and that consequently a "stretched" version of the Concorde, having a moderate increase in payload, could be designed and be an economic success. The Concorde Consortium is in fact said to study such a project.

There are also many indications of strong beliefs in the USA that it is possible to design a profitable SST and that therefore a new American SST project will likely be initiated in a few years. [20.21]

In view of these ambitions it is highly important to find out in quantitative terms the aeronautical and other constraints that must be overcome for making SSTs economically viable.

Fig. 6 is prepared for studying this problem in particular with respect to a Concorde successor, or, in general, a "second generation" SST defined as a Mach 2 to 2.2 aircraft based on evolutionary rather than revolutionary advances in supersonic technology. The figure is based on eq. (11) and shows $(f \cdot l)_{req}$ as function of the two most important parameters i.e. the ratio between the payload/empty-weight ratios, x_s/x, and the relative purchase price/empty-weight ratio, i_s/i. The productivity ratio, M_s/M, has been chosen to range from

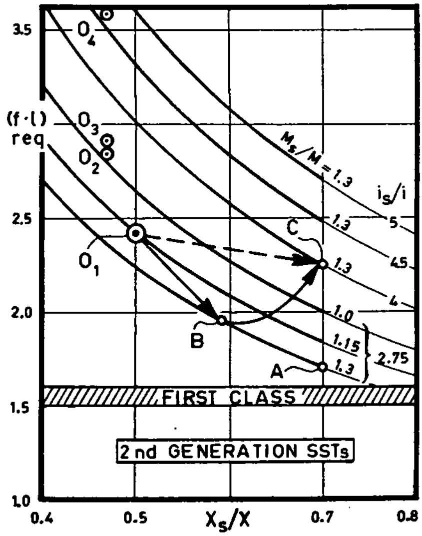


Fig. 6. Required Surcharge Number for second generation SSTs as function of the relative payload to empty weight ratio, x_s/x, and the relative price to empty weight ratio, i_s/i.

1.0 to 1.3 assuming that the sonic boom still limits supersonic operation almost exclusively to oversea routes. For the other parameters the realistic set of values indicated above has been applied.

The 128-seat Concorde is taken as the basis for possible improvements. Its x_s/x is about 0.5 based on S/S_s = 4.25 and empty weights 170,000 lbs for Concorde and 356,000 lbs for 747. [22] Further assumptions for this Concorde version, marked O_1, at $(f \cdot l)_{req}$ = 2.4, are M_s/M = 1.15 and i_s/i = 2.75 based on the earlier price estimates I_s = \$ 34 m for Concorde and I = \$ 26 m for 747 (I_s/I = 1.31).

It may be emphasized here that this i_s/i level, which corresponds to the lowest P_s/P level indicated above, namely 5.5 (= 2.75/0.5), now appears to be based on a too low Concorde/747 price ratio. According to recent information [23] the prices without spares are \$ 36 m for the 104-seat Concorde and \$ 23.85 m for 747, yielding I_s/I = 1.51. The prices with spares are \$ 44.345 m and \$ 28.345 m respectively, i.e. I_s/I = 1.56. The relative price/weight ratio i_s/i would thus be 3.16 without and 3.28 with spares. On the basis of M_s/M = 1.15 and the other detailed assumptions above (e.g. 350 seats and 465 "effective" seats for 747) P_s/P would be 6.7 without and 7.0 with spares, and $(f \cdot l)_{req}$ would be 2.84 and 2.91, respectively. The corresponding points O_2 and O_3 are marked in Fig. 6 at the approximate relative "effective" passenger load ratio 0.47 that applies for the seating capacities in question.

It may furthermore be noted that for the 104-seat Concorde i_s/i would be 4.2 on the basis of Pan Am's statement that Concorde (with spares) would cost twice as much as 747. This estimate might be realistic anticipating rises in Concorde prices for later deliveries. It corresponds to P_s/P = 9.0 (see above) and x_s/x = 0.47, these data being marked as point O_4 in Fig. 6. Finally, all the points O_1 - O_4 are based on purchase prices which do not cover the high R&D costs for the Concorde. Considering the total economics of the Concorde enterprise the points are therefore located on too low i_s/i levels.

In spite of all this i_s/i = 2.75 and point O_1 will, very conservatively, be retained as the basis for the following analysis.

A substantial improvement in SST economics, i.e. reduction in $(f \cdot l)_{req}$, can only be achieved by great increase of the ratio between the payload to empty weight ratios (thus increase in x_s/x); the possibilities of increasing M_s/M are very limited and the other parameters have a relatively minor significance. In order for the SST to be reasonably competitive in the first-class market the necessary reduction in $(f \cdot l)_{req}$ is at least from 2.4 to 1.7. Assuming that M_s/M can be improved from 1.15 to 1.3, by extreme efforts to reduce maintenance and overhaul times, it follows from Fig. 6 that x_s/x must be increased from 0.5 to 0.7, i.e. by 40 %, for point "A" to be attained.

It follows, however, from eq. (11) and Fig. 6 that this great increase in x_s/x must not be appreciably offset by a consequential increase in the relative price per ton empty weight, i_s/i. We shall therefore in the first place discuss the possibilities and implications of bringing about a 40 % increase in x_s/x under the assumption that there are no appreciable advances neither in supersonic technology, as represented by Concorde, nor in subsonic technology, implying an approximately unchanged ratio between the cost/weight ratios, i_s/i (= 2.75). The necessary improvement in x_s/x would thus have to be achieved mainly by building the new SST very much larger than Concorde. The development and manufacture of such a large Concorde successor would, however, take considerable time, during which also enlarged subsonic jets will be developed either by "stretching" existing types or by new designs. It is conservatively assumed that the subsonic payload/empty weight ratio is improved by only 10% over the current 747 and that this can be achieved at a retained cost/weight ratio, i.

This improvement in the subsonic x means that the new SST would need to have a payload/empty weight ratio = (1.4 · 1.1 - 1) = 54% better than the 128-seat Concorde. For achieving such an improvement the payload of a Concorde successor would have to be increased from 128 to 197, i.e. by 69 passengers or 69 · 210 = 14,500 lbs. This primary weight increase causes in the first place an additional direct weight increase for seats and such equipment which would grow roughly in proportion to number of passengers, e.g. galleys, toilets, cabin attendants, part of the air conditioning system and a portion of the fuselage (for holding the additional passengers). This addition is estimated to fall between 50 and 100% of the increase in payload.

As is well-known to aircraft designers an initial weight increase inevitably causes secondary or indirect weight increases if the performance of the aircraft project, in particular its range and cruise and landing speeds, are to be retained at original levels. The ratio between the resulting total weight increase and a primary weight increase is commonly called the Weight Growth Factor, or WGF. In a paper to the R.Ae.S. in 1963 (5) I pointed out that WGF is much greater for SSTs than for subsonic jets (about 9 vs 5) "because of the higher relative fuel weight" and warned that "This impairs the possibilities of "stretching" an SST of a given basic type even if there were no sonic-boom limitations".

This warning will now be repeated and explained in greater detail because of the tremendous significance of the WGF with respect to the possibility of improving the economics of SSTs. In support of the statement the following equation (derived earlier (24)) was presented using here somewhat modified symbols. Furthermore the primary weight increase is defined as comprising only the increase in payload, thus including in the WGF concept the direct increases in empty weight (seats, etc.) due to the increase in payload.

$$g_p = \frac{\Delta W_t}{\Delta W_p} = \frac{k}{1 - \frac{W_{ewo}}{W_{to}} - \frac{W_{fo}}{W_{to}}} = \frac{k}{\frac{W_{uo}}{W_{to}}} \qquad (12)$$

The symbols and the underlying concepts in eq. (12) are the following:

g_p = Weight Growth Factor referred to the increase in payload

W_t = Gross weight

W_p = Payload. Note that W_p in this WGF analysis is the total payload which, if also cargo can be carried, is greater than a full load of "effective" passengers.

ΔW_t = Resulting total weight increase

ΔW_p = Increase in payload

k = Increase factor, 1.5 to 2.0, see above

$k \cdot \Delta W_p = \Delta W_i$ = Initial weight increase

W_f = Fuel weight

W_u = "Useful load", this somewhat inadequate name being retained from (24)

W_e = Operating weight empty

W_{ep} = (k - 1) W_p = The portion of W_e that is roughly proportional to payload

W_{ew} = The portion of W_e that is roughly proportional to gross weight, e.g. weight of wings (at retained landing speed, i.e. wing loading) tail surfaces and landing gear, as well as of a considerable portion of the fuselage (the one not included in W_{ep}) and also of the major portion of the power plant assuming an unchanged thrust to engine weight ratio

W_c =. The portion of W_e that is roughly constant, i.e. independent of changes in gross weight, such as crew and cockpit, or the like, and minor portions of the weight of the power plant and the hull (e.g. wing tanks)

$$W_t = \overbrace{W_{ew} + \underbrace{W_c + W_{ep} + W_p}_{W_u}}^{W_e} + W_f \qquad (13)$$

Index o is used for a basic or original aircraft, e.g. the current Concorde, and index 1 is used for a "final" project resulting from a primary weight increase. Index s is deleted in this analysis until SST/subsonic comparisons are made. It follows from the definitions that

$\Delta W_t = k \cdot \Delta W_p + \Delta W_{ew} + \Delta W_f$

$\Delta W_{ew} = \Delta W_t \cdot (W_{ewo}/W_{to})$ = The increase in empty weight required for retained wing loading and speed, thus including also the increase in power-plant weight

$\Delta W_f = \Delta W_t \cdot (W_{fo}/W_{to})$ = Increase in fuel weight required for retained range at unchanged fuel consumption

It may be emphasized that the dependence of the weight of different portions of the aircraft on the gross weight and other design parameters is a highly complex matter. It is believed, however, that the simple linear approach applied here is adequate for the purpose of broad studies of this kind.

Introducing W_u from eq. (13) eq. (12) can be written

$$g_p = \frac{1}{W_{po}/W_{to} + \sigma} \qquad (12a)$$

W_{po}/W_{to} = Original payload to gross weight ratio

$$\sigma = \frac{W_c/W_{to}}{k} \qquad (15)$$

W_c/W_{to} = Original constant weight to gross weight ratio

σ = Original "effective" constant weight to gross weight ratio

The weight growth factor, g_p, is shown in Fig. 7 as function of σ for the W_{po}/W_{to} levels that apply for Concorde and 747 (0.07 and 0.21 resp.). An estimate is also made for an advanced future SST project discussed later. For reasons indicated below, σ will normally be about 0.03 yielding g_p = 10 for Concorde-technology SSTs and about 4 for subsonic jets like 747.

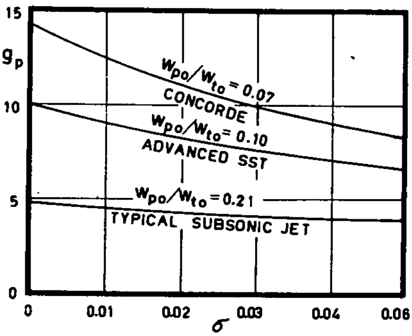


Fig. 7. The Weight Growth Factor, g_p, as function of σ, the original "effective" constant weight to gross weight ratio.

It may be noted here that a relative increase in W_p will result in the same relative increase in "effective" passenger load. It follows that for enlarged aircraft carrying cargo

$$\frac{W_{p1}/W_{e1}}{W_{po}/W_{eo}} = \frac{S_1/W_{e1}}{S_o/W_{eo}} = \frac{x_1}{x_o} \qquad (16)$$

Let us now investigate the possiblities and implications of increasing the payload to empty weight ratios for enlarged subsonic jets and SSTs. It is in particular of interest to find out the increases in payload, gross weight and empty weight that are required in order to attain a desired increase in the payload to empty weight ratio. For these purposes the following equations are derived:

$$\frac{W_{p1}}{W_{po}} = \frac{(1 - \xi)\,(x_1/x_o)}{1 - \xi x_1/x_o} \qquad (17)$$

$$\xi = \frac{W_{po}/W_{to} - \sigma W_{po}/W_{eo}}{W_{po}/W_{to} + \sigma} \qquad (18)$$

$$\frac{W_{t1}}{W_{to}} = 1 + \frac{W_{p1}/W_{po} - 1}{1 + \sigma/(W_{po}/W_{to})} \qquad (19)$$

$$\frac{W_{e1}}{W_{eo}} = \frac{W_{p1}/W_{po}}{x_1/x_o} \qquad (20)$$

W_{p1}/W_{po} is shown in Fig. 8 for an enlarged subsonic jet based on 747 and in Fig. 9 for a second generation SST based on "Concorde technology". Fig. 10 shows W_{t1}/W_{to} as function of W_{p1}/W_{po} for the two categories of aircraft. As is apparent from Fig. 8 and 9 the magnitude of σ is of decisive importance for the possibility of attaining great improvements in x and x_s. From eq. (15) follows:

$$W_c/W_{eo} = k\,\sigma/(W_{eo}/W_{to}) \qquad (21)$$

which yields the following <u>table for W_c/W_{eo} in percent</u>:

	Concorde			747		
σ \ k	1.5	1.75	2.0	1.5	1.75	2.0
0.05	17.0	19.8	22.6	16.3	19.1	21.8
0.045	15.3	17.8	20.3	14.7	17.2	19.6
0.04	13.6	15.8	18.1	13.0	15.2	17.4
0.03	10.2	11.9	13.6	9.8	11.4	13.1

It seems obvious that the "constant weight", W_c, which comprises the weights of cockpit and crew, and other empty weight items which are not affected by the weight growth factor, can hardly appreciably exceed about 10 % of the empty weight; this percentage would for Concorde mean W_c = 17,000 lbs and for 747 about 35,000 lbs. For a large aircraft (747) W_c/W_{eo} can in principle be expected to be somewhat smaller than for a lighter aircraft, but

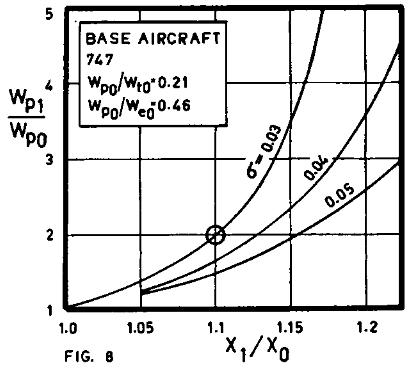


FIG. 8

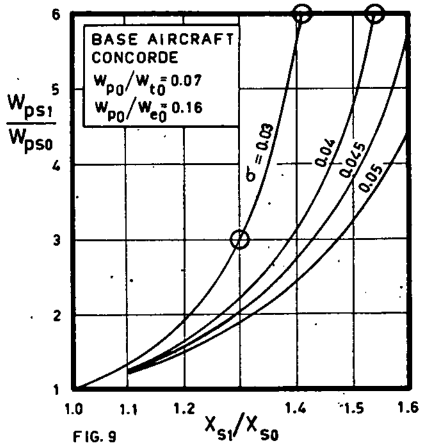


FIG. 9

Fig. 8 and 9. Required increase in payload for achieving a desired increase (x_1/x_0) of the payload/empty-weight ratio, for enlarged subsonics and SSTs based on 747 and Concorde, respectively.

for an SST/subsonic comparison, this is counteracted by the facts (a) that the factor k, catering, inter alia, for part of the weights of air conditioning equipment and fuselage skin, is likely to be greater for SSTs and (b) that the "built-in-stretch" capability normally (and more easily) provided for in designs of subsonic jets implies that a greater portion of the empty weight is exempted from the "weight carrousel". It is therefore maintained that for both SSTs and subsonics σ is about 0.03.

Fig. 8 shows that for new subsonic jets and for σ = 0.03 an increase in x by 10 % requires an increase in payload by 100 %. Fig. 10 shows that the corresponding increase in gross weight would be 87 %, and eq. (20) indicates that the empty weight would be increased by 82 %. Using 747 as the base aircraft the gross weight would be increased from 775,000 to 1,450,000 lbs. Such a large subsonic jet appears to be fully feasible.

As stated above the second generation SST would have to increase the payload to empty weight ratio by 54 % over the Concorde in order to improve x_s/x by 40 % (point A in Fig. 6) over a 747-based subsonic for which x has been improved by 10 %. Fig. 9 indicates that x_{s1}/x_{so} = 1.54 would, for σ = = 0.03, require an infinitely large SST, and that the payload would have to be increased by a factor of 6 (770 passengers) even at the probably unrealistically high σ value of 0.04. It is therefore altogether impossible to reach the point A on the basis of current supersonic technology.

The greatest realistic enlargement over the 128-seat Concorde is probably by a factor of 3 in payload (nearly 400 passengers). For σ = 0.03 this would mean x_{s1}/x_{so} = 1.3 (Fig. 9). W_{t1}/W_{to} would be 2.35 (Fig. 10) and thus the gross weight about 900,000 lbs. Disregarding the great increase in sonic boom level, the size of such an SST cannot be regarded as unrealistic. It should be noted, however, that although the relative cost/weight ratio, i_s/i, would be retained at about 2.75, the relative increase in purchase price would be greater for the new SST than for the new subsonic: $I_1/I_o = (i_1/i_o)(W_{e1}/W_{eo})$ would be 1.82 for the subsonic and 2.31 for the SST, eq. (20). The price of the latter would then increase from the (probably too low) value of \$ 34 m to nearly \$ 80 m.

The increases in x_s by 1.3 and in x by 1.1, on the basis of current technology, would mean an increase in x_s/x by 1.3/1.1 = 1.18, thus to 0.59. This yields the point B in Fig. 6 at $(f \cdot 1)_{req}$ = = 1.95, thus far too high for competition even in the first-class market.

It follows from the above that an increase in x_s/x to a value higher than about 0.6 cannot be achieved without advances in supersonic technology. And these have to be quite dramatic because they must be much greater than the considerable advances that are continuously made in subsonic technology. The reason for this is, of course, that the advances during the time it takes to develop a new SST will result in appreciable improvements in the subsonic payload/weight ratio and that the supersonic advances must be so much greater that the ratio between the payload ratios, x_s/x, is substantially increased.

There is no denying that advances in supersonic technology greater than the subsonic advances are conceivable in view of the fact that Concorde and TU-144 are the first SSTs ever built. But the big crux is that advances in SST technology appreciably greater than in subsonic technology will in general also result in a higher price/empty weight ratio, i.e. a greater i_s/i. The simpliest way to make this clear is perhaps to consider the structural

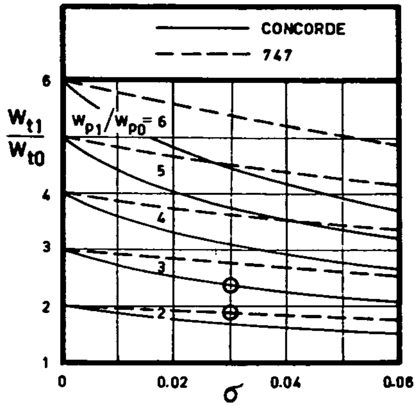


Fig. 10. Resulting increase in aircraft gross weight due to increase in payload (W_{p1}/W_{po}).

field - i.e. advances in light-weight materials and design - which is probably the most promising area for great improvements to appear within the relatively near future both for subsonic aircraft and for a second generation SST.

CORTRIGHT (Director, Langley Research Center) believes [25] that "Composite structures can reduce structural weight by 20 percent". This statement apparently refers to subsonic aircraft. To make a similar reduction in a new SST is perhaps conceivable, but will likely be much more expensive because of the kinetic heating at supersonic speeds: The cycles of very high and low temperatures will make it much more difficult not only to develop reliable bonding in the composite materials but also to ensure a sufficiently long fatigue life of the structural assemblies.

It seems therefore safe to state that one and the same percentage reduction in empty weight, i.e. unchanged x_s/x, used to accomodate more passengers will result in a higher cost/empty weight ratio for SSTs than for subsonics, thus an increase in i_s/i without an appreciable increase in x_s/x. This would increase $(f \cdot 1)_{req}$, thus impair instead of improve SST economics.

Obviously then, if the supersonic structural technology is "pressed" so very hard that the ratio between the payload ratios, x_s/x, is greatly increased, this would result in a very considerable increase in i_s/i. It is also evident that the increase in i_s/i rapidly grows with the increase in x_s/x. In Fig. 6 the bent arrow reaching point C (on the curve for $i_s/i = 4.0$ and for $x_s/x = 0.7$) is intended to illustrate the nature of this continous dependency of i_s/i on x_s/x. The $(f \cdot 1)_{req}$ at this point is a very slight improvement over the original level in point 0_1.

It may be emphasized that neither the shape of the bent arrow nor the location of point C is based on quantitative analysis, accurate calculations being exceedingly difficult to make. I do believe, however, that at least with respect to structural improvements, it is fully realistic to assume that an increase in x_s that exceeds the increase in the subsonic x by as much as 0.7/0.59, i.e. about 20 %, would increase the relative cost/weight ratio, i_s/i, by 40 to 50 % (4.0/2.75 = 1.46).

It follows that the great efforts that might be made with the purpose of improving SST economics substantially by means of increasing its payload/empty weight ratio will inevitably be counteracted, and might be completely offset, by the high costs of the very same efforts.

There are two reasons why the location of the arrows in Fig. 6 give a too favourable picture (too low $(f \cdot 1)_{req}$) of the economics of a second generation SST (even disregarding the much too low location of the base point 0_1, see above).

(1) In the first place one must assume that future SSTs will have to comply with the international airport noise standards for new contemporary subsonic aircraft. To base a new SST project on a hope that it would be exempted from the subsonic noise standards would be exceedingly hazardous. On entering service the production version of Concorde is expected to be some 15 to 20 PNdB noisier than current DC-10s and L-1011s. This discrepancy is probably representative of the improvement in SST jet noise that must be achieved for second generation SSTs x: Such a very great improvement is bound to affect adversely the payload ratio for the SST not only because of the direct increases in engine weight resulting from the silencing measures but probably also because of increased fuel consumption and hence fuel weight. The weight growth factor will multiply these primary weight increases, yielding a substantial total increase in empty weight and hence reduction in payload/empty weight ratio. Furthermore, the extreme silencing measures required are likely to increase the cost/empty weight ratio i_s.

(2) Secondly, the attainment of $M_s/M = 1.3$ for a "sea-limited" SST, assumed in Fig. 6, probably calls for extreme and costly measures to reduce turnaround, maintenance and overhaul times by means of special equipment and shift work. The costs would increase the maintenance coefficient k_m in the factor K_2 in eq, (11). This means that the point B cannot be reached; $(f \cdot 1)_{req}$ will likely be about 2.0 even disregarding the increase due to airport noise.

To sum up - and considering also that the base point for the analysis, 0_1, represents a too low Concorde/747 price ratio - it appears impossible to design a new engine-noise acceptable SST having

---

x CORTRIGHT [25], for example, has indicated a "subsonic transport goal" of 90 PNdB for 1985 (the current level is 108), i.e. at least 25 dB lower than the expected level for the first Concorde version.

a Required Surcharge Number low enough for competing economically in the first-class market (it would, of course, be even less competitive in the economy-class market) without such a drastic "break-through" in supersonic technology that it would have no counter-part in subsonic developments.

b. Third Generation SSTs

Radical supersonic advances will, however, inevitably take long time. Let us therefore call an SST that is based on more or less revolutionary developments, and having a likely Mach Number of about 2.7 or 3.0, the "third generation" SST (thus disregarding the fact that it might be found wise to refrain from developing a second generation SST in the meaning of a Concorde successor based on less spectacular supersonic advances).

Before discussing the prospects of economic viability for such an SST it seems prudent to review briefly the reasons for the apparent great difficulties to design a supersonic aircraft that is economically competitive with subsonic jets. The main reasons are:

(1) An SST must fly in two different aerodynamic environments, subsonic and supersonic, with different "aerodynamic laws" with respect to stability and optimum configurations etc. Solutions must be found which satisfy minimum requirements for both environments. The necessary compromises (e.g. with respect to wing aspect ratio) can usually not be ideal for either ends of the tremendous speed range from landing speed to supersonic cruise speed.

(2) Over and above this general drawback, the SST has a drag component, the wave drag, which does not exist for subsonic aircraft. For current SST projects the wave drag is one third to half of the total drag, which includes also friction and induced (lift) drag. The wave drag is the primary reason for the poor lift/drag ratio of SSTs. L/D is about 7 for Concorde and about 18 for subsonic transports.

(3) The aerodynamic heating at each supersonic flight necessitates (a) lower stress levels in order to obtain the same fatigue life and safety of the primary structure as for subsonics and/or more sophisticated materials and detail design, (b) a more complicated and heavier air conditioning system and (c) more complicated and/or robust design of such systems that are not cooled.

(4) The higher cruise altitude of the SSTs necessitates a heavier skin of the fuselage in order to withstand the greater pressure differential.

(5) In general it is more difficult with SSTs than with subsonic jets to comply with a given airport noise standard, e.g. because high by-pass, large diameter engines are rather incompatible with supersonic speed. For an SST to comply with the noise standard of the future - which are expected to be much more stringent than the present - will therefore result in extra weight penalties due to impaired specific fuel consumption and thrust.

All these five "hard facts of life" are inevitable and bound to imply increased structural weight (i.e. less payload/empty weight than for subsonics) and more complex designs (i.e. higher cost/weight). In particular the wave drag (due to the shock waves which also cause the sonic boom) is a "law of nature". So far no one has put forward a well-founded hope that the wave drag can ever be reduced substantially. MORGAN, for example states (26):

"The total wave drag term is large, and forms the major obstacle to economical supersonic flight", and observes that the resulting "Poor lift/drag ratios are only tolerable at supersonic speeds because their adverse effect on range, direct operating costs - or any of the parameters denoting efficiency - may be counter-balanced by a very marked increase in the propulsive efficiency of jet engines as we sweep through the Mach Number range between 1.0 and 3.0".

So far, however, such a counter-balance has not been achieved. The general consensus, expressed for example by LOFTIN (27), seems to be that "flight values of the lift-drag ratio of the order of 10 appears to be possible with configurations which, though perhaps not practical today, may be practical in the future".

In view of these observations it seems to be a research area of great importance to make a general study of the improvement in the propulsive efficiency of SST engines, over the improvements that can be expected to be made in the propulsive efficiency of subsonic jets in the same time period, in order to offset not only the poor basic L/D of the SST but also the additional penalties (again over the subsonics) that will burden the SST, due to the factors (1), (3) and (4) listed above with respect in particular to structure weight. In such a study the following "percentage equation" based on eq. (13) has to be observed.

$$\frac{W_f}{W_t} + \frac{W_{eng}}{W_t} + \frac{W_{hull}}{W_t} + \frac{W_c}{W_t} + k\,\frac{W_p}{W_t} = 1 \qquad (22)$$

W_{eng} = the major portion (the one varying with the size of the aircraft) of the engine weight

$W_{hull} = W_{ew} - W_{eng}$

It follows from the foregoing that an SST for economic viability must attain roughly the same payload/gross-weight ratio, W_p/W_t, as competing subsonic jets (or, in fact, an even higher ratio in order to offset the higher cost/weight ratio of the SST which can hardly be compensated by the productivity ratio, M_s/M, and other factors that might be favourable to the SST). Let us furthermore assume the same values for W_c/W and k for SSTs and subsonics. Considering also that the high fuel consumption of SSTs has hitherto been the greatest obstacle for attaining a good payload the issue at stake is elucidated by the following self-explanatory approximate condition:

$$\left(\frac{W_f}{W_t}\right)_{subs} - \left(\frac{W_f}{W_t}\right)_s = \overbrace{\left(\frac{W_{eng}}{W_t}\right)_s - \left(\frac{W_{eng}}{W_t}\right)_{subs}}^{(a)} + \underbrace{\left(\frac{W_{hull}}{W_t}\right)_s - \left(\frac{W_{hull}}{W_t}\right)_{subs}}_{(b)} \qquad (23)$$

We can thus draw the important conclusion that a necessary but probably not sufficient condition for economic SST operation is that the "supersonic" fuel consumption must be so low that the relative fuel weight of an SST is so much smaller than the relative fuel weight of contemporary subsonic jets that the difference equals the sum of the difference (also in relation to improved subsonic jets) in (a) the relative engine weight (caused, in part, by the likely requirement of equally low engine noise) and (b) the relative hull weight (caused in particular by the kinetic heating of SSTs, their higher flight altitudes and more complex design).

At the face of these observations the prospects that a future SST project can ever comply with this minimum condition appear to be very slim indeed. The question is, however, worthy of a quantitative study. Whereas the relative fuel weight, for a certain range, is rather well-known for current subsonics and can be estimated for future jets with reasonable accuracy, estimation of the relative fuel weight for SSTs - for any given or assumed basic specific fuel consumption, e.g. in cruise - is a much more complicated matter. It is dependent in a complex way on the specific fuel consumption and L/D throughout the whole flight path. For the cruise segment the fuel consumption can be estimated on the basis of Breguet's range formula and a similar approach would have to be used for the subsonic and supersonic climb and descent segments, the high fuel consumption in climb being particularly important.

It seems fully possible to assess the relationships between a "basic" specific fuel consumption and L/D that are required for compliance with eq. (23) assuming realistic values for the relative subsonic fuel weight and the differences (a) and (b). Furthermore it is certainly possible to make a more general study - by applying eq. (22) both for SST and subsonics but without assuming equal payload ratios - for assessing overall relationships between all the most significant parameters governing the relative SST/subsonic economics, in particular payload/empty-weight, specific fuel consumption, M_s/M and resulting cost/weight ratios.

Pending research of this kind, the only way to get further in judging the prospects of improved operation economics of a third generation SST is to analyze information about performance of advanced SST projects believed by their proposers to be attainable. CORTRIGHT [25] indicates as design goals for an advanced SST (apparently believed attainable during the 1980's) an "L/D near 10", a payload/gross-weight ratio of 0.1, a noise level of 108 EPNdB and a range of 5000 nautical miles, to be achieved by a Mach 2.7 to 3.0 aircraft with a gross weight of 800,000 lbs. As

$$\frac{W_p}{W_e} = \frac{W_p/W_t}{1 - W_p/W_t - W_f/W_t} \qquad (24)$$

and if we assume that this SST project would have a relative fuel weight, W_f/W_t of from 50 to 55 %, its payload/empty-weight ratio would range from 25 to 29 %. This might be compared with a subsonic jet of the 1980's whose payload/empty-weight ratio is improved over the current 747 by 20 %. If we furthermore conservatively define the payload of the subsonic aircraft as the weight of merely a full load of "effective" passengers this ratio would be 1.2 · 545 · 210/356,000 = 0.385.

The relative payload/empty-weight ratio, x_s/x, would thus be from about 0.65 to 0.74. On the assumption that the coefficients $K_1 - K_4$ in eq. (11) for $(f \cdot l)_{req}$ are roughly the same as indicated above the curves in Fig. 11 would apply. If we furthermore believe that this Mach 2.7+ SST could achieve a productivity ratio of 1.5 its $(f \cdot l)_{req}$ would fall between the heavy-drawn vertical lines marked, assuming that the cost/empty-weight ratio, i_s/i, would be at least 4.

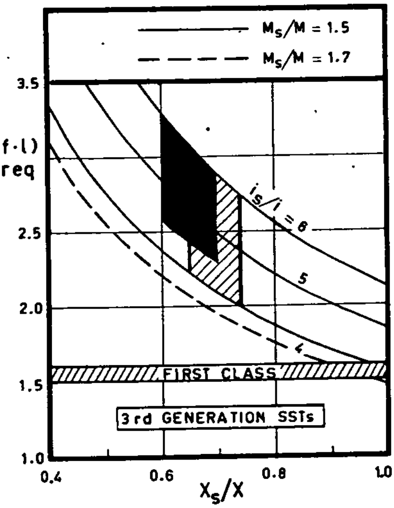


Fig. 11. The Required Surcharge Number for a Mach 2.7+ SST project suggested by CORTRIGHT will likely fall within the dark area if the SST is to conform with the 1985 airport-noise design goal of 90 EPNdB, indicated by C. for subsonic jets.

In the light of the foregoing analyses regarding second generation SSTs and considering the extreme complexity and sophisticated design of a Mach 2.7+ SST with a high L/D (e.g. with "semi-integrated" wing-body configurations and lengthwise varying cross section of the fuselage with a warped center line) using also "exotic" composite, heat-resistant materials, i_s/i will in all likelihood be considerably higher than 4, perhaps 5 or 6. The Required Surcharge Number would thus fall somewhere within the hatched area between the two heavy lines in Fig. 11. The whole of the area falls above $(f \cdot l)_{req} = 2$.

In envisaging this advanced SST project CORTRIGHT has, however, assumed a noise level of 108 EPNdB, whereas he predicts that 90 EPNdB will be attained by new large subsonic jets by 1985. The modern trend is that what is achievable as regards low airport noise should also be prescribed in noise requirements for new aircraft. One must therefore assume that SST projects appearing at the end of the 1980's, or later, will have to comply with a 90 EPNdB noise level. The reason why CORTRIGHT has not set this noise level as a goal for his SST project is probably that he believes that such a quiet SST either is impossible to design or would suffer from unacceptable weight and fuel consumption penalties.

Whatever the reason, we can conclude from CORTRIGHT's prognostication that, if compliance for SSTs with the 90 EPNdB level is achievable at all, it will be very costly indeed in terms of both reduced payload/weight (x_s/x) and increased cost/weight (i_s/i). It therefore appears that the Required Surcharge Number for a third generation noise-acceptable SST will likely fall within the dark area in Fig. 11. This would yield an $(f \cdot l)_{req}$ anywhere from about 2.5 to about 3.

Conclusions about SST economics

The analyses above yield three main conclusions:

1. Concorde cannot compete in the economy-class market without enormous losses or subsidies. It cannot either compete in the first-class market without a great deficit in relation to the requirement of equal return on investment as for competing subsonics. This applies for a purchase price per aircraft, without spares, of the order $35 m which, however, does not cover the R&D costs. At a purchase price covering the R&D costs Concorde would be still more uneconomic.

2. Provided that one does not base the judgments on speculations about advances in supersonic technology far beyond what is conceivable today, it appears impossible ever to develop an SST which - without great subsidies for covering considerable portions of the development, manufacturing and/or operation costs - could be economically competitive even in the first-class market. (Still less could it compete in the economy-class market).

3. The second conclusion applies even if boom-alleviating SST configurations would lead to abandoning all overland boom restrictions. Disregarding that such an advancement seems impossible, and also that near-boomless SST configurations would increase substantially the purchase-price/weight ratio and/or decrease the payload/weight ratio (thus increase the purchase-price/payload ratio), the improvement in mileage productivity that could be achieved at full freedom to fly supersonically over land would be far from sufficient to make the SST economically viable.

Market Penetration

In view of these conclusions it would seem wise not only to terminate the Concorde enterprise - in order to avoid great losses that will increase with number of Concordes built and put into service - but also to abandon the plans to develop Concorde successors or third generation SSTs until and unless analyses of the kind presented above, clearly indicate that the level of the art permits the design of an SST that is economically competitive in the contemporary "subsonic-jet environment".

It must be feared, however, that such decisions will not readily be made mainly because of the vast investments in the Concorde already made and because of the rather common belief in the aviation community, and hence also on governmental levels, that it is possible to develop economically viable SSTs in the future and that such developments therefore should be undertaken considering also alleged social benefits with respect to employment and the like (see below). One must therefore count with the possiblities that Concordes will be put into service and second and/or third generation SSTs will be developed and introduced later on. The great losses, or deficits, that will be incurred might then come, more or less, as a surprise, but will likely be covered, as long as possible, by hidden subsidies, e.g. in the form of increased subsonic fares for compensating deficits in SST operation. It seems therefore important to make an approximate assessment of the likely or possible encroachment by SSTs on the subsonic market.

Operation, also of future SST projects, at fares close to subsonic economy-class market would clearly incur altogether unacceptable losses. About first-class fares will therefore probably be applied in SST operation, at least to begin with. It must then in the first place be observed that the first-class market is quite a small fraction, some 10 percent, of the total scheduled market. A second limitation of the available market is caused by the fact that the time gains by SSTs are normally pointless on distances below about 2000 miles. A third limitation is that the overland boom restrictions, that in all likelihood will be applied also for future SST projects, will drastically reduce the number of feasible supersonic routes.

Furthermore, and most important, the SSTs will only be able to take over a portion of the resulting small potential market. The magnitude of this portion can hardly be accurately assessed, but it follows from Chapter II that at about equal (first-class) fares the SST/subsonic preference split can, on the average, hardly be better than 50/50 because of the marginal net benefit to the passengers of flying the SST, in particular on oversea routes crossing 5 or more one-hour time zones. The average preference split will be further reduced because of another factor, not mentioned in Chapter II:

Overland sonic-boom restrictions will often necessitate considerable detours around mainland areas and inhabited islands which will increase SST flight times and thus reduce the time gains.

It has been alleged [1] that some businessmen who fly subsonic today might prefer SSTs even at first-class fares because "historically people are willing to pay extra for higher speeds". Honestly I think that such an extrapolation from the piston-to-jet advance is entirely unsupported. It is true that a moderate surcharge was applied for a limited time on jet fares partly in order to protect fully serviceable but not yet amortized piston aircraft. The decisively important difference compared to the SST/subsonic jet situation is, however, that whereas the benefits to the passengers of flying jets instead of pistons were tremendous and could well justify even a considerable surcharge, the benefits of the SST over the subsonic is at best moderate. It therefore appears that the portion of economy-class passengers that would pay first-class fares will be almost negligible.

It follows that current and future SST projects can at best take over half of the, rather small, potential market, (long-haul, first-class and mainly oversea), provided that economic considerations are to govern the fare setting. One cannot be sure, however, that this proviso will apply in the long run. The required number of SSTs will be so small - resulting in great losses also in production, even if the R&D costs are written off - that the whole concept of civil supersonic aviation would appear to be a failure. The billions of dollars that have already been spent on the Concorde and other SST developments and the further billions of dollars that development of new generation SSTs would require, and also the political prestige that has gone into the various enterprises will, however, make the SST sponsors very reluctant to admit a failure of the SST concept.

In other words, the sheer inertia of the billion-dollar spending might well override normal airline economy considerations. Thus the motto may well be: "As we have already entered the Supersonic Age, wisely or not, we have to see it through, if not by Concorde so by second or third generation SSTs". And the consequential ambition - although not spelled out - will logically be to generate, litterally at any cost, a great appeal and demand for supersonic travel.

A great demand for SST services can, however, only be attained by considerable enchroachment on the economy-class market, and for achieving this it is necessary to apply about economy-class fares. By doing this the operation losses will greatly escalate but the goal, a large SST market, might well be reached.

To sum up, in the event that SSTs, in particular Concorde successors, are developed and introduced at all, strong economic reasons speak for applying about first-class fares, implying a very small SST market. For mainly political reasons the SST fares might, however, be set so low that the total fleet of SSTs becomes quite large.

In this context it may be observed that Boeing [8, 28] founded its estimates of the SST market on the presumption of economy-class fares (yielding a demand for over 500 298-seat US SSTs), that ZIEGLER, Chairman, SNIAS [6], foresees a demand for over 900 Concordes by 1989 (if there are second generation SSTs) and that EDWARDS [29] foresees "1500 Concorde and Concorde development aircraft to be in service by the end of the century".

It follows that, in spite of the inevitable great losses that will be incurred by SST operation at about economy-class fares, the assessment of the environmental effects should be based on the assumption of a total SST market penetration corresponding to the order of 1000 to 2000 SSTs, including USSR aircraft.

IV. Social Aspects

Cost/Benefit of the SST, Disregarding Social Costs

Let us now apply the modern cost/benefit concept for judging the justification of major technological enterprises. It stands to reason that in the field of aviation the cost/benefit ratio has continously decreased in the past; in particular the piston-to-jet transition implied reduced transportation costs and greatly increased benefits in the form of really important time savings and much smoother flights.

This trend would, however, be drastically changed by SSTs, even if one disregards their social "diseconomics": Firstly, the SST transportation cost per passenger mile is much higher than for subsonics. Secondly, and even more important, the real benefit to (or need for) passengers to fly at supersonic speed can at best be considered moderate and will, in the opinions of many, be marginal, i.e. approach zero. The denominator being quite small the cost/benefit ratio for the SST would clearly be extraordinarily high.

In a world of limited resources and great poverty this fact would appear sufficient for abandoning the plans on supersonic travel, and thus there would be no need to investigate the social aspects of the SST, be they positive or negative. But the ambitions to launch large-scale supersonic aviation prevail almost intact. It is therefore necessary to consider also the social implications of the SST. For the purpose of this paper, i.e. to see the SST in a total and global perspective, it is sufficient, however, to make a rather brief survey of the social effects.

Social Aspects Alleged in Favour of the SST

We may define here the social aspects as all factors, significant for the justification of the SST, other than operation economics including demand (the demand for SST being related to the need as pointed out in Ch. II).

The main "social" arguments put forward for the Concorde and for the (abandoned) US SST are employment, preventing loss of investments made (or profits in production), improved balance of payment, technical "spin-offs", aeronautical leadership and national prestige. The four first of these arguments have economic implications.

Employment. Development and manufacture of SSTs require very considerable numbers of scientists, engineers and workmen. This would be an important argument for SST production if such aircraft were greatly needed and economic in use. If this is not the case, however, the employment aspect appears to be invalid; most economists would agree that production of goods the use of which would be an economic burden to taxpayers and/or the users is not a sound way to fight unemployment.

Preventing loss of investments made and/or profits in production. These two arguments, which are closely related, have been strongly advocated in favour of SST production, in particular of continuing production of Concorde (and before also of the US SST). Both arguments can, however, be questioned. It has been officially declared that most or all of the R&D costs that have gone into the Concorde Project (about 650 million pounds) cannot be recovered. With respect, for example to Concorde, there is also reason to doubt that, even if the R&D costs are written off, the price that airlines would be willing to pay for "sea-limited" SSTs could yield a normal profit to the SST manufacturers over the production cost per aircraft at the limited number of "boom-restricted" SSTs that can be expected to be sold. (30)

Improved balance of payments. This argument was the subject of intense debate with respect to the US SST project. The general consensus among leading economists in the U.S. was that the net effect of an SST enterprise on the balance of payments - considering also outflow of money due to the alleged increase in travels abroad - would be small even if, as was assumed, the SSTs could be sold at a profit. (31) I will not venture an opinion on this subject except that, if SSTs can only be sold abroad at a loss (taking also the R&D costs into account) then such sales appear to be a dubious method of strengthening the economy of a country, including the balance of payments aspect.

Technical "spin-offs". A certain amount of by-products in the form of new knowledge, usable in other fields, does normally result from any major technological effort. It appears, however, that the value of "spin-offs" can be regarded as an argument for an enterprise only if this is profitable or otherwise desirable on its own merits.

Aeronautical leadership. The justification of this argument, too, depends upon the need and economic viability of an SST enterprise. Surely, if the SST is bound to be an economic failure it would be better to ascertain leadership by more sound and important aeronautical developments, e.g. in the V/STOL, noise-alleviation and safety areas.

National prestige. It seems that the prestige that could lie in "showing the flag" on faster-than-sound aircraft is no longer advocated as a strong argument for the SST. By contrast, however, the loss in national prestige that might lie in termination of, say, the Concorde enterprise - to which so much pride, hope and enthusiasm has been attached and on which so much money and efforts have been spent - appears to be felt by the sponsors as a very strong argument "to see it through", as was indicated above.

Overall judgment. As indicated in these brief observations there is room for considerable differences in opinion about the justification and strength of all these (social) pro-SST arguments. But whatever strength is attached to these aspects there can be no denying firstly that they have nothing to do with the main purpose of aviation, which is to provide safe, cheap and reasonably rapid transportation, and, secondly that they are all of a national character, promoting (at best) the interests of a few nations. Commercial aviation is, however, fundamentally of international scope and aim, serving the whole mankind. National arguments are therefore hardly a relevant aspect for judging the justification of international supersonic aviation.

Social Disadvantages and Hazards of the SST

a. Sonic Boom Over Land

As of August 1972 ten ICAO Member States - Canada, Denmark, Ireland, Japan, the Netherlands, Norway, Sweden, Switzerland, the U.S. and West Germany - have imposed restrictions on civil supersonic flights, or plan to do so in the near future. The restrictions of Denmark, Norway, Sweden and Switzerland are in the form of laws that prohibit supersonic overflight, and the same will probably apply to Japan. In the U.S. a regulation is about to be promulgated which prohibits overflight of SSTs generating a sonic boom "which will touch the surface in the United States" including the territorial waters. This is equivalent to prohibition of civil supersonic flight at speeds above about Mach 1.15, thus at speeds commonly called supersonic. Also the "conditional" restrictions of the remaining four States are de facto equivalent to prohibition of supersonic overflight because they stipulate that the boom must not cause damage to health which SST booms are certain to do (see below).

Furthermore, the Government of the United Kingdom has declared that in its view "commercial supersonic flights which could cause a boom to be heard on the ground should be banned". (32)

The Council of Europe "urges" in its Resolution 512 (1972) "on repercussions of supersonic civil flights on human and natural environment" that

> "civil flights at supersonic speeds over land should be banned",

and makes the following statement in its Resolution 511 (1972) "on the economic implications of the introduction of civil supersonic aircraft"

> "Recalling with approval that it is now commonly accepted at both governmental and professional level that supersonic flights will not be permitted over inhabited land".

This recognition was based on the Explanatory Memorandum (10) to the Council's Economic Committee which in turn was based on the deliberations of a Round Table organised "to discuss the Concorde Project" with representatives of the Aérospatiale/BAC Consortium and led by General Ziegler, Chairman and Managing Director of Aérospatiale. The Memorandum states twice

"that nobody (including the Consortium constructing Concorde) envisaged the operation of the aircraft at supersonic speeds over inhabited land areas".

These assertions of early 1972 seem very reassuring indeed but they appear to have been already negated: BOAC has made it known that they plan to fly Concorde at supersonic speed across the USSR and to apply for permissions to erect "supersonic corridors" over sparsely populated portions of many countries, e.g. Canada and in Africa and Central America, and on the planned route to Sydney (18, 33), see Fig. 12. In view of this it seems prudent to discuss briefly whether or not it would be morally defendable to subject people of any country, more or less sparsely populated, to disturbances and hazards^x deemed unacceptable (and therefore banned) to the people of those 10 to 11 States which have studied the effects of SST sonic booms particularly thoroughly.

Fig. 12. Concorde routes as indicated by BOAC.

Understandably, in a way, the public interest in, and the research on, various effects of the SST sonic boom have until recently been focussed on the more spectacular effects of the boom, such as window breakage, house rattles, possible damage to churches and historical monuments and severe startle - possibly with disastrous results - to people and animals. I will not review here the mass of litterature on boom effects of this kind that has been written by a great many authors, e.g. (35-40). May it suffice to state that there is abundant proof that startle effects, house rattle, window breakage, or the like, begin at a nominal, or calculated, boom overpressure of the order 0.7 to 1.0 psf, the inevitable atmospheric and/or topographic magnifications being the reason why such effects result from so low nominal boom intensities.

This overall result renders, of course, the boom of current and hitherto planned (e.g. the Boeing 2707) SST projects entirely unacceptable: As Fig. 13 (based on (41) and (42)) shows the nominal boom of such SSTs ranges from about 2 psf in cruise up to 2.5 to 4 psf in climb, after the "horseshoe", or "crescent", area, and up to some 6 to 15 psf in this area.(42) So, even if one could disregard the intense crescent boom, the SST boom in the first half of the vast climb carpet (over 4000 sq miles) would roughly be up to 4 times greater than the approximate threshold level for beginning startle effects and structural damage.

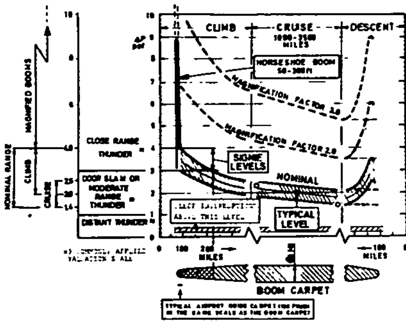


Fig. 13. Ranges of SST boom overpressures along the flight path.

Even worse, however, the crescent boom, see Fig. 14, cannot be disregarded. As I have pointed out in my dissenting Statement, published in (40), to the Report of the ICAO Sonic Boom Panel and also

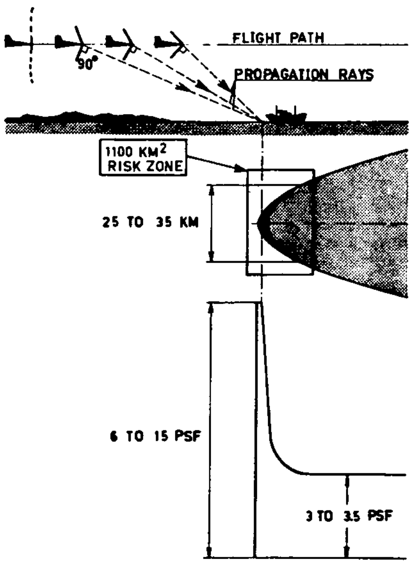


Fig. 14. Schematic illustration of the generation of the "crescent", or "horseshoe", boom.

---

^x This issue has recently been studied by ADAMS and HAIGH.(34)

in [43] and [44], to place the exceedingly frightening and potentially destructive crescent boom so that it with certainty does not hit people and buildings, is an unsolved and seemingly insoluble problem.

Strangely enough, practically all attention as regards the acceptability of the SST boom has been focussed on the intensity of the SST cruise boom. But even the cruise boom is some 2 to 3 times stronger than the threshold level for beginning startle effects and structural damage. This fact appears, in most cases, to be the main reason (and surely a sufficient one as has been clearly proved by the Concorde test flights over the west coast of the U.K. [45]) for the boom restrictions, imposed or intended, by the 10 to 11 States mentioned above.

The extensively applied policy of judging the acceptability of the SST boom mainly on comparison of the cruise boom intensity with the threshold intensity for startle and structural damage is, however, most deplorable for two reasons: In the first place the discrepancy between the two intensity levels might to SST sponsors not seem to be so great that it unquestionably outrules supersonic flight over sparsely populated areas, implying that they could hope that such operation would be acceptable to some countries located on planned SST routes. Secondly, this policy has given rise to a rather common belief that, if the nominal cruise boom of future SST projects could be reduced to about 0.6 psf, the effects of SST booms over land would probably be acceptable. This belief, maintained, for example by FERRI [46, 47], is apparently the very basis for the extensive current research programmes aiming at boom-alleviating SST configurations.

Both these hopes, or beliefs, are unfounded. The crescent and climb booms must, of course, be considered, and, even more important, it is not the more spectacular effects, such as window breakage and startle of people awake, that determine the limit for the acceptable boom intensity. As has been emphasized since 1961 [2-5] the acceptability limit is set by the "Sleep Disturbance Criterion" which is much more critical, i.e. yields a much lower acceptable boom intensity, than does a requirement that the SST must not cause window breakage, or the like. The Sleep Disturbance Criterion is suggested to be defined as follows [40]

> "Because of the exceptional vastness of the SST sonic boom carpets - making it virtually impossible to escape - the acceptable nominal SST boom must be so weak that it, taking due account to atmospheric and topographic magnifications, does not usually awake those people who are in the greatest need of undisturbed sleep, in particular the sick and old, and people with sleeping difficulties".

This condition is, in fact, a self-evident consequence of accepted humanitarian considerations in civilized countries for suffering citizens. Since this criterion was recognized at the OECD Conference on Sonic Boom Research [48] it is beginning to become more generally accepted. A most important, also self-evident, consequence of the criterion is that sonic booms, which are so weak that they do not usually awake light sleepers, or the like, cannot possibly cause appreciable or harmful startle to people awake in daytime, nor noticeable damage to structures or serious harm to animals.

As regards the value of the acceptable nominal boom as determined by this Criterion there is now clear evidence that the limit in all likelihood falls below 0.4 psf. Only one such evidence will be mentioned here, namely the Gallup polls in connection with the extensive daytime boom tests over Oklahoma City in 1964. Fig. 15 shows that very high proportions of the daytime sleepers were awakened by booms of about 1.0 psf, and the trend of the curve for sleep interruption indicates that some 10 to 15 percent of people asleep would be awakened by booms of the order 0.2 to 0.3 psf. As most people belonging to the Critical Group obviously (almost by definition) are to be found in the low percentage portion of sleep-interruption curves booms of this strength will awake a considerable proportion of such people.

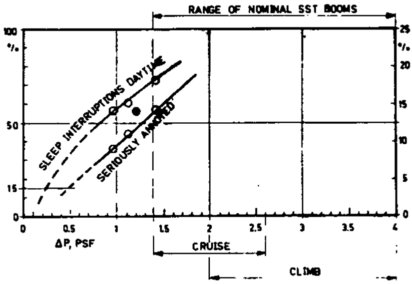


Fig. 15. Percentage - scale to the right - of Oklahomians polled who reported sleep interruption caused by 8 daytime booms per day and serious annoyance due to such disturbance. If the number of daytime sleepers is assumed to 25 %, the percentage of daytime sleepers who were awakened is to be read on the scale to the left. (The black dot represents roughly some recent Swedish tests.)

It is, of course, difficult to determine, and obtain general agreement on, an exact limit for the acceptable nominal boom intensity, but nor is it necessary:. Even if the acceptable limit is set as relatively high as 0.4 psf, the SST climb boom would be some 7 to 10 times and the cruise boom about 5 times too strong for compliance with the Sleep Disturbance Criterion.

Considering the self-evident fact that the sufferings from sleep disturbance by people belonging to the Critical Group rapidly increase with boom strength, it would clearly be ruthless to subject any inhabited land (or island), however sparsely populated, to SST booms of current levels. In every community, also in sparsely populated countries, there are sick and old people, and people with sleeping difficulties.

In view of all this it seems imperative

(a) that all countries of the world as soon as possible ensure themselves protection against SST sonic booms by prohibiting civil supersonic overflights, and

(b) that, until this has been realized, SST operating airlines conform with the assertion of the Concorde Consortium to the Council of Europe that "operation of the aircraft at supersonic speeds over inhabited land areas" will not take place.

b. Sonic Boom Over Sea

As I have dealt extensively with this topic in the past [38-40, 43, 44] only a brief summary will be made of the most important observations.

As is well-known the Concorde manufacturers and sponsors take for granted that the sonic boom will cause no appreciable disturbance or hazard to people at sea, the alleged proof for this being that there has so far been no reported complaints from boats that have been overflown at supersonic speed by military aircraft or by the Concorde prototypes. By contrast I have persistently maintained that SST booms, which in the vast climb carpets are some 5 to 10 times too severe (disregarding the crescent boom) for being acceptable over land, in all likelihood will often cause considerable disturbance and fright to people on boats, in particular in calm weather.

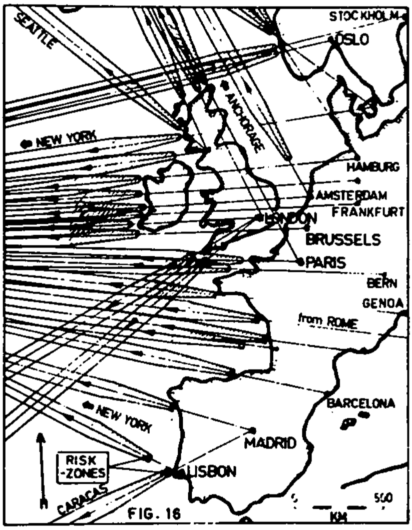
The figures 16-18, reprinted from [43], indicate the approximate coverage of the coastal waters of the North Atlantic by SST climb boom carpets.

The waters southeast of New York constitute the most "critical area" on the globe because they, for any given total fleet of SSTs, will be subjected to a far greater number of supersonic climb-outs than could conceivably occur anywhere else, and also because the boat traffic in these waters is relatively dense.

The allegation that the absence of complaints from boats is sufficient proof of the harmlessness of the booms must be objected both on statistical grounds - large-scale SST operation will cause a much higher daily frequency of occurrences where boats are struck by booms than has ever occurred up to now - and because the SST climb and crescent booms are much stronger than most of the booms that so far have been imposed on boats. In particular with respect to the intense crescent booms it must be observed that, whereas the probability that the rather thin crescent (some 200 ft) would have hit boats in the supersonic oversea flights so far conducted has been quite small, the risk that SST crescent booms - produced, for example, with a frequency of many dozens per day (on the "critical" waters off New York) - will hit boats is so high that such events can be expected to occur many times per year, perhaps per month.

This conclusion applies, of course, only if adequate measures are not taken to warn ships not to enter the crescent-boom risk zones which will have a minimum extension of some 1100 km^2. [44] To do this, however, appears to be very difficult and expensive.

An indication about the unlikelihood that SST booms will be acceptable to people at sea was pro-



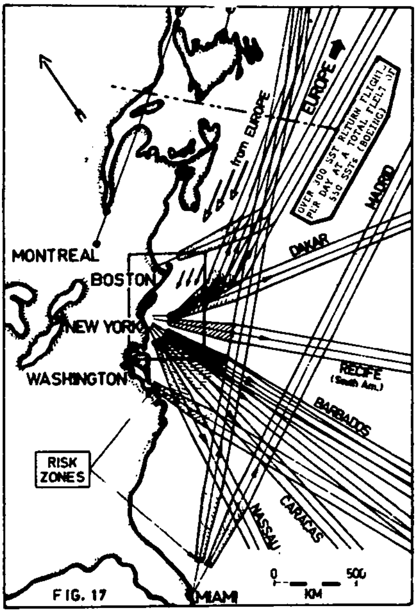


Fig. 16 and 17. Approximate locations of SST boom carpets west of Europe and east of U.S. assuming prohibition of supersonic flight over land. The hatched areas indicate the vast climb carpets with nominal overpressures of 2.5 to 4.0 psf, see Fig. 13. The intense crescent booms (Fig. 14) occur in the beginning of each climb carpet.

vided by the boom tests carried out by the Swedish Air Force over the Baltic in 1969. The purpose of the tests was to find out whether or not the current lowest permissible supersonic flight altitude over sea of 5000 m could be appreciably reduced without creating undue disturbance and hazards to people at sea due to the boom. As a result of the tests the Air Force decided that this altitude limit, which for the military aircraft in question yields a nominal overpressure of about 2.7 psf, should not be lowered, it being maintained that booms exceeding this level could be too frightening to passengers and crew members on boat decks. The level 2.7 psf is to be compared with the nominal SST boom intensity of up to 4 psf in the climb boom carpets and 6 to 15 psf in the crescents.

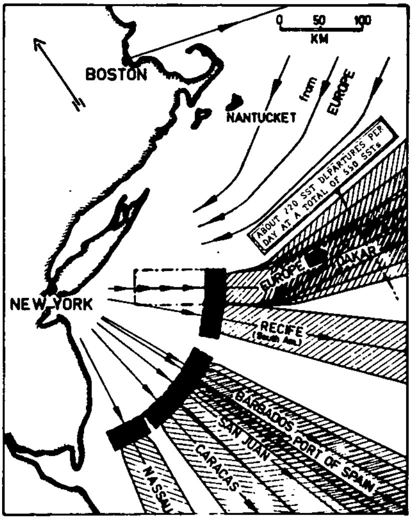


Fig. 18. Possible locations of crescent boom risk zones off New York. The vast light zone illustrates the area within which the crescents would fall if transonic speed is applied as soon as possible. The dark areas, of about 1100 km^2, are the risk zones within which most crescents would likely fall if efforts are made to locate them within an as small area as possible; some crescents will inevitably fall outside the risk zones. [57]

These observations should be sufficient to show that there is an urgent need for boom tests, and other research, in order to assess the SST boom intensities and daily frequencies that can be deemed acceptable to people at sea for various kinds of boats and weather conditions, etc. Such tests have been recommended by the Nordic Council in a Resolution of early 1971, and also in the Memorandum that supported the Resolution 512 (1972) of the Council of Europe, from which may be quoted

> "Sonic boom effects upon man at sea are still relatively unknown. As boom effects on man at sea is still a matter on which diverging views exist it seems necessary to conduct adequate boom tests on boats of various kinds, in order to find out the acceptable maximum limit of the civil supersonic boom over sea."

Needless to say it appears to be in the best interest also of SST sponsors and operating airlines that such tests - which should, of course, be made in co-operation with representatives of various categories of people at sea - be carried out without further delay in order not to risk unexpected severe opposition against SST booms over sea at a later stage.

c. Airport Noise

The take-off and landing noise of the first version of Còncorde will far exceed current international standards (106 EPNdB for aircraft of Concorde's weight) and still more exceed the noise levels of the latest wide-bodied jets, DC-10 and L-1011. As was also pointed out above, it is inherently much more difficult to achieve the same low future noise levels (of the order 90-95 EPNdB) that are achievable with future large subsonics which levels will be guiding for future standards. Most likely, however, these difficulties will not be taken as a justification for exempting SSTs from contemporary future noise standards for subsonics. Moderately higher noise levels of SSTs could possibly be defendable if it could be asserted that supersonic travel is much more important and more economic than subsonic transportation, but the opposite applies.

In view of this it seems highly desirable that an international agreement be reached that SSTs should comply with the noise standards for contemporary new subsonic jets. If such an agreement is not realized and SSTs do produce appreciably more noise at airports than the subsonic standards permit, this would weigh heavily against the SST as regards social acceptability.

d. Effects on Climate

As a result mainly of recent reports by JOHNSTON, e.g. [49], there has been much concern lately about the possibility of serious depletion of the ozone shield by exhaust emission of SSTs in the stratosphere. The ozone shield protects the earth from dangerous ultra-violet radiation. After thorough discussion of this possible danger the Symposium on Inadvertent Climate Modification held in Stockholm in 1971 (as a preparation for the UN Conference on the Human Environment) stated [50]

> "We consider that answers of these questions (regarding ozone depletion) should be produced before large-scale aircraft operation in the stratosphere becomes commonplace, and we believe that solutions might be produced by concentrated research."

Recent work by CRUTZEN [51, 52], a leading expert in this field, support this recommendation. Research programmes with the indicated aim have already been initiated.

e. Ionizing Cosmic Radiation

In a recent Memorandum [53] written upon consultation with Professor Bo Lindell, Director of the

Swedish National Institute of Radiation Protection,[x] I made the following main observations:

(1) The International Commission of Radiobiological Protection, ICRP, concluded in 1966 that the radiation at SST altitudes would be within permissible limits only if exposure to major solar flares can be avoided. (54)

(2) According to the Airworthiness Standards for Concorde (55) solar flares will, however, not be avoided: In such events the aircraft will reduce altitude only if the radiation dose rate, according to the radiometer, amounts to the rather high "Action Level" of 100 millirem per hour, and then it will only dive as much as is necessary for preventing the dose rate from exceeding this level.

(3) The SST occupants could thus receive up to 200 mrem in a 2-hour supersonic flight. Such a dose and possibly even smaller ones, e.g. 20 mrem, can conceivably cause foetal damage, such as malformation, or childhood leukaemia.

(4) In spite of the low frequency (probability) of solar flares producing 20 to 100 mrem per hour female air passenger of child-bearing age might prefer flying at subsonic heights where the risks due to solar flares are negligible.

In its aforementioned Resolution 512 the Council of Europe invited ICRP to study the SST cosmic radiation problem. This was done in a Statement of April 5, 1972, from which may be quoted

> "The Commission recognizes that the latter radiation (from solar flares) may on rare occasions increase in intensity so rapidly that early planning will not suffice as a measure of keeping exposures to an appropriately low level. The only way of avoiding high exposures would then be to descent to lower altitudes. In the exceptional situations when this is necessary, radiation risks would have to be weighed against any hazards related to the remedial action".

This recommendation, however, does not solve the problem at issue. The risk connected with "the remedial action", i.e. un-planned simultaneous diving by perhaps a great number of SSTs to a lower altitude (where there might be dense subsonic traffic) is one that many SST pilots are likely to consider greater than the statistically small combined risk that some SST occupants are pregnant and that their foetus could be harmed.

It follows that, at the present level of the art and planned measures for avoiding solar flare radiation, female passengers cannot be certain that they will not be subjected to unadvisably high radiation doses. Thus there is a need for further research in this area before SSTs are put into service.

f. Flight Safety

The Concorde and TU-144 are undoutbtedly the most thoroughly tested aircraft ever built. In particular the full-scale fatigue tests with realistic heat/load cycles are most impressing. In my opinion, however, this is not enough for ensuring the same very high safety level as that of commercial subsonic aircraft. On the basis of extensive studies (4, 56) I have concluded that SSTs will inevitably be less safe, both with respect to the aircraft itself and its operation, than contemporary subsonics. Briefly, the main reasons for my conviction are

(1) The incomparably greater complexity of the SST.

(2) The simultaneous introduction of an unprecedented multitude of radically new design features; subsonic developments are characterized by few and usually "small-step" design novelties for each new model.

(3) The supersonic speed as such which, inter alia, increases the risks of collision with unforeseen "weather", e.g. hail, jet streams and cumulonimbus clouds which could contain destructive turbulence.

(4) The severe aerodynamic heating (and subsequent cooling) of the structures, and some of the systems, of the SST at each supersonic flight which is bound to imply increased risks of unpredictable failures due to creep, distortions and metal fatigue. These risks cannot be eliminated by only one full-scale fatigue test because the heat/load history in real operation will always differ from the heat/load schedules applied in the test.

Over and above the safety aspect as such, the SST buyers will get no proof about the safe fatigue life of the structures until many years after the purchases because of the exceptionally long times required for fatigue testing when a heating cycle - which should be of nearly the same duration as in actual flight - must be applied for each simulated flight.

V. Conclusions

The transition from piston aircraft to subsonic jets implied substantially reduced operation costs and greatly increased benefits in the form of really important time savings and much smoother and less tiring flights. The cost/benefit relationship reached a lower level than ever before.

By contrast, for the first time in history a further big increase in speed - by introducing SSTs - is neither greatly needed nor would it bring about reduced operation costs or fares. The seat-mile costs of current SST models, as well as of improved SST projects conceivable in the future, are, in fact, so high that the operation would be grossly uneconomic, even if subsonic first-class (or higher) fares are applied, and even if no overland restrictions are imposed due to the sonic boom. And at such fares SSTs can take over at most half of the long-haul first-class markets and an even smaller proportion of the medium-haul first-class markets, the portion of the economy-class markets that can be encroached upon by SSTs at first-class fares being negligible.

Moreover, the SST market penetration will be further reduced because there seem to be no prospects that the SST sonic boom can be decreased to such a very low level that it would be acceptable to people on land, considering the self-evident, decisively significant condition that those people who are in the greatest need of undisturbed sleep - the sick and old and those who suffer from sleeping

[x] Dr Lindell is Vice Chairman of ICRP and Chairman of its Committee on External Radiation.

difficulties - must not often be awakened by the boom at night or if asleep in daytime.

Thus, and again for the first time in history, a new type of aircraft, the SST, would not be permitted to fly over inhabited land at the speed it is designed for. This exceptional drawback would from the outset make the SST a cripple among civil aircraft.

The operation costs being very high, the extent to which air passengers will fly the SST being quite small and the benefit to those who can afford to use it being at best moderate, the cost/benefit relationship for SST enterprises would be exceedingly high. In a world of limited resources and great poverty this fact alone, thus disregarding social "diseconomics", appears to be a sufficient reason for abandoning plans on civil supersonic flight, until and unless SSTs can be built which have roughly the same operating costs as subsonic jets so that they could operate economically at economy-class fares.

The issue at stake would seem simple enough if the commitments to introduce two SST models, the TU-144 and Concorde, had not come to the present advanced stage. In particular with respect to Concorde the facts that roughly two billion dollars have already been invested, that series production of 22 aircraft (in addition to two pre-production aircraft) is in full swing and that, when this is written, BOAC and Air France have ordered five Concordes each, might appear as an unsurmountable obstacle for abandoning the projects.

These commitments cannot, however, be taken as a justification for exposing, on an international level, the public to serious pollutions and hazards. Still less should the commitments be accepted as an incontrovertible evidence that mankind has already irrevocably entered the "supersonic age".

It should follow from the observations made in this paper that minimum international requirements for introduction of SST ought to be

(1) that they are forbidden to fly supersonically over inhabited land,

(2) that they comply with airport noise standards for contemporary subsonic aircraft, and

(3) that it has been proved that no adverse effects result from sonic booms over sea, cosmic radiation or exhaust emission in the stratosphere.

In conclusion, the course that will be followed with respect to introduction of the Concorde and TU-144 into international service, and as regards further developments of and plans on introducing new-generation SSTs, will be of great significance not only for civil aviation but also as an example of the ability of Man to steer technology when there is a conflict between alleged economic advantages and detrimental social effects.

References

1. Concorde for the Airlines, Flight Int special ed, 1971.

2. Lundberg, B. Should Supersonic Airliners be Permitted? New Scientist Vol 9, 1961.

3. Lundberg, B. Some Special Problems Connected with Supersonic Transport. Prep for the IATA Conf on Supersonic Air Transport in Montreal, April, 1961. Publ in Proceedings and as FFA Memo PE-11.

4. Lundberg, B. Speed and Safety in Civil Aviation. The Third Daniel and Florence Guggenheim Memorial Lecture. Pres at the Int Congress of the Aeron Sciences in Stockholm, Aug, 1962. Publ in Proceedings and as FFA Reports 94, 95 and 96.

5. Lundberg, B. Pros and Cons of Supersonic Aviation in Relation to Gains or Losses in the Combined Time/Comfort Consideration. Pres Feb, 1964 at the Bristol Branch of RAeS. J RAeS Vol 68 No 645, Sept, 1964.

6. Ziegler, H. The Major Development Trends in Air Transport and European Co-operation. Lecture to Cranwell Branch of RAeS April 9, 1970. J RAeS Vol 75, Maj, 1971.

7. The Financial Times, June 14, 1972.

8. Swihart, J.M. (Boeing Co), Our SST and its Economics. Astron and Aeron, April, 1970.

9. Hughes, L.M. How Passengers Would Outfit the 747. Marketing, May, 1967.

10. De Grauw. Explanatory Memorandum to Resolution 511 (1972), of the Council of Europe (on the economic implications of introduction of SSTs).

11. Krzyczkowski, S. IATA Requirements for the Supersonic Airliner, Interavia Vol 17 No 9, Sept, 1962.

12. Lundberg, B. The Economics of SSTs in Competition with Wide-Bodied Subsonic Jets. BL Report 149, June, 1972 (an updated version is under work).

13. Schaffer, J.H. (Adm FAA), The Economics of Supersonics. Address to Long Island Assoc of Commerce and Industry, Nov, 1969.

14. Withington, H.W. Why an SST: the View from Boeing, Wall Street J, Oct, 1969.

15. Goldsmith, H.A. Flight Efficiency Trends for the SST. CASI/AIAA Meeting. Toronto, Canada, July, 1970, AIAA P No 70-871.

16. Statement by Mr A.N. Tupolev: "An airliner going at 2,500 km/h, for example, can do the job of three conventional (subsonic) machines", Pravda, June 3, 1971.

17. NY Times, May 27, 1972.

18. The Times (London), May 26, 1972.

19. Communications from David Price, Secr of State for Trade and Industry, UK, May 10 and 12, 1971.

20. Statement by Mr W.M. Magruder (consultant to the President of U.S.). Flight Int, Feb 10, 1972.

21. Statement by J.H. Shaffer (Adm FAA), Av Daily, Nov 30, 1971.

22. Jane's All the World's Aircraft 1970-71.

23. The Economics of the Concorde. Interavia No 8, 1972.

24. Lundberg, B. Useful Load Ratio with Jet and Airscrew Propulsion of Aircraft, J RAeS Vol 51, Aug, 1947.

25. Cortright, E.M. The New Civil Aviation Within Our Grasp, Astron and Aeron, Jan, 1972.

26. Morgan, M. A New Shape in the Sky, Aeron J, Jan, 1972.

27. Loftin Jr, L.K. Aeronautical Vehicles - 1970 and Beyond, J of Aircraft, Dec, 1971.

28. The Boeing Co. The SST in Commercial operation, May, 1969.

29. Statement by Sir George Edwards, Chairman BAC, to the Amer Ch of Com, London. Flight Int, Dec 23, 1971.

30. Edwards, C.B. CONCORDE - a Case Study in Cost-Benefit Analysis, Univ of East Anglia, April, 1971.

31. Garwin, R.L., et al. Final Report of the ad hoc Supersonic Transport Review Committee, Off of Science and Technology, Washington D.C. March, 1969.

32. UK White Paper on Environmental Pollution, May, 1970, para 46.

33. What the BOAC Order Means for Concorde's Sales Campaign. Financial Times, May 26, 1972.

34. Adams, J., Haigh, N. Booming discorde. Geographical Magazine, July, 1972.

35. Lilley, G.M. Report in Five Parts On the Sonic Boom, Prep for the OECD Conference on Sonic Boom Research, Aug, 1969.

36. Parent, M. Effects of Supersonic Flights. Les Monuments Historiques de France. Jan-March, 1968.

37. Wiggins, Jr, J.H. Effects of Sonic Boom. J.H. Wiggins Company, Calif 1969.

38. Lundberg, B. The Acceptable Nominal Sonic Boom Overpressure in SST Operation over Land and Sea. Pres at the National Conf on Noise, the American Speech and Hearing Assoc, Wash, D.C. June, 1968. B.L. Report 110. Publ abbreviated in the Congress Proceedings.

39. Lundberg, B. Essential Considerations and Research Required for Governmental Decisions on Rational Policies with Respect to the SST Sonic Boom. Pres at the OECD Conf on Sonic Boom Research, Paris, 1970. BL Report 128.

40. Lundberg, B. Is Civil Supersonic Aviation Justified? BL Report 147, July, 1971. Pres to the Committee on Social and Health Questions of the Council of Europe in Stockholm, July, 1971.

41. Boeing's latest SST proposal. Flight Int, Jan 16 and 23, 1969.

42. Report, ICAO Sonic Boom Panel, 2nd Meeting Montreal, Oct, 1970, Doc 8894, SBP/II.

43. Lundberg, B. Comments on Aérospatiale's Statement "Supersonic Aircraft and the Environment" Pres to the Committee on Social and Health Questions of the Council of Europe. Sept, 1971. Also publ as BL 148.

44. Lundberg, B. Observations Relating to the Effects and Localization, on Land and Sea, of SST Sonic Booms in the "Crescent" Areas of Focussed Booms. Working Paper to the 1st Meeting of the ICAO Sonic Boom Committee, Montreal, May, 1972. (SBC I-WP/30).

45. Some Effects of Supersonic Flight. Committee for Environm Conserv, London, April, 1972.

46. Ferri, A. Practical Aspects of Sonic Boom Problems. ICAS VII, Sept, 1970.

47. Ferri, A., Schwartz, I. Sonic Boom Generation Propagation and Minimization, AIAA 10th Aerospace Sciences Meeting, San Diego, Calif, Jan, 1972.

48. Highlights of the (OECD) Conference on Sonic Boom Research (Febr, 1970), Report by the OECD Secretariat, ENV (71) 14, March 10, 1971.

49. Johnston, H.S. Reduction of stratospheric ozone by nitrogen oxide. Science 1973, 1971.

50. Inadvertent Climate Modification, Report of the Study of Man's Impact on the Climate (SMIC), MIT Press, Cambridge, USA, 1971.

51. Crutzen, P.J. On Some Photochemical and Meteorological Factors Determining the Distribution of Ozone in the Stratosphere; Inst of Meteorology, Univ of Stockholm, Oct, 1971.

52. Crutzen, P.J. SST's - a Threat to the Earth's Ozone Shield. Ambio, April, 1972.

53. Lundberg, B. The Hazards for Female CONCORDE, and other SST, Passengers and Stewardesses of Reproductive Age of being Subjected to Harmful Cosmic Radiation. BL Memo 24, Nov, 1971.

54. Radiobiological Aspects of the Supersonic Transport, Report of the ICRP Task Group on the Biological Effects of High-Energy Radiations, Health Physics, Pergamon Press, 1966.

55. U.K. Air Registration Board, Tentative Airworthiness Standards for Supersonic Transports (SST), No 7-1, p 9 and 10, Sept 21, 1970.

56. Lundberg, B. The "Allotment-of-Probability-Shares" - APS - Method, a Guidance for Flight Safety Measures. Pres at the In symp on Civil Aviation Safety in Stockholm, April, 1966. FFA Memo PE-18.

57. Gilbert, G.H., Lee, R. Some Meteorological Problems of Supersonic Flight. Can. Aeron and Space J, April, 1972.

58. Lundberg, B. Development Trends in the Configuration of High Speed Aircraft, Flyg och Motor, 1943.

Corrigendum: In the paragraph preceeding eq. (12), page 9, the reference should be No. 58 instead of No. 24.

Enclosure B

THE NEED FOR RECONSIDERING THE SST ISSUE

Shall We Drift into the Supersonic Age by Accident?

Presented at the International Congress of Communications and Transports Genoa, Oct. 8-13, 1972, organized by Istituto Internazionale delle Comunicazioni.

On the occasion of the Eighth International Congress of the Aeronautical Sciences, held in Amsterdam Aug. 28 to Sept. 2, 1972, I presented a paper, "Economic and Social Aspects of Commercial Aviation at Supersonic Speeds". The purpose of this Memorandum is to describe the current "supersonic dilemma" against the background of the main conclusions of the ICAS paper, and to indicate ways and means of preventing a development that would be detrimental to civil aviation and most undesirable for air passengers and large numbers of people on the ground.

Main Conclusions

1. Air passengers' need to travel at supersonic speeds is, by and large, only marginal.

2. Airlines operating the Concorde will suffer a deficit of at least $10 million per year per aircraft in relation to the return on the same capital investment in subsonic jets.

3. It will never be possible[x)] to design an SST which is economically viable in competition with contemporary subsonic jets.

4. The main "direct" reason for the poor SST economics is the much higher purchase-price/payload (or price per seat) ratio, the second important reason being the high fuel consumption per seat mile.

5. The productivity of an SST - i e the great-circle mileage per aircraft seat per year - is only at most 25 to 50 percent greater, for the two cases of extensive and no overland boom restrictions, than that of subsonics in spite of the roughly three times higher cruise speed of the SST. This moderate productivity increase is far from sufficient to compensate for the higher price/payload ratio of the SST.

6. The much higher price/payload ratio is due to (a) the inevitably much higher price/empty-weight ratio (inevitable because of the greater complexity and smaller production series of the SST) and (b) the much smaller payload/empty-weight ratio of the SST.

7. It follows that intense future efforts aimed at improving SST economics by still more sophisticated aerodynamic, structural and propulsive design features for obtaining a better payload/empty-weight ratio will be greatly counteracted by the increase in price-per-ton empty weight and in maintenance cost that will result from the increased complexity.

[x)] provided that a break-through in supersonic technology that is today inconceivable is not made in the distant future; how enormous such a break-through has to be for the SST to be economic can be determined quantitatively by theoretical research along the lines indicated in the ICAS paper.

8. The main technical reason for the small payload/weight ratio is the large wave drag which does not exist for subsonic aircraft but is inevitable at supersonic speeds, as it is caused by the inevitable shock waves.

9. The conclusions that current as well as future SST projects will be grossly uneconomic apply even if no overland boom restrictions are imposed. The exceptional drawback for the SST to be extensively forbidden to fly over land at the speed it is designed for makes, however, its operation economics exceptionally bad.

10. The sonic boom of current SSTs and of SSTs conceivable in the future is far too severe to be acceptable - in particular with respect to sleep disturbance - in any inhabited land.

11. The SST boom will in all likelihood also impose unacceptable disturbance, fright and hazards to people at sea.

12. The take-off and landing noise of the production version of the Concorde will far exceed the international standards for new subsonic jets.

None of these conclusions were refuted in the two special discussion periods arranged for debating the paper. I should nevertheless welcome further comments.

The Supersonic Dilemma

The decision in November 1962 to develop the Concorde would most certainly not have been made if it had been clear at that time that this SST would so completely fail to comply with the three, as regards economics, most important of IATA's far-sighted "ten imperative design objectives" issued earlier in 1962:

a. "SST seat mile costs must be equal to or better than those of subsonic jets of comparable size and range operating at the time of its introduction."

b. "Economic operations at supersonic speed must (in spite of the sonic boom) be practicable over inhabited areas at any time of the day or night."

c. "No increase in the level of engine noise can be tolerated. In fact, engine noise from the SST must be lower than that of subsonic jets operating at present in order to permit round-the-clock operations."

How then could it ever happen that the Concorde enterprise has been carried forward to its present advanced stage?

A complete answer will not be attempted here. May it suffice to recall the well-known fact that until about 1966-68 the Concorde Consortium firmly believed that operation of the Concorde would be an economic success, that SSTs would be permitted to fly supersonically over inhabited land in spite of the sonic boom, and that the noise of the Concorde would be acceptable.

When, two or three years ago, it became clear to most aviation experts that all of these beliefs were erroneous, it was too late, in the opinion of the two Concorde-sponsoring governments, to terminate the project. The openly admitted main reason for this opinion[x)] was the tremendous amounts of money spent on research and develop-

x) In the Explanatory Memorandum (Doc. 3072) to the Resolution of the Council of Europe No 511 (1972) "on the economic implications of the introduction of civil supersonic aircraft" the primary alleged reason against cancellation of the Concorde is that "some US $1,350 million have already been sunk in the Project".

ment. This "money-already-spent" reason for continuing the enterprise is, of course steadily gaining in strength along with the by now far advanced series production of 16 Concordes. Consistently - and in spite of growing fears among option-holding airlines that Concorde will be an economic failure, the British and French Governments recently authorized the manufacturers to buy long-lead-time materials for 6 more Concordes for keeping the production line alive, and the state-owned BOAC and Air France ordered a total of 9 Concordes.

The vitally important question is now: Will, or should, these giant investments and other commitments by two governments be accepted internationally as irrevocable first steps down the supersonic road ? In other words, will these steps be followed, for example, by other airlines buying great numbers of Concorde, by a Concorde successor being designed, and/or by development of a "third-generation" SST in the US ?

Such a course of events would likely mean that we continue to let ourselves passively be drifted into the "Supersonic Age" virtually by "accident". The words "by accident" and "drifted" are clearly justified because of the failure of Concorde even to come close to IATA's design objectives and because none of the decisions that have led to the present situation have been supported by objective analyses of the need for civil supersonic flight, or of its economic and environmental implications.

The consequences of continued developments towards large-scale supersonic aviation are easy to foresee:

1. Not only will SST airlines suffer from the uneconomic operation; the great deficits, or losses, incurred by SST operation would have to be paid for, to a great extent, by subsonic passengers in the form of higher fares than would otherwise be required.

2. This would counteract the development of civil aviation to a means of inexpensive transportation for the great masses.

3. The inevitable strain between SST airlines and all-subsonic airlines would cause exceedingly difficult fare-setting problems - or an open fare war.

4. SST airlines would be facing increasingly severe opposition against the detrimental environmental effects of SST operation, in particular against excessive airport noise and disturbance and hazards of the sonic boom to people at sea and in "boom corridors" over land.

5. These adverse effects would imply a second serious economic burden to SST airlines; directly due to payments for damage claims, and indirectly because SST operation will become increasingly unpopular, in pace with its growth, which will reduce passenger appeal for flying SSTs.

6. Even more important, however, people on the ground will increasingly suffer from the environmental effects unless the opposition succeeds in imposing extensive restrictions on SST operation (which would still further worsen the economics).

7. Finally, SST airlines and sponsoring governments might be subjected to an unparallelled economic disaster in the more distant future - when the investments in large fleets of SSTs have become enormous - if world opinion eventually succeeds in terminating supersonic aviation. This might well

happen when the noise and sonic boom of the SSTs have grown to really excessive levels (e.g. in daily frequency) considering also that the general public in the future undoubtedly will be much more environment minded than today. If, however, such a future reversion to all-subsonic aviation does not occur, the serious consequences 1 to 6 will continue to apply and get worse.

These prospects are alarming. There cannot be the slightest doubt that it would be best for all parties concerned that the Concorde enterprise is terminated and that the plans to develop second- and third-generation SSTs are either abandoned or halted for a long time (see below). Terminating the Concorde project would be best also for Britain and France because in the long run it weakens the economy of a country to produce goods that are grossly uneconomic to use and cause serious social "diseconomics".

Apparently, however, it can no longer be expected that the British and French Governments will deliberately decide to put an end to the Concorde. They and the Concorde Consortium are in desperate need of more, and big, airline orders soon. These have to be quite big as the production break-even number is said to be about 150 Concordes. If the total airline orders are much smaller, the losses in production will be staggering.

The series production being in full swing it is furthermore exceedingly important for the Concorde manufacturers that the two governments decide, in the near future, to extend their orders to more than the current 22 Concordes. This decision must be taken long before the 22 are ready to fly. Series production is a hungry beast. One cannot stop and restart a production line without drastic increases in cost, i.e. in losses. A slow production, too, is a costly production!

But on the other hand, how can the two governments possibly commit themselves to further enormous investments in extended series production without very considerable airline orders having been received ?

Describing this terrific dilemma is no doubt to put salt in open wounds. This I regret, in particular in view of the enormous skill, enthusiasm and hard work that have resulted in the Concorde which I fully appreciate as an outstanding technological achievement.

Yet, the long-term benefit of civil aviation and mankind must not be hampered by sentimental considerations. So the all-important question is, how can the developments towards civil supersonic aviation be halted ?

Recommended Actions

It is, of course, conceivable that the current Concorde enterprise will be stopped "by itself" in the near future if no substantial airline orders for Concorde are obtained x), or,at a somewhat later stage, if passenger appeal for flying the Concorde soon upon introduction turns out to be very insignificant. Such a development, however, would in all likelihood not alone be sufficient for shelving the SST idea. So much national prestige and taxpayers' money have gone into the Concorde concept that the designers will probably be ordered back to the drawing boards to design a Concorde successor, and declarations in the

x) By October 1, 1972, Air Canada and Sabena have cancelled their options on 4 and 2 Concordes, respectively, and there are clear indications that also Qantas and Lufthansa will cancel their options for 4 and 3 Concordes.

US from high officials indicate firm intentions to start development of a new US SST in a few years time.

It follows that the intense efforts necessary for preventing continued drifting into the supersonic age should be directed towards both the current Concorde issue and the SST concept as such. The following actions are proposed:

1. The general public all over the world should be enlightened about the serious implications of civil supersonic flight. The facts should be emphasized that the pro-SST side mainly represents current or potential future SST industries and the governments of four great powers, and that for these bodies huge economic interests are at stake, as well as prestige and considerations of employment. By contrast the SST-opposing side consists of individuals who have no similar powerful support, the motivation for their efforts solely being their conviction that the SST would be a serious mistake.

2. It is imperative that countries which have not as yet forbidden civil supersonic overflights (or taken a similar stand) do so, without delay, thereby following the example of about 10 countries (including the US) which have studied the effects of the SST sonic boom particularly thoroughly. As the SST boom has been deemed unacceptable by the latter countries, many of which have vast sparsely populated areas, the boom is, of course, equally unacceptable in proposed, sparsely populated "boom corridors" in the former countries. It is important that this is emphasized in massmedia.

3. Such media are also urged to stress that further environmental conditions for international acceptance of SSTs should be that they comply with airport noise standards for subsonic aircraft and that it has been proved that no significant detrimental effects or hazards will result from sonic booms over sea, from exhausts in the stratosphere or from solar-flare radiation to fertile female SST passengers.

4. It is particularly important that organisations for various categories of people at sea demand that regular SST operation over sea does not take place until and unless it has been proved by adequate tests that the SST boom has no significant adverse effects. This demand should be made widely known and be specifically directed to the United Nations and its organisations WHO, ICAO and IMCO (Intergovernmental Maritime Consultative Organisation), to the current and prospective SST-sponsoring governments and to airlines which have orders or options for Concorde.

5. Establishment of minimum conditions for acceptance of the SST is a matter of great concern for people all over the world and should hence be considered by the UN as has, in essence, been requested by the Council of Europe in its Resolution 512 (1972) and Doc 3071 "on repercussions of civil supersonic flights on human and natural environment". In view of this it is most deplorable that the SST issue was not taken up for consideration at the United Nations' Conference on the Human Environment in Stockholm, June 1972, as was proposed by the Council of Europe and planned by the Governments of Denmark, Norway and Sweden. It is now important that one or more governments propose to the UN that the minimum conditions for international acceptance of the SST, indicated in point 2 and 3 above, are agreed upon internationally.

Highly important as such an agreement would be, recommendations by the UN for limiting environmental effects of the SST would probably not be sufficient for prevention of premature introduction of supersonic aviation. Deliberations in the UN take considerable time, and the SST propoents are convinced that the environmental problems can be solved, or that exceptions will be made in favour of the SST, e.g. in airport noise regulations and in allowing "boom corridors", so as to make the SST "environmentally feasible"; they will therefore no doubt continue their efforts to sell the Concorde and to plan new SST projects.

6. In view of this it is most important that the economic weakness of the SST be emphasized by mass media and scientists, etc. It should be demanded that current SST models must not be put into large-scale operation, and that large investments into new SST projects should not be made, until and unless it has been proved that SST operation has a reasonable chance to be economical. It should in particular be stressed that the failure of the Concorde and proposed SST projects even to come close to the conditions of yielding equal return on investment as competing subsonic jets is caused by "laws of nature", or the like (especially the wave drag), and that technological advances for compensating these constraints cannot be conceived today.

7. It is finally most desirable that IATA reminds prospective SST airlines about its three "requirements", quoted above, for economic viability of the SST. However, even if such a reminder is not expressly made, the three conditions are quite as valid today as ten years ago, a fact that should be stressed in the enlightenment efforts.

Concluding Remarks

This action programme is in sharp contrast to the "wait and see" attitude held by most people informed about the SST issue. Even in countries which have severely restrained supersonic overflights of SSTs it seems to be commonly maintained that, as this gives protection for the own country against the SST sonic boom, there is no need, or obligation, to go further and oppose civil supersonic flight in general because of ill-effects other than overland booms. To do that could offend the SST sponsoring governments, so why not just wait and see what happens with respect to Concorde and further plans on SST developments ? Consistent with this general passivity is the philosophy (e.g. indicated in ICAO documents) that it would be sufficient that regulations, deemed necessary for SST operation over sea and for countries which have not forbidden supersonic overflight, are agreed upon, or imposed, only shortly (a year or so) before the first SSTs are expected to enter service.

Formally such passive attitudes appear to be neutral and objective. In reality, however, they very effectively assist the pro-SST side and contribute to civil supersonic flight becoming "inevitable". With series production of Concordes rolling, with continuing intense sales efforts and with plans on new-generation SSTs becoming more and more acute, the prospects for civil aviation of preventing deep and irrevocable drift into the supersonic age rapidly decrease with every month that passes without countermeasures becoming successful.

Should we not learn from past experience about other pollutionary activities, such as dumping in the sea of poisoneous materials or widespread use of DDT ? The lesson is that it would have been relatively easy, and inexpensive, to prevent such activities from ever being started, or to stem them at an early stage, whereas stopping or curbing the activities today is usually exceedingly difficult and costly. Most of such other activities give great economic dividends (if their "diseconomics" could be disregarded) - but even this is not true of the SST.

Bromma, Sweden, October 8, 1972

Socio Onorario, Istituto Internazionale delle Comunicazioni, Genova.
Hon. F. AIAA, F. R.Ae.S.

Enclosure C

CONCORDE ECONOMICS

Summary

The Concorde manufacturers have overestimated the operation economics of Concorde in relation to contemporary subsonics (a) with respect to payload by at least 60 percent (partly due to the complete neglection of the fact that subsonics, unlike Concorde, can carry great cargo loads), (b) as regards depreciation period by about 25 percent, and (c) with respect to productivity by at least 45 percent. These greatly overoptimistic assumptions explain the vast difference in results obtained: Whereas the manufacturers claim that Concorde will be extremely profitable, my analyses show that Concorde operating airlines will suffer a yearly loss of at least $10 million per aircraft in relation to equal return on capital investment in subsonic jets. The main reason for this is that the purchase price per "effective" seat (i.e. considering revenue of cargo in subsonic jets) is at least 8 times higher for Concorde than for competing subsonics (in spite of the fact that Concorde's price does not reflect its development costs).

Introduction

The main findings in my report "Economic and Social Aspects of Commercial Aviation at Supersonic Speeds", presented at the Eighth International Congress of the Aeronautical Sciences in Amsterdam, Aug. 28 - Sept. 2, 1972, are:

1. Even if there are no sonic boom restrictions it is not possible - on the basis of current supersonic technology or foreseeable advances - to design an SST which is economically viable in competition with contemporary subsonics.

2. The main reasons for this are fundamental and inevitable, namely (1) the wave drag (causing the exceptionally poor lift/drag ratio of SSTs), (2) the kinetic heating, due to the great aerodynamic friction at supersonic speed, (3) the compromise solutions required for enabling the SST to fly in two widely different aerodynamic environments, subsonic and supersonic, (4) the much higher SST flight altitude necessitating heavier fuselage skin and (5) the fact that the weight penalties for compliance with the same airport noise standards as for subsonics are much greater for SSTs.

3. These five basic facts result in a much smaller payload/empty weight ratio of the SST in relation to subsonics, and a much higher price/empty weight ratio, the latter also being caused (unless great subsidies are applied) by the high research and development costs and the small production series of SSTs. This in turn results in a much higher price/payload ratio for the SST, the most important "direct" (or "mathematical") reason why SSTs are bound to be grossly uneconomic.

4. The exceptional drawback of the SST to be almost totally forbidden to fly over land at the speed it is designed for is a further serious economic constraint, not experienced before in the history of aviation.

5. The productivity of Concorde (and similar SSTs) i.e. the great-circle mileage per aircraft per year, is only at most 25 percent greater than for subsonics, in spite of Concorde's 150 percent (2 1/2 times) higher cruise speed. This modest productivity increase cannot markedly counteract the higher price/payload ratio of the SST.

None of these conclusions were refuted in the two special discussion periods arranged during the ICAS Congress for debating my paper. Warnings based on the paper were sounded in my Statement to the Twentieth International Congress of Communications in Genoa, Oct. 8-13, 1972, "THE NEED FOR RECONSIDERING THE SST ISSUE, Shall We Drift into the Supersonic Age by Accident?"

In the method for comparing the economics of SSTs and subsonics presented in my ICAS paper only ratios between significant economic parameters are applied in the equations derived, the subsonic "comparison aircraft" being Boeing 747 for evaluating the relative economics of Concorde. This "relative method" gives in my opinion greater accuracy, because the parameters involved have to be directly matched, than does the commonly applied "absolute method" characterized by separate calculations of the economics of SSTs and subsonics on the basis of assumed absolute values of the economic parameters for each of the two kinds of aircraft.

For my evaluations of the economics of future generation SSTs the "relative method" is combined with fundamental "laws" for aircraft design, in particular weight-growth-factor theory.

Differences in Assumptions

There is an enormous difference between my results and those recently obtained by the Concorde Consortium (e.g. in "Concorde General Economics" reviewed in "Supersonic Economics", Flight, Oct. 5) and by its supporters (e.g. Sir Peter Masefield in"Can Concorde make a profit?", Flight, Aug. 10, and Andrew Hofton in "Concorde returns", Flight, Oct. 12). Whereas I have found that Concorde is grossly uneconomic, the Concorde favouring analyses indicate that Concorde will produce so very great returns that, to quote from Flight, Oct. 5, "operators will find, as the Prime Minister said at the IATA annual general meeting, 'No airline will be able to do without one'".

It is not easy to trace in detail the reasons for the diametrically opposite results obtained, the two methods applied being so widely different. It seems obvious, however, that the following assumptions in the documents referred to unduly and greatly favour the Concorde.

1. The assumption of only 344 seats in 747 is far too low. Boeing assumed 440 seats in their own comparison (1969) with the Boeing SST project and I have used the same figure in spite of it being too SST favourable: Introduction of the Concorde being planned to commence in 1975, the early 1980s will be significant for the competition, and at that time "stretched" 747s, or still larger jets, will undoubtedly have seating capacities of at least 600 to 700.

2. The Concorde-favouring analyses consistently neglect the considerable revenue of cargo obtained by subsonics. Whereas Concorde can take no cargo to speak of, the cargo capacity of 747 can be estimated to yield about the same revenue as 105 seats, assuming that on a weight basis the revenue of cargo, including mail, on the average is half of that for passengers. This, airlines have told me, is a conservative assumption.

3. The assumption of the same depreciation period, 12 years, for Concorde as for 747 unduly favours Concorde. One reason for this is that the SST will be subjected to a severe kinetic heating/cooling cycle for every flight. This means firstly that each flight will likely "consume" a greater proportion of the total fatigue life of the structure, and, secondly, that there are greater risks of unexpected major failures in structures and systems of such a serious nature that the resulting and increasing repair rate would make a shortening of the expected service life economically advisable.

It will no doubt be claimed that the current ambitious heat/load fatigue test with a complete Concorde structure will practically eliminate these two kinds of risks. However, this is not so, for a great many reasons explained in earlier papers[1,2], the main one being that in the Concorde fatigue test only one load/heat/time history is applied, representing a typical case, whereas in actual service the load/heat cycles always differ, sometimes very appreciably, from any test case, such deviations being much more significant when heat is involved than for "cold" subsonic aircraft.

A second reason for applying a cautiously short depreciation period is that the fatigue test will in all likelihood not be concluded until several years after prospective Concorde airlines have ordered the aircraft. In comparison with subsonic aircraft there will thus be much lesser means of knowing the actual fatigue life - i.e. the life until beginning of a high fatigue-crack rate - of the structural assemblies.

A third reason for a rapid amortization is that SSTs will be very poor sales objects on the second-hand market. After first-line use for, say, 2/3 of its depreciation period a subsonic long-range aircraft is usually attractive for medium- and short-haul airlines, not least for charter traffic. The corresponding residual value for an SST is practically nil, because it is basically a long-range premium-fare aircraft, which is ruinously unprofitable at economy or charter fares on medium and short distances.

Mainly for these three reasons I have assumed the depreciation period for Concorde to be 80 percent of that for 747, thus 9.6 years instead of 12. I would, however, not be surprised if a banker for financing purchases of Concorde will demand his money back within 7 to 8 years.

4. As regards productivity Masefield assumes 4,100 hrs/year both for Concorde and competing subsonics, whereas the Concorde manufacturers assume 3,600 hrs for Concorde and 4,000 hrs for 747. The latter figure is based on airline statistics, although it is taken pronouncedly on the low (SST favouring) side. (Many European airlines for example obtain about 4,400 hrs/yr for their long-range jets.) The 3,600 hrs/yr estimate for Concorde appears, according to "Supersonic economics", to be based on the subsonic 4,000 hr estimate, a reduction by only 10 percent apparently being judged sufficient to allow for the shorter flight times of SSTs.

It must be pointed out that this method of basing the productivity on utilisation in hours in economic SST/subsonic comparisons can be treacherous: Circumnavigating continents and prolonged subsonic flight portions (because of the sonic boom) would for example increase the utilisation in hours of an SST, but would impair its economics because of both decreased number of flights per year (and hence decreased great-circle mileage) and reduced passenger appeal.

The only correct method for SST/subsonic productivity comparisons is realistic assessment of the great-circle mileage per year that can be produced by the SST (M_s) and by the subsonic aircraft (M). Whereas the assessment for the subsonic can be supported by statistics, the estimate for the SST must be based on a realistic whole-year route schedule with due time allowances not only for turnarounds and daily and weekly maintenance and inspections, but also for major overhauls and repairs.

By and large all these ground times are proportional to number of flights per year, not to hours of flight. It follows that the increase for an SST, over a subsonic aircraft, in mileage-per-year production, is not nearly equal to the ratio between block speeds (roughly 2 for Concorde/747 on Atlantic distances), the reduction being much greater than the 10 percent, i.e. $M_s/M = 1.8$, assumed

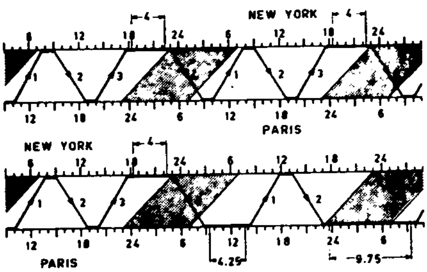


Fig. 1. Assuming for Concorde 3.75 hrs flight time over the Atlantic and 1.25 hrs turnaround time, 4 single flights per 24 hrs (upper figure) allow a daily inspection and maintenance time of only 4 hrs, i.e. one hr/flight. For a subsonic jet normally making 2 flights in 24 hrs of about 7.5 hrs each, the time per day available for inspection and maintenance is 6.5 hrs, i.e. 3.25 hrs/flight. For Concorde to attain an average time per flight of 3 hrs available for inspection and maintenance it can on the average only make 3 single flights per day, e.g. as shown by the lower figure.

by the Concorde builders. As follows from Fig. 1, Concorde cannot average more than 3 single Atlantic flights per 24-hour day if it is to have about the same average time per flight available for inspection and maintenance (about 3 hours) as a subsonic jet making 2 single flights per day (which is normal). If the total in-service time per year is the same, say 10 to 11 months, M_s/M would thus be 1.5 for Atlantic distances. There are, however, five reasons why this Mileage Ratio is too high for Concorde, the following four being of a general nature applying also if there are no overland boom restrictions:

(a) The reduction in mileage productivity due to turnarounds and maintenance time per flight during in-service periods is, of course, greater for all route legs that are shorter than the maximum range achievable by Concorde, i.e. over the Atlantic.

(b) The subsonic jet often produces a greater mileage per 24-hour day than is obtained by 2 single flights over the Atlantic, for example by longer direct flights, such as Frankfurt to New York, or by "tag-end", or "feeder", flights to or from the coastal cities, e.g. Frankfurt to Paris. Concorde cannot, however, make direct flights longer than over the Atlantic and the possibility of economically advantageous use of the "left-over" ground times (= 24 minus sum of block, turnaround and minimum inspection hours per day) is practically non-existent for all SSTs because short supersonic "tag-end" flights, to and from the main route, are particularly uneconomic (due to, *inter alia*, the high fuel cost per seat mile for short flights) and also because such flights are usually pointless to the passengers due to the very small time gain.

(c) For equal in-service time per year the Mileage Ratio, M_s/M, will thus be less than 1.5, but it will in all likelihood be still further reduced because the SST can be expected to require a longer total off-service time per year for major overhauls and repairs due to its greater complexity and the kinetic heating.

(d) Night curfews, i.e. prohibition to land and take-off between, for example, 23.00 and 07.00 hrs, will probably be applied to an increasing number of airports. It can easily be found that in general night curfews result in a greater reduction of the mileage achievable by SSTs than for subsonics[x].

Together the reasons (a) to (d) may well reduce M_S/M for the no-boom restriction case to about 1.25, M_S/M = 1.5 being a very optimistic upper limit.

For the "sea-limited" SST, forbidden to fly supersonically over inhabited land, the achievable Mileage Ratio will be still more reduced mainly because of the necessity either to circumnavigate mainland areas and islands located on the great circle routes or to fly over such land at subsonic speed. A further reason is that supplementing the main oversea operations, e.g. over the Atlantic, with subsonic "tag-end" flights over land (e.g. Zürich - London) will normally be out of the question for economic reasons, including lack of passenger appeal at SST fares. Detailed studies have convinced me that M_S/M will likely fall between 1.0 and 1.25 for a truly "sea-limited" Concorde.

This conclusion seems to be confirmed by BOAC's planned operation (with the 5 Concordes ordered,) comprising "two Concorde services each day from London to New York, three each week on the routes to Sydney and Johannesburg, and two a week across the Soviet Union to Japan." This appears to yield a total great-circle distance per week of the order 220,000 miles. Let us first optimistically assume that the schedule will be performed during all the 52 weeks. The over-the-year average mileage per day per Concorde would then be about 6,300 miles. This may be compared with the mileage production of a long-range subsonic jet with an annual utilisation of 4,000 hrs - which is conservatively low, see above - operating mainly on routes of some 3,600 miles, e.g. over the Atlantic. The latter assumption, too, is conservative as long-range subsonics often fly routes of at least 5,500 miles, e.g. Copenhagen - Los Angeles, but this conservatism is roughly offset by the fact that the many short "tag-end" flights reduce the total distance flown in 4,000 hrs. With a block time of 7.5 hrs the number of flights per year would be 533 and the average mileage per day would be (533 · 3600/365 =) 5,250 miles, yielding M_S/M = = 6,300/5,250 = 1.2.

This appears, however, to be a practically unattainable upper limit. It is true that the seasonal fluctuations of the demand for SST flights would be less than the average for subsonics because SST passengers mainly consist of high-level businessmen and executives. But the Concordes are supposed to take over almost all first-class subsonic passengers, and as a great proportion of those are tourists, the demand for Concorde flights will undoubtedly also be reduced during off-season periods. If we assume (a) that this reduction corresponds to BOAC's weekly schedule being applied during 50 weeks/yr (which still seems optimistic) and (b) that the utilisation of the subsonic comparison aircraft is 4,400 hrs/yr, the Mileage Ratio for Concorde would be only 1.05.

It follows that for BOAC's planned use the about 150 percent higher cruise speed of Concordes over subsonics will result in merely some 5 to at best 20 percent increase in "productive speed".

It should furthermore be observed that BOAC's intended operation is far from "sea-limited" with respect to preventing the boom carpets from covering inhabited

---

[x] This is particularly obvious in cases where the flight time between two airports applying night curfews is shorter than the night duration, with due account to the difference (if any) in local time. Night flights between the airports are impossible, unless the difference in local time is big enough (which happens to apply for flight No. 4 in Fig. 1).

land. The major portion (about 57 percent/ of the weekly mileage, i.e. the routes to Japan, Sydney and Johannesburg, carries over inhabited areas of continents and inhabited islands. If these three routes are to be flown in a truly "sea-limited" way the SSTs must either make extremely long detours at supersonic speed around the continents (Africa, Australia, and most of Asia) or fly at subsonic speed, on mainly great-circle routes, practically all of the time. (It is obvious from the globe that the oversea legs of the routes are so short that the "leaps" at supersonic speed, and altitude, that could theoretically be made - e.g. over the Mediterranean - by and large are entirely unfeasible because of the almost negligible time gain at the cost of a tremendous increase in fuel consumption). In both alternatives the Mileage Ratio, for a truly "sea-limited" Concorde would be greatly reduced, possibly to less than 1.0 - for this major portion of BOAC's schedule - considering the need for more refuelling stops than for subsonics and the greater time losses due to airport night curfews.

To sum up, it follows that the Concorde builders have overestimated the economics of Concorde in relation to subsonics with respect to payload by at least about 60% (545/344 - 1), with respect to depreciation by at least 25% and as regards productivity by at least 45% (1.8/1.25 - 1) and possibly about 80%.

Annual Deficit. Future Prospects

Then, what would Concorde's economics look like if realistic SST/subsonic ratios are applied? I is apparent from the foregoing that the following values for the three most important parameters are probably on the conservative (Concorde-favouring) side rather than fully realistic, or cautious, for the competitive situation of Concorde around 1980: The ratio, P_s/P, between purchase price per "effective" seat (including "cargo" seats) = (45.94/108)/(28.35/545) = 8.2 (!), the amortization period ratio, A_s/A = 0.8, and the Mileage Ratio, M_s/M = 1.25.

With these values, and with pronouncedly optimistic ratios also of all the many other parameters of significance for the relative economics of SSTs, anyone can easily find from the relevant equation in my ICAS paper that the deficit per year would appreciably exceed $10 million per Concorde in relation to the same capital investment in 747s or similar wide-bodied jets.

I am currently working on a modified analysis of SST/subsonic economics. It differs from the ICAS paper mainly in that a general equation is derived for the yearly deficit per SST as function of, inter alia, (a) the ratio between the payload/empty-weight ratios for SSTs and subsonics and (b) the ratio between the purchase-price/empty-weight ratios (see point 4 in the Introduction).

The new method lends itself well for tracing in detail the reasons for the vast difference in results, as regards Concorde economics, obtained by the manufacturers and myself.

Combined with the weight-growth-factor functions developed in the ICAS paper the method also confirms, in an even more concrete way, that it is not possible to design a "Concorde successor", or any "future-generation" SST, that can compete economically with contemporary subsonics (see point 1 of the Introduction).

References

1. Lundberg, B. Speed and Safety in Civil Aviation. Presented at ICAS III, Stockholm, Aug. 1962. FFA Reports 94-96.

2. Lundberg, B. The "Allotment-of Probability-Shares" - APS - Method. Pres. at Int. Symp. on Civil Aviation Safety, Stockholm, April, 1966. FFA Memo PE-18.

Enclosure D

Letter to the Editor of The Times (London)

CONCORDE, sold on incorrect pretences?

Sir, -- I was amazed at the many incorrect assumptions, and hence conclusions, regarding Concorde that characterized most of the articles in the Special Report of The Times, Nov. 28, 1972. Examples: The journey times, i.e. the door-to-door times, are not "cut by half" by Concorde; because of the long ground times to and from the airports the journey times are reduced by a mere 25 to 30 per cent. There does not exist any substantial "continuing quest for speed"; modern jets are fast enough for the overwhelming majority of passengers. But there are instead very strong continuing quests for reduced fares and airport noise - and these real needs will be seriously counteracted by SSTs.

The allegation that "Concorde will shorten dramatically the time of air travel after 1975, to the enormous benefit of all (italics by me) who must fly long distances" is also incorrect because, inter alia, of the often announced intentions to apply first-class fares; Concorde can thus only be catering for a fraction of the small minority that can afford such fares. This fraction is undoubtedly less than 5 per cent (not 100) of the long-haul market (the first-class portion of which is merely 10 per cent) firstly because Concorde can, due to the boom restrictions, duplicate subsonic jets only on a limited number of routes, and secondly because only a portion of the first-class passengers on such routes will prefer Concorde to the spacious de-luxe first-class compartments of the competing jumbos - clearly it is sheer wishful thinking to believe that airlines not operating Concorde can be forced to refrain from competing for the first-class passengers.

As regards Concorde's operation economics the article "The profit test" is based on the manufacturers' document "Concorde General Economics". It is found that in general the return on investment for a mixed fleet of Concordes and all-economy class 747s will be about twice as high as for an all-747 fleet with a mixed, about 90/10, economy/first-class seating, and furthermore, that "A calculation of return on investment shows the Concorde/747 fleet earning 14 per cent compared with 5 per cent for the all-747 fleet in a typical market" - thus an almost 3-fold gain by injecting some Concordes into the fleet!

In my report to the International Congress of the Aeronautical Sciences (ICAS, Aug. 28 - Sept. 2, 1972), "Economic and Social Aspects of Commercial Aviation at Supersonic Speeds" (summarized in "Concorde Economics", BL Memo 26), I arrived at a diametrically opposite conclusion: Airlines operating Concorde will suf´ɪr a yearly loss of at least $ 10 m (about £ 4 m) per Concorde in relation to equal return on investment in subsonic jets (as was correctly recorded by R. Wiggs in his "Case against" article in The Times), thus a total yearly deficit of over $ 2.5 billion for "the 250 Concordes on which the manufacturers have always based their marketing forecasts."

Who is right? Will the Concorde incur tremendous gains or tremendous losses? This question must be answered before civil aviation, and indeed mankind, are pushed into the "Supersonic Age", considering also the grave social "diseconomics" of SSTs. The significance of the question is dealt with in my Statement to the International Congress of Communications in Genoa, Oct. 1972, "The Need for Reconsidering the SST Issue. Shall we Drift into the Supersonic Age by Accident?", BL Memo 26.

The question can be answered by applying the method developed in my ICAS paper for direct comparison of the economics of SSTs and subsonics. But as explaining the method would take too much space I will only point out the most gravely biased assumptions made by the manufacturers in order to prove the economic superiority of the Concorde: Firstly, and most remarkably, they have neglected the fact that 747s (and similar subsonics), unlike Concorde, can carry great cargo loads yielding very substantial extra revenues (some 25 per cent of the revenue of passengers). Secondly, the assumption of only 347 seats in competing mixed-class 747s is far too low. The Concordes will already in the introduction years meet competition with mixed-class 747s with at least about 400 seats, and, even more important, this number is expected to grow to 600 or more at the midpoint, around 1980, of the Concordes' service lives.

Thirdly, the assumed 347 seats in a mixed-class 747 are very liberally increased by no less than 100 seats (to 447) in the all-economy 747s which greatly improves the Concorde/all-economy-747 alternative - by the good help of the 747s(!). Fourthly, to apply the same depreciation period of 12 years for Concordes as for subsonics is financially insane because of the many unknowns regarding the usable service life of the SST and its near-zero value on the second-hand (e.g. charter) market.

Fifthly, the assumption "annual use 3600 hours for Concorde and 4000 hours for the 747" (thus a "utilization" ratio of 90 per cent) combined with Concorde's 2 times higher "block speed" (e.g. over the Atlantic) is clearly meant to imply that the productivity of the Concorde - in terms, for example, of number of flights per year over the Atlantic - would be 1.8 times greater for Concorde (this being for example the conclusion drawn in "Concorde returns", Flight, Oct. 12, 1972). This, too, is incorrect. The relative SST/subsonic productivity cannot be measured in hours of flight (it would then be improved the more the SST flies at subsonic speeds or circumvents continents!); the productivity has to be measured in the total yearly great-circle mileage between city pairs that can be flown by an SST as compared to a subsonic aircraft. As I have thoroughly shown in my ICAS paper this ratio can for Concorde/747 hardly exceed 1.25; the alleged productivity of Concorde is thus exaggerated by about 50 per cent.

If realistic assumptions are made in the five respects discussed above it is easily found, by applying the equations in my ICAS paper, that Concorde will incur tremendous losses. Surely, airline economics cannot be improved by introducing grossly uneconomic Concordes into a fleet of basically very economic wide-bodied jets, however sophisticatedly the cocktail is mixed.

Then, what about the furure? Many of the articles breath confidence that "supersonic air travel (will become) a regular feature of everyday life", it being specifically observed that "the (Concorde) partner governments and manufacturers will have to consider a second-generation Concorde" (this already being planned "behind the scenes") and that such a "Concorde Mk 2 and perhaps the American SST Mk 2 will almost certainly be the standard mode of long-distance travel before the end of the century".

Further findings in my ICAS paper are (1) that it will remain impossible to design an SST - on the basis even of foreseeable and great advances in supersonic technology - which is economically viable in competition with contemporary subsonics, and (2) that the reasons for this are of fundamental nature, in particular the shock-wave drag and the aerodynamic heating at supersonic speed together with the weight-increasing compromise solutions required for enabling the SST to fly safely in the two widely different aerodynamic environments, subsonic and supersonic.

I think it would be wise not to spend further great amounts of money on SST projects until my analyses and conclusions have been thoroughly dissected - and refuted. And I offer to come to England, or any other country contemplating development or use of SSTs, in order to defend my allegations in public. I will also be glad to send my three papers indicated above to anyone interested.

Bo Lundberg
Holbergsgatan 120, Bromma, Sweden, December 11, 1972

(F.R.Ae.S.; Hon. F. AIAA; former Director General, the Aeronautical Research Institute of Sweden)

Chairman PROXMIRE. Thank you very much, Mr. Lundberg.

You have obviously done a tremendous amount of work on this, and it is very impressive and helpful. You must have put in a great deal of time as well as your obvious talent and understanding of these complicated technical subjects, but I am a little put off by the flat dogmatic statement that never will it be possible to design an SST that will be able to compete with the subsonic jets. Those are the kind of statements which I thought scientists and scholars never engaged in—even that generalization "never" is perhaps a little strong—but I thought they rarely would because, of course, the whole history of aviation is one of breakthroughs that were unforeseen. A few years ago, 30 years ago, most of us could not envision television or space travel or atomic energy and, of course, those things are now realities. The relatively simpler technological problem that the SST confronts should be capable of solution, but you say never. How can you so comfortably assert that there is no possibility of ever developing a commercially competitive SST?

Mr. LUNDBERG. Mr. Chairman, I think that is a very good question which I think I am prepared to answer. It is indeed to go very far these days to say that something is impossible when you can land a man on the moon, when you can create atomic power, when you can do practically anything; I agree. But to do something economically, so that it can pay its own way without subsidies, that is quite another thing. We will always have subsonic aviation, so SST's will always meet competition with such aviation, both with economy-class and with first-class fares, and for a great many reasons subsonic aircraft will be continuously more and more economic. There will, of course, also be improvements in the supersonic technology so the significant question is which advances will proceed with the greatest speed.

But even if the supersonic technology were to proceed a bit faster than the fast advancements that will continue to be made in subsonic technology, in particular with respect to improved materials and the like, there is such a tremendous gap in the deficit factor that it just cannot be overcome. Just at the end of my talk I mentioned the five fundamental reasons why this is so. Most important of all, SST's will always have to overcome the wave-drag and the wave-drag is about one-third to one-half of the total drag of a supersonic aircraft. The SST has to overcome the drag of this enormous parachute of the shock wave to cone, the same shock wave that creates the sonic boom.

I am sure that that problem can never be licked. The sonic boom can possibly be slightly alleviated on the ground but the shock wave in the air cannot be overcome. And then there are the four other main reasons—listed in the summary of the written statement—why the operation economics of SST's will always be much inferior to those of subsonics.

So, I am personally quite sure about this, but I do admit that it will take a lot more discussion within the aeronautical community to convince all my friends in aeronautics that I am right.

Chairman PROXMIRE. Well, your technical arguments are hard for me to evaluate because, of course, it takes time to study the mathematics and to have all of the parts of the equation explained, and you didn't have time to do that, but as I understand it, to put it very simply, the SST will cost a great deal more. The Concorde now costs how much per copy, about $40 million, $45 million?

Mr. LUNDBERG. The recent figure, which I have used here, is about $46 million for a Concorde.

Chairman PROXMIRE. About $46 million for one plane. And what life do they expect on a Concorde, how long do they expect it to last?

Mr. LUNDBERG. The Concorde Consortium has assumed the same life, that is, the same depreciation period of 12 years, as for the subsonic, and that I think is economically insane for a great many reasons explained in detail in the prepared statement.

Chairman PROXMIRE. I understand that. But let's accept their assumption even though it may be wrong; at any rate, it is approximately twice as expensive as the big Boeing plane, the 747, which costs, as I understand it, somewhat more than $20 million. The Concorde costs somewhat more than $40 million, so the depreciation, No. 1, would be twice as great on the SST as on the 747.

Mr. LUNDBERG. That is correct, if referred to the aircraft and not to the number of their seats.

Chairman PROXMIRE. How about the fuel consumption per mile?

Mr. LUNDBERG. The fuel consumption per seat mile is of the order——

Chairman PROXMIRE. Well, all right, per seat mile.

Mr. LUNDBERG. Per seat mile I think is the best way of defining it, because otherwise you have the size of the aircraft to take care of.

Chairman PROXMIRE. All right.

Mr. LUNDBERG. The seat-mile consumption is of the order of three to four times higher for the Concorde.

Chairman PROXMIRE. Three to four times higher for the supersonic transport.

Mr. LUNDBERG. Yes. One thing——

Chairman PROXMIRE. How important is, No. 1, depreciation in the total cost and how important is the fuel consumption in the overall cost? What percentages? Would you say the depreciation is one-half or one-quarter of the total cost of operating a subsonic jet? I know it is variable, it depends on how intensely the plane is used and so forth, but can you give us a rough estimate?

Mr. LUNDBERG. It is all discussed in the evaluations in the prepared statement. In general I would say that the depreciation factor is one of the biggest cost items because it is related to the purchase price per seat, and this is at least eight times higher for the Concorde over the 747.

Chairman PROXMIRE. Let's go back to the seating capacity then. The SST would have how many seats available for its passengers?

Mr. LUNDBERG. In my ICAS paper of August I counted on 128 passengers in the Concorde—it has now been reduced to 108 all first-class seats.

Chairman PROXMIRE. How many in the 747?

Mr. LUNDBERG. At that time I counted on 440 real passenger seats, but I will now make a most important point: The Concorde Consortium has forgotten, in all its evaluations, forgotten, or at least neglected, the great contribution to revenue of subsonic jets due to cargo. The cargo revenue, over and above the capability to haul passengers' luggage, contributes at least 20 percent of the revenue of subsonic aircraft, and the Concorde can take no cargo to speak of.

Chairman PROXMIRE. All right. I just have one more dimension here. The 747 costs one-half as much, it has three times as many seats, that gives it a 6 to 1 advantage there. Now the speed, of course, is the alleged equalizer, that the SST advocates argue for. They say that all of these disadvantages are offset by the fact that the SST can fly so much faster than the 747. You argue that there is a turnaround problem.

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. And that the SST cannot make two round trips in the same day, at least not for more than 1 day or 2 days in a row, is that right?

Mr. LUNDBERG. That is right.

Chairman PROXMIRE. Would you briefly explain that once again so it is clear in our minds?

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. Let me just preface that by saying the subsonic jet can make one round trip——

Mr. LUNDBERG. Right.

Chairman PROXMIRE (continuing). In a day, in a 24-hour period.

Mr. LUNDBERG. That is right, yes.

Chairman PROXMIRE. We are talking about flights between New York and Paris.

Mr. LUNDBERG. The reason why the productivity ratio in general cannot be higher than 1.5—thus for example three single flights per day over the Atlantic by Concorde to be compared with two by the 747—even if there were no sonic boom restrictions, I have explained in great detail in enclosure C, "Concorde Economics," to the prepared statement and in even greater detail in the ICAS paper. Briefly the reasons are that when people speak about turnaround time they only consider the time for unloading passengers and loading new passengers and filling up with fuel. But there are other factors, which I had time just to mention, and they are the maintenance time, and the time for repairs and inspections, and all airline experts know that these factors, these extra ground times, are proportional, almost directly to number of flights and not to hours flown.

Chairman PROXMIRE. Now once again let me say that in all fairness we are not talking about the new U.S. SST when we compare the Concorde with the 747. We are talking about the British-French Concorde which our people say is a far less efficient plane. The seating capacity of the proposed American SST would be much greater, the speed would be substantially greater, and they say those advantages would compensate for the competitive disadvantage you are discussing to some extent. But I think the British-French Concorde is of central importance because of the great concern expressed over and over again that if we don't compete, if we don't build an SST, the British and French and Russians will come along and take the market away from us; it will be a great factor in our balance of trade and markets if we don't build an SST.

How do you account for the fact that the airlines had some firm orders, not many but some, and they have also taken some options on the British-French Concorde. If this plane is such an economic disaster, if it costs so much more, if its revenues are going to be so much less, if it can't compete with the subsonic jets, why would any airline make this kind of a commitment.

Mr. LUNDBERG. Mr. Chairman, I just don't know.

Chairman PROXMIRE. Well, give us the figures first. How many firm orders are there and where do they come from for the British-French Concorde?

Mr. LUNDBERG. The only firm orders are, as I think is well known, by the state-owned British and French airlines, BOAC and Air France, for five and four Concordes, respectively.

Chairman PROXMIRE. So the British and French airlines are owned by the Governments.

Mr. LUNDBERG. Yes. Owned by the Governments.

Chairman PROXMIRE. And those are the only orders, firm orders, they have for the Concorde, is that correct?

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. And how many orders are there, nine, is that right?

Mr. LUNDBERG. Yes. Five for BOAC and four for Air France.

Chairman PROXMIRE. Nine altogether, five for BOAC and four for Air France. There are 47 options, it is a minimum commitment, but a commitment of some kind. Don't they have to make a down payment on an option?

Mr. LUNDBERG. Yes, they have. But I think the downpayment is to be paid back if a great many conditions in the option contracts are not complied with, if, for example, the price has escalated too much or if the Concorde can't use important airports for noise reasons.

Chairman PROXMIRE. And the actual option fee, too, is considerably less as a percentage than for the subsonic jets; is that right?

Mr. LUNDBERG. I don't know exactly the downpayment that has to be made on the options. I think it is a rather small sum of money.

Chairman PROXMIRE. Let me ask, we have heard about the absolute determination in the British and French Governments that the Concorde should succeed. Can they conceivably make it succeed through some pricing policy or subsidy scheme adequate to render it economically attractive to the airlines?

Can they subsidize acquisition costs enough to offset the high operating costs?

Can they subsidize the operating costs to foreign airlines?

What combination of such subsidies would be best from their standpoint?

Mr. LUNDBERG. It is difficult to say. I think they wish to get as high a price as possible, of course, and I think the price is based on the production run of between 150 and 250 Concordes, because the break-even number of aircraft produced has to be considered.

I do think that at the price for which they are now offering it, the airlines will find that the Concorde is quite as uneconomic as I have shown here, thus they will, in fact, lose much more than $10 million per year per aircraft.

Chairman PROXMIRE. Now let me ask you about another matter.

There is the TU-144, the Russian plane. I can remember when we debated this on the floor of the Senate, Senator Henry Jackson held up ads in American magazines for the TU-144, pointing out that the Russians are very earnest about trying to sell this plane. Whereas the

British and French Governments might have some constraints about subsidy and so forth, the Russians might have far less because of course they have a different kind of economic-political operation.

What can you tell us about the competitive threat of a TU-144 if we do not develop our own supersonsic transport? Why would not the Russians be able to offer their supersonic plane and, if necessary, subsidize it to a point where it can drive out our subsonic jets in some over-ocean traffic?

Mr. LUNDBERG. There are many reasons.

In the first place, it is a very serious limitation not to be able to fly supersonically over land. This restriction is quite serious and, as you have certainly seen, all of the BOAC planes——

Chairman PROXMIRE. Let me just interupt at that point to say that the Russians have indicated little concern about the sonic boom. They have indicated as far as their vast territory is concerned, including all of Siberia and so forth, that they are perfectly willing to have the SST's fly over their territory, in fact, right over Moscow for that matter. They do not seem to be concerned about it.

Mr. LUNDBERG. That is probably correct, although I know, from the deliberations last May of the Sonic Boom Committee of ICAO in Montreal, that the Soviet representative stated that they will probably forbid the Soviet SST to fly supersonically over their country at night.

But, even disregarding this, I cannot see how they could be a threat to western airlines. And if they are flying, say, from Moscow to New York—if their SST can achieve that range, which it has not as yet—they have to fly over Norway and Sweden. We however, have forbidden supersonic flight over our countries—the New York-Moscow great-circle route carries over Norway and Sweden—and it is enormously uneconomical to first fly supersonic from Moscow to the Baltic Norway, and then up again to supersonic speed; that is simply impossible.

Chairman PROXMIRE. One of the great commercial developments, one of the great economic miracles of recent years, of course, is Japan, and there will be increased traffic and flights between Japan and the United States. That is over a great ocean area which would permit supersonic speed.

Why would that not be an area where the TU-144, the British-French Concorde, or other supersonic planes could enter effectively?

Mr. LUNDBERG. Of course, there will be a market, but it could only be flown at a tremendous loss because of all those factors that I have analyzed in detail in my prepared statement: The high fuel consumption, the high depreciation cost per seat, et cetera.

There would be a market, but it can only be flown at a loss.

Chairman PROXMIRE. Then, as I understand it, the Russian TU-144 also has all the problems of noise, atmospheric emission, high seat-mile costs and high fuel consumption that the Concorde has.

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. And the range, as I understand it, is only 3,500 miles for the SST, which I guess is far less than it is for the 747 and, therefore, a great deal of the advantage of being able to fly at this high speed would be lost if they had to refuel; is that correct?

Mr. LUNDBERG. That is correct, Mr. Chairman.

Chairman PROXMIRE. My time is up.

Congressman Reuss.

Representative REUSS. Thank you, Mr. Chairman. And thank you, Mr. Lundberg, for coming all this way to be of assistance to this committee.

In your prepared statement you end up by saying that you, and I quote, "I take the liberty of advising against any Federal support for the new U.S. SST program" and you derive that advice largely from your view that in order for Government support to be justified for any new and costly enterprise, the economic and social benefits, including the real need for the activity, must clearly outweigh the costs as well as any particular drawbacks—for example, adverse effects on the environment. That is contained in your prepared statement.

Now I draw your attention to the fact that since Boeing was cut off from Government subsidy on the SST and, hence, stopped its development of it, it has done interesting and resourceful things in certain other fields; housing, new methods of homebuilding, mass transportation, remedies for water pollution, new methods of solid waste disposal.

Could you give us a judgment as to the relative cost-benefits to the Nation in continued research and development on the areas I have mentioned—housing, mass transportation, water pollution, solid waste disposal—as opposed to subsidized research and development on the SST?

Mr. LUNDBERG. It is a tremendously important question, and I think the background for answering this and similar questions should be the rather new apprehension of the fact that the resources of this earth are limited. We all know about some of these rather alarming doomsday investigations.

One is from Professor Forrester in Boston. Another is from the Club of Rome, and we have a Swede active in the same field—Prof. Gösta Ehrensvärd. They all conclude that fuel and other things will get more and more scarce and the prices will rise. So, against this background, the whole matter of priorities is becoming more and more important, and I am sure that is in the back of your minds as well.

I will say that next to war, and I repeat, next to war, I can think of no higher cost-benefit ratio than what would be produced by putting vast sums of money in SST's. For one thing, very few people can possibly afford to pay first-class fares or more. Furthermore, while some of us might admittedly get a bit tired by lengthy subsonic flights, such things are marginal inconveniences, and to overcome them cannot possibly justify the spending of billions of dollars when there are so many other really serious needs in this country—I think you mentioned a few—and in all countries, not least, of course, in the developing countries.

I do not know if I have answered your question or given some opinions about it that might be of some value. I have just indicated my own feelings. I think, if I might add this, that when I started my studies of the SST issue around 1958 and first presented my findings a few years later, I tried to find out the optimum speed if there were no transonic difficulties when one passes the speed of sound. It is after mach No. 1 that the difficulties become serious. You have the wave drag and you have to fly higher, and so on. But if there would have been smooth subsonic conditions up to, say, twice the speed of sound, the question I asked myself was how fast would it have paid, or made sense, to fly then?

I thought that was an interesting question, and I found that the need for and benefits of increasing the speed, even if you could disregard the difficulties beyond mach 1, is tapering off rapidly. My conclusion was that it would hardly make sense to fly more than 25 to 30 percent faster than the speed of sound for a great many reasons.[1] But now, as we do have all these special difficulties coming along at or above mach No. 1—for example increased drag, due to the shock wave, the sonic boom, the aerodynamic heating, and so on—it makes very good sense to put the limit rights at mach 1. And this endlessly repeated argument for the SST, that "past experience has shown" that it has always paid to increase speed, simply cannot be extrapolated to apply far into the supersonic speed regime.

For the same reason, that is, if the "extrapolation" conjecture were right, we would have increased the height of the skyscrapers all the time, but there is a sensible limit as to how tall one should make buildings. You just cannot say that, because a trend has been good in the past, it must be good also in the future. But this was perhaps beside your question.

Representative REUSS. It is very helpful.

Let me ask you one more question. I am sure one of the reasons that Chairman Proxmire called these hearings was because there have been some hints recently that, despite the decisive action of Congress in ending the SST, the administration is toying with the idea of starting the game again.

There was President Nixon's remark in the Azores about a year ago that America would some day have its own supersonic transport plane; then more recently Federal Aviation Administrator Shaffer has predicted that in this next year, 1973, the Government-subsidized SST would be revived; and Domestic Affairs Chairman Erlichman has not only said that the SST is not dead, but that there might be some start-up money in the budget which will come up to the Congress next month.

To most of us these hints are alarming, but is it possible that this kind of talk—I think it is loose talk by the Nixon team—might in a perverse way do some good?

As you pointed out, the Concorde is the creature largely of the British and French Governments who, having invested their reputations in it, insist on continuing it. Well, would not the threat that the United States is going to develop a second- or third-generation SST and thus fracture even the pitiful orders from China, Iran, and from their own French and British in-house air carriers—might that not finally bring the SST people in the British and French Governments to their senses and induce them to do what the United States did—to stop pouring good money after bad—or is that too wishful and optimistic a hope on my part?

---

[1] Lundberg, B., "Speed and Safety in Civil Aviation." The third Daniel and Florence Guggenheim Memorial Lecture Presented at the International Congress of the Aeronautical Sciences in Stockholm, August 1962. Published in proceedings and as FFA Reports 94, 95, and 96; and Lundberg, B., "Pros and Cons of Supersonic Aviation in Relation to Gains or Losses in the Combined Time/Comfort Consideration." Presented February 1964 at the Bristol Branch of the R.Ae.S. Jour. of R.Ae.S., vol. 68, No. 645.

Mr. LUNDBERG. Well, those are questions that are more the concern of the United States, of course, than myself. But if you mean to imply that the United States might feel compelled to have an SST because there is a Concorde, and the British and French would be compelled to proceed with the Concorde and build perhaps a Concorde successor because there is a possibility of developing a U.S. SST, this is just the kind of cross arguments which one could play with but which I think are rather, in a way, if I may be permitted to say so, childish. I do not think we can go on arguing that because those other people have an SST, we have to have it.

What I can say is that, because the Concorde is basically grossly uneconomic, and the more they fly it the more they will lose money, I cannot see that it could be taken as an argument or a threat to the U.S. civil aviation or that the United States would have to follow suit.

Perhaps I did not catch exactly what you meant to ask.

Representative REUSS. I meant really something different.

What I meant was, is there not perhaps a possible, conceivable benefit in all of this talk by various administration figures about the revival of the American SST. Since the Concorde is on such shaky ground anyway, might not this be the final push that caused it to be abandoned by the Governments of France and Britain which are now supporting it?

If there really is a threat that the United States is going to produce an SST which, however silly, is somewhat better than the Concorde—this might, I suggest for your consideration, induce the people who are supporting the Concorde in France and Britain to back away from it just as this country backed away from the SST.

Mr. LUNDBERG. I think the reasons for terminating the Concorde as soon as possible are good enough as they are, and whether they would be any better if the United States announces plans also to make what one might call the same mistake is difficult to say, but perhaps it would help Britain and France to terminate the Concorde a bit earlier. Thus I think they might be more inclined to terminate the project if they know that very soon there will be a better U.S. SST, disregarding that this too will be a very uneconomic so-called white elephant.

Representative REUSS. So the ideal solution would be enough hints and murmurs out of the situation to convince the Concorde people that they have something that should be stopped but not enough to really start it over here again.

Mr. LUNDBERG. Right.

Representative REUSS. Thank you, Mr. Chairman.

Chairman PROXMIRE. Thank you, Congressman Reuss.

I see our next witness is here now. I am going to just ask a couple of more questions of you, Mr. Lundberg.

Mr. Lundberg, there has been some talk about the British and French developing a second generation of a British-French Concorde, an improved version, one that would have greater seating capacity, one that would have greater speed. Do you see any basis for this possibility and what improvements could it offer? If they did offer it, do you think that a substantially improved version could provide competition for our subsonic jets?

Mr. LUNDBERG. Those questions are dealt with in great detail in enclosure A of the prepared statement, headed "Prospects of Future Improvements."

Chairman PROXMIRE. Can you summarize that detail in a minute and a half?

Mr. LUNDBERG. Summarizing my views, I will say that if you make a stretched Concorde——

Chairman PROXMIRE. If you make a what Concorde?

Mr. LUNDBERG. A stretched, that is a bigger Concorde.

Chairman PROXMIRE. Stretched?

Mr. LUNDBERG. Yes. By that you will gain very little, surprisingly little, because of the reasons explained in enclosure A.

As you wish me to be short, I can't possibly explain the reasons in a minute or two but I would very much like to go into the aeronautical reasons why this is so. Shall I do that?

Chairman PROXMIRE. Well, perhaps you can do that for the record. We would appreciate having that in the record.

Mr. LUNDBERG. Well, it is all in the prepared statement.

Chairman PROXMIRE. That will be fine.

The second question is, SST's have been criticized for generating excessive airport and community noise. I am not talking about the sonic boom, but I am talking about the airport and community noise.

Do you have current figures for the Concorde on sideline noise, approach noise, and takeoff noise levels? I am very concerned about this because when the SST was under attack we worked very closely with some of the leaders in the State legislatures who proposed limitations on the noise level, the decibel level of planes allowed to land at their airports. I think we had some 13 or 14 States with legislation introduced to prevent the excessive sideline noise of SST's. Then of course, the SST was killed and the legislation was not pressed.

Mr. LUNDBERG. Right.

Chairman PROXMIRE. Of course, the Concorde would not be a competitor if it could not be allowed to land at Dulles or Kennedy or the airports in Florida in this country—so much of the traffic originates in the United States that if the noise is too high that would be a prohibitive factor.

So can you tell us, could you compare the noise level for the 747, the DC-10, the L-1011 and the British-French Concorde? How much more is the sideline noise, community noise for the British-French Concorde than it is for our domestic subsonic jets?

Mr. LUNDBERG. In the three standard measuring points in the U.S. regulations, which are very much the same as those of ICAO, the Concorde will produce, according to promises—because the production Concorde has not yet flown—something between 111 up to 115 effective perceived noise decibels. By contrast the DC-10 and the L-1011 produce less than the required standard implying that they are below the basic figure of 108 decibels. So there is a very big difference.

Chairman PROXMIRE. How about the 747?

Mr. LUNDBERG. The 747 is rather close to the line; that is, just complying with the requirements.

Chairman PROXMIRE. About 108?

Mr. LUNDBERG. Slightly below for the new version of the 747.

Chairman PROXMIRE. Now, let me put that in perspective. It sounds as if it is very little more for the Concorde but, as I understand the way the decibel system works, that would be very considerably louder. Would it be twice as loud? Is there any way you could compare it? Give us a notion how loud 115 decibels are compared to 108.

Mr. LUNDBERG. It can be evaluated either in acoustic energy or in loudness, as you say. If there is a difference of 10 decibels, the subjective loudness is twice as high. Seven decibels means 50 percent higher loudness.

Chairman PROXMIRE. I see. So there would be a difference of between 50 percent and 100 percent in loudness, in the perception of the loudness.

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. And the energy is even more, I understand?

Mr. LUNDBERG. Yes, much more. If there for example is a difference of 12 decibels the energy will be higher by a factor of 16, so it would take 16 subsonic aircraft to land or take off simultaneously for the same energy output.

Chairman PROXMIRE. At any rate the critical point here I think we probably ought to focus on, because the noise is a subjective matter, is that the British-French Concorde would have to be reduced in loudness very substantially in order to land at our airports if we apply the rule of 108 decibels as the maximum permissible to supersonics as well as subsonics; is that right?

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. And what prospect is there that they could reduce their noise from 111 to 115 down to 108?

Mr. LUNDBERG. I think there are very little, if any such prospects.

Chairman PROXMIRE. Very little prospect.

Mr. LUNDBERG. Yes, because the prototypes that are now flying are much more noisy than these promised levels of 111 to 115 decibels. They are the prototypes that are in the neighborhood of 125 to 130 decibels. I have here a very good summary which I received 2 days ago. "The Concorde SST—Can its landing and takeoff noise be reduced?" by a Mr. Goldberg in the scientific journal, "Search," and it contains a very good summary of the situation; that is, of the gloomy prospects, or at least the very great difficulties, of reducing the noise of the production Concorde even to the promised levels.

Chairman PROXMIRE. Well, Mr. Lundberg, thank you very much. You have been a most helpful witness and I want to congratulate you on the remarkable amount of work you have done in this area. It has been enlightening for all of us in this field, both those advocates of the SST and those who are opponents. You have been a leading scholar and expert in all the technical aspects of it and I apologize for not being able to give you more time because you undoubtedly could have used it.

Mr. LUNDBERG. Yes.

Chairman PROXMIRE. But I think you appreciate the fact that we have to have limitations on this, and your full prepared statement, which is a most helpful statement, will be printed in the record.

Mr. LUNDBERG. May I just respond and say that this has been a most enjoyable and honorable occasion which I appreciate very, very much. Thank you, Mr. Chairman.

Chairman PROXMIRE. Our next witness will be William M. Capron, associate dean of the John F. Kennedy School of Government, Harvard University.

I understand, Mr. Capron, you are an economist and administrator and not an aeronautical specialist, but we are delighted to have you here because, of course, the problem of the SST is not simply an aeronautical or technical or scientific problem, it is an economic problem, it is a problem of allocation of resources. Perhaps that is the most significant reason why the SST was defeated and why the SST will be highly controversial if it is offered again by the administration—the allocation of resources and priorities. The name of this subcommittee, incidentally, is the Subcommittee on Priorities and Economy in Government. So we are delighted to have you.

We have your statement. We have a 10-minute rule on presentation which I think you understand. If you don't cover your entire statement it will be printed in full in the record. All right, sir, go ahead.

STATEMENT OF WILLIAM M. CAPRON, ASSOCIATE DEAN, JOHN FITZGERALD KENNEDY SCHOOL OF GOVERNMENT, HARVARD UNIVERSITY

Mr. CAPRON. Mr. Chairman, Congressman Reuss, it is an honor and pleasure to appear before this subcommittee on any subject, but this is one that has been dear to my heart since I was a member of the Kennedy and then Johnson administrations, And all I can say for our record then was that we slowed up the SST but we didn't quite derail it.

Chairman PROXMIRE. Mr. Capron, would you tell us just briefly your association with those administrations, what your career was?

Mr. CAPRON. Yes. I was, first of all, on the senior staff of the Council of Economic Advisers, and then I was an assistant budget director under Kermit Gordon and Charlie Schultze, both of whom have appeared before you many times.

Chairman PROXMIRE. Yes.

Mr. CAPRON. Big projects, especially if they involve "high techology," die hard. It seems clear that, whatever some may have thought, the last congressional rejection of the SST was not a knockout blow, but merely stunned and slowed down this proposal and its proponents. My remarks today are addressed to the following question: If an attempt is made by the administration to resurrect direct Federal support for the development of a commercial U.S. SST, should the Congress take a different position than it did the last time around? Have some of the key facts and factors which affect—or at least should affect—one's position on this issue change in the intervening period in such a way as to suggest that a different congressional posture is prudent?

I address this question as an economist who has had a longstanding interest in research, development, and technological change, and the role of Government with regard thereto. Since we do not yet have before us a specific proposal, I will assume that the administration will urge action along the same general lines as it put forward the last time around.

However, what I have to say is quite general and not dependent on the wrinkles of a proposal.

There are two separate sets of issues which need to be addressed in developing a position as to whether the Federal Government should undertake to underwrite the development of a commercial SST. First, we must evaluate the proposal itself: Is it technically feasible? Can unacceptable environmental costs be avoided? Is it economically viable? If it is expected to be a commercial success, why should the Government be involved? In other words, in the broadest terms, and considering all factors, are there benefits to the Nation and its citizens which we can reasonably expect to exceed the total cost, both monetary and nonmonetary?

A second group of issues, which, strictly speaking, we only face if we get an affirmative answer to the first set of issues, requires us to look at national priorities: Even if the SST looks feasible in both technical and economic terms, should it command Federal taxpayer support in competition with the many other programs which are candidates for such support?

Turning to the first issue, and focusing on its economic aspects, have things changed in the last 2 years so that the array of distinguished economists who then questioned this project would reverse their position? I might remind the committee that the economists who previously spoke out on this question included those identified with almost the complete spectrum of American economic thought. It is not often that Milton Friedman stands side by side with Paul Samuelson and Walter Heller on an important policy issue. It remains significant, as was noted in 1971, that among the economic opponents were included several of us who had served in the Kennedy and Johnson administrations during the period when this project worked its tortuous way forward to the firm recommendation finally made by the present administration. We had been forced on a number of occasions to examine this program in some detail. I would also remind the committee that one of the most trenchant statements questioning this project came from this country's newest Nobel laureate in economics, Prof. Kenneth J. Arrow, my colleague at Harvard, and, I am proud to add, my sometime collaborator.

Chairman PROXMIRE. So we have two Nobel Prize winners in economics in this country, Samuelson and Arrow, and both of them have spoken out vigorously against the SST.

Mr. CAPRON. Yes. I might just interject that I happened to see Ken Arrow yesterday. He just returned from Sweden after receiving the prize, and was on his way as president-elect to the Toronto meeting of the American Economic Association, and I told him what I was going to be doing today, and his comment was, "My God, I thought that was completely dead." So maybe he will be back again if you have further hearings.

The proponents of the SST have argued that eventually this will be a commercially viable undertaking, both for the producers of the plane and for the airlines. Ordinarily this would suggest that there is no reason for Government support of the project. However, it has been argued that there are overriding national interests which make it proper, if not imperative, that the Government force feed this technology at a faster pace than private firms are willing to move.

In short, in the lexicon of the economist, it is argued that there are external benefits to the Nation which can be realized only if the Government organizes the undertaking and underwrites its development and initial production financing.

Turning first to the second point, we have heard a number of national interest arguments made: potential contribution to our balance of payments, additional employment, increased tax revenues, maintaining U.S. technological leadership in a field we have long dominated, and enhancing our national prestige. Almost all economists who have spoken out on this issue in the past have questioned the rationale for these arguments. I see no point in repeating the bases for this rejection, since these arguments were questioned, not because of particular assumptions about the SST, but as being inherently fallacious or irrelevant.

They were dealt with and, in my view, effectively disposed of, in a series of statements prepared by 11 economists and introduced into the Congressional Record on March 16, 1971, appearing on page S3303 ff. I should add that the economist claims no special expertise with regard to the promotion of the SST in order to enhance our national prestige. That is an argument which is very hard to get hold of; when it is made I would only urge that we consider the large array of competing policies and programs which are put forward under the same banner. Given these alternatives, is the SST really the best available means of using our resources to increase the respect and regard with which we are regarded elsewhere in the world?

What of the argument that, although requiring initial Government subsidization, the SST promises eventually to be commercially feasible? In 1971 and before, the public and the Congress heard a number of expressions of skepticism on this score. Have factors affecting this judgment changed in the intervening period to suggest that the decision reached then should be reconsidered?

With regard to the demand for a U.S. SST, and the demand of passengers to fly on such a plane at the high fares which are assumed to be necessary to make it flyable at all, developments have provided additional reasons for skepticism. The Concorde seems clearly to be in deep trouble. Mr. Magruder in his 1971 statement assumed that 200 of these planes would be purchased. Current indications are that the number procured in the next several years will be closer to 20. I should note that the Concorde has long been the cornerstone of the argument for urgency regarding a U.S. SST program. The present prospects for that plane, as far as anyone can tell in the press, certainly seem to diminish the weight of this line of argument. Even that number of sales is very shaky evidence of the attractiveness of the plane to airline executives, since the press has repeatedly reported the arm-twisting which has been necessary to get the two captive national airlines of the collaborating producing nations. Britain and France, to take it on. Apparently they can do so only with substantial subsidization. While airlines of other nations, including U.S. carriers, may acquire a handful of these planes for prestige purposes, their lack of enthusiasm for the Concorde, which promises, in the jargon of the industry, to be a dog, is manifest.

Another change in recent months which seems to undercut the assumptions about the strength of demand for an admittedly high-cost, high-fare SST, is the tremendous pressure to reduce rates because of the impact of the jumbo jets on the air travel market. While the present situation in these markets is a reflection of temporary excess capacity, the airlines seem to be learning that the real payoff in the air travel market, and especially in the international market, lies in exploiting a potentially large demand for air travel at relatively low fares. If it is still true that the economics of an SST require a surcharge anywhere near as large as that assumed by the administration in its previous defense of the program, it seems clear that by the time a U.S. SST could enter service, the differential fare compared to subsonic jumbo jets would be substantially greater than previously assumed. This throws into question the assumptions regarding the number of passengers willing to pay this differential—while the jet-set is often visible, it is never numerous.

Turning from demand for the SST to supply, I am again unaware of any changes which suggest that the cost of developing and producing a U.S. SST seems more favorable. No hard evidence in this regard was available 2 years ago, though many of us seriously questioned the estimates put forward by the administration on the grounds that they were almost certainly low.

I have seen nothing in the general or trade press to suggest that there have been some dramatic technical advances which might promise to reduce development, production, and operating costs. It is my impression that the research effort which has gone forward on supersonic technology in the intervening period has focused primarily on overcoming some of the serious technical and environmental difficulties which influenced the Congress earlier rejection. It is possible that, should the program be reintroduced by the administration, evidence will be put forward indicating that the basic economics of the vehicle itself look more favorable. Such new evidence should, of course, receive careful evaluation and consideration.

Let me return to a point mentioned briefly above; namely, whether the SST is a project which should be underwritten by the Federal Government, even if it looked much more promising, and we gave greater weight to the noneconomic benefits which this project might bring the United States. In other words, if the project looks as if it would be genuinely feasible on economic grounds—taking account not only of the cost side, but also of expected demand—does this strengthen the case for Federal support? My answer is "No." I see nothing so special or different in a commercial SST from any other major commercial innovation to suggest that our customary practice of leaving such developments to private markets should be modified. Personally, I will not be surprised if there is a fleet of U.S. SST's flying sometime in the next decade or so.

I should note that I am assuming that the various environmental problems, including noise, effects on the upper atmosphere, and so forth, can be designed around; this asumption may, of course, be wrong, in which case the project shouldn't go forward, with or without Federal sponsorship.

In other words, I have confidence that when the technology is ready, U.S. firms in the airframe, engine, and allied industries will move forward to develop an economically viable commercial vehicle. They will do so when such a project can meet the test of the market, a test we wisely rely on in activities of this sort.

I might add that part of this test is whether or not capital markets are willing to make the necessary funds available. I recognize that our capital markets are not perfect, but I see nothing about a potential SST program to suggest that it would be unfairly and undesirably discriminated against. While it will indeed be a large program, it is no larger than other privately initiated programs in fields like telecommunications, electric power, and so forth. Though it may appear to be of somewhat higher risk when first begun, that higher risk can be offset by the promise of higher-than-average returns.

I turn now to the second basic set of issues which must be faced by the Congress if it is asked to reconsider Federal support of a U.S. SST.

If we suppose, for a moment, that we are sure that we can handle the technical and environmental problems, and that in the longer run the project looks economically viable, we must still ask ourselves whether, in the strenuous competition for taxpayers' dollars, such an undertaking should command our support. To answer this question affirmatively, one must persuade himself that, taking proper account of all the economic and noneconomic benefits and costs, the proposed program promises a more favorable "rate of return" to the Nation than do alternative ways of using these resources.

There seems to be a consensus that, at least over the next 2 or 3 years, we face a period of extreme budgetary stringency. Indeed, the major issue facing the Congress in the session convening next week will be where to cut back programs already on the books, many of which have been held to rank very high on our list of priorities. This committee has played a leading role in putting the spotlight on Federal programs which seem rife with inefficiency. Better management of existing programs and elimination of those which were ill-conceived in the first place, or have now become obsolete, could unquestionably make available tax dollars for other purposes. While I hope very much the Congress and the administration will move aggressively in this direction, my own reading of the political realities suggests that we cannot expect major windfalls from this source.

The list of new programs and projects not yet on the books, which command substantial support and rate very high on the priority scale of many of us, is already very long. In other words, the SST faces very tough competition.

In this context, let me say one word about a subset of these priority projects; namely, those with a high technological content. This is relevant, since an argument often made for the SST is that it will employ that part of our labor force which has high technical competence, and training and management skills, appropriate to running high technology activities. We make a mistake when we regard these skilled and relatively specialized resources as lacking any versatility. They don't have to be used for building airplanes. There seems to me to be urgent public need for harnessing such resources to attack some of our most pressing problems. It is clear that our growing interest in maintaining and enhancing the quality of our environment in all its dimensions poses difficult challenges, some of which, at least, may lend themselves to technical solutions. For example, I, for one, believe that we should mount a really major effort to develop a replacement for the internal combustion engine. It is my understanding that our present attempts to fix up this technology are not likely to be really successful, since the internal combustion engine is inherently "dirty." One could list many other candidates for programs, many of which will require Federal support, which deserve a high priority, and would make use of our high technology capabilities.

Lest my position on the SST be misconstrued, I would like to add one further note: I do think that the Federal Government should continue an active program of basic and applied research in the field of supersonic technology. I think there is a major difference in the cases that can be made, on the one hand, for Federal funding of research and, on the other, for Federal support for the development of a particular commercial product. The surest way to get a really good U.S. SST in the air is to push ahead with research on the related technologies involved, leaving to private firms the decision with regard to when these technologies have been brought to a point that firms are willing to bet on commercial success.

Thank you very much, Mr. Chairman.

Chairman PROXMIRE. Well, thank you, Dean Capron, very, very much. I think you are especially well-qualified to speak to us this morning—and an excellent supplement to Mr. Lundberg, who is so expert in the technological areas—because you are familiar with our own budget and with our own priorities, and what particularly concerns me is that the administration has indicated this is going to be a tight budget for 1974. I think there is little prospect that the SST will be in that budget. They have indicated that it probably will not be in that budget but, as you say, we are going to have a tight budget for years to come.

Mr. CAPRON. Yes, sir.

Chairman PROXMIRE. In fact, a projection by Fortune magazine, "The Budget in Trouble"—did you have a chance to see that?

Mr. CAPRON. Yes.

Chairman PROXMIRE. That indicated that over the next few years there is going to be an actual decrease—decrease in physical terms—in the amount that the Federal Government would allocate for health, and for education. I was shocked to read that. It is a very small increase in education, a little larger in health, but when you correct it for the projected inflation, it would actually provide less. I just do not think that we are going to end up with that, but that is the present plan for the administration.

So that to come along in this atmosphere—this was a 5-year projection—and to propose a $5½ billion program for a supersonic transport, it seems to me, raises some serious questions.

Under the circumstances—since you served on the staff of the Council of Economic Advisers, and also in the Budget Bureau, and were familiar then with the appearance of people from the executive branch before the Congress—can you understand, or can you explain, why the administration would agree to send a representative of the Department of Transportation, and of the FAA, to appear before us, and then change their minds 24 hours before they were to appear? If they did not have something in mind, they could simply come up and say it is not in the budget. Does this indicate they might want to preserve their options; they might have second thoughts at the last minute and put something for the SST in the budget?

90-912 O - 73 - 6

Mr. CAPRON. My service, as you have indicated, was in the previous administrations, and I find the workings of the Nixon Administration often very puzzling, and I think it would be fruitless for me to speculate on the specifics.

I would guess that either the decision is still "up" and has not been made; that representatives of the administration do not want to be put on the spot of stating their own views when they are not sure what the Office of Management and Budget, and the White House, are going to decide. That seems to me a very likely explanation.

Chairman PROXMIRE. Yes, because they said they would appear, and then when we asked them why they would not appear, they said because their department is in a period of transition, and the only reason why that would have any relevance is that the transition might encompass a change of view on something like the supersonic transport.

Mr. CAPRON. Yes.

Chairman PROXMIRE. This morning's newspaper indicated that the aerospace industry is going to lobby for what they call an aid bill, legislation in the next session of Congress, which will provide up to $3 billion with Government support for new commercial aircraft such as the supersonic transport, STOL, that is short take-off and landing aircraft.

Now, the aerospace industry is notoriously powerful and influential in the Congress of the United States; we have seen that many times. What would you think of a $3 billion Government support for new commercial aircraft, such as SST and STOL, as a policy? They say that what they would try to do with this $3 billion is provide assistance in terms of guarantees and so forth. It could not be for ongoing programs, but new programs, new breakthroughs, new technology? What would you think of that kind of an allocation of Federal resources?

Mr. CAPRON. I am just not persuaded, Senator, that this particular industry, which I believe had an increase in sales of over 5 percent during the year just ending—some of its firms are in trouble partly because of some very shoddy management of some major Government-funded programs which I think this committee has helped to uncover—but I do not see any special reason for singling out aerospace for some kind of special loan or guarantee program.

Now, I will qualify that to the extent of saying that if objective and competent analysis indicated that there were peculiar reactions in major capital markets to programs in this industry so that it was really discriminated against, whatever the reasons, then some sort of loan or loan guarantee program might possibly be worth considering. But I know of absolutely no evidence to indicate that this is in fact the situation, and I see no reason why we would provide a fund of this sort for the aerospace industry as opposed to any other industries.

Chairman PROXMIRE. That is what puzzles me. Why we should single out an industry and provide Federal assistance there, any more than we should——

Mr. CAPRON. Yes.

Chairman PROXMIRE (continuing). For any number of other industries.

Let us put this in an objective light now. You are undoubtedly right on expansion this year. The spokesman for the industry says the total sales rose 9.7 percent in 1972, but that was the first increase since 1968, and he predicted that sales would decline slightly next year. Employment dropped from 924,000 to 917,000 in 1972. They said it would slip below 917,000 in 1973. Do you see that as any kind of a reason for a Federal subsidy, the fact that the industry may be declining somewhat?

Mr. CAPRON. No, sir, I do not.

Each industry goes through a great many phases. They go through phases of stabilization or contraction as well as growth.

Chairman PROXMIRE. What kind of an economy would we have if the Federal Government came in for a multibillion dollar program in every industry in which employment was diminishing or sales were dropping? Does that make any sense?

Mr. CAPRON. Not to me. I come from a region of the country which I am sure would be very anxious to get on such a gravy train of special loans for declining industries.

Chairman PROXMIRE. Would we not be allocating our funds to those industries in which public taste and various technological developments and so forth dictate we should be shifting resources away?

Mr. CAPRON. We have, I am afraid, often tried with various kinds of Federal actions and programs to prop up industries which should be allowed to die or at least to contract.

Chairman PROXMIRE. On that basis, we could be providing hundreds of millions for buggies and harnesses for horses——

Mr. CAPRON. Yes.

Chairman PROXMIRE (continuing). To take us back and forth to work. Employment undoubtedly declined in that industry.

Proponents of developing an American SST have argued that we must go ahead in order to prevent slippage by the U.S. aerospace industry—that is, that England, France, Russia, and possibly others are going to have supersonic entries, and U.S. dominance of aerospace technology is threatened if we do not go ahead.

Would you comment on that?

Mr. CAPRON. I see no evidence of that, and particularly since it seems quite clear that at least for the next 2 years the Federal Government is going to be very helpful in the aerospace development business because of military considerations, and that is where the thrust toward ever more advanced technology has come anyway.

It is quite clear that without the U.S. aerospace industry and development of the last two decades, we would not be here this morning seriously debating the development of a commercial U.S. SST, because the technology just would not have advanced. I think our leadership, our technical leadership in this field, is assured for at least the next few years primarily because of federally supported programs in the defense sector.

Also, the firms in that industry, some of them, have been aggressively successful in pushing technology in civilian markets, and there is no evidence that they are about to sit on their past success and let the British, French and others pass them by.

Chairman PROXMIRE. You see, there is another argument here that it is not fair to compare development of the supersonic transport with other commercial developments. It is argued that it is impossible to raise the immense amounts needed for an SST even in our great capital markets, so it is unrealistic to expect a privately funded SST.

They say this is very different because it is an enormous amount of money that you cannot expect a consortium of private firms to put together, considering the unusual degree of risk involved.

The argument runs that, when you come to something that involves $5 billion, you have to go to the Government or forget it. These other countries where they have gone to the government are perhaps falteringly moving ahead, but they are moving ahead.

What do you think of that kind of argument, that if you want an SST at all you have to realistically compromise the strict free enterprise position?

Mr. CAPRON. I do not think that the sheer size of the undertaking means that we should give up expecting private markets, including private capital markets, to come forward when the time is ripe, when the commercial judgment, the judgment of people in the business, including the airlines and the airframe manufacturers and persons knowledgeable in the other technologies that are involved, think that it is right; I see no reason to argue that private capital markets are not going to respond to something that looks like a good bet.

Chairman PROXMIRE. You would not be impressed by the size of this?

Mr. CAPRON. No.

In the first place, the total funding will not be required all in one lump, it will be spread out over a number of years, so that the "shock" effect on the capital market, which some people portray, I think is just unrealistic. They would not try to fund the whole $5 billion or whatever it is in a single year. They would require those funds and acquire them over a long period of time. And, put in that context, when you compare the kind of funding that is already occurring in fields such as telecommunications, electric energy, and so forth, I do not see that this is going to look all that big.

I think it is really a phony argument to picture $5 billion being asked for on Wall Street in one day. I just do not think that the funding would be done that way. It would not make any sense to do it that way.

Chairman PROXMIRE. I have some other questions, but I am about to yield to Congressman Reuss because my time is up, but I would like at this point, with unanimous consent, to have printed in the record a letter which I received from Milton Friedman—you commented on him in your opening statement—in which he vigorously opposes a government-funded SST but says that he would have no objection if it were entirely paid for by private capital, and environmental problems were solved.

He says he is for the free enterprise system, and he does not see any reason why this should be subsidized any more than any other kind of enterprise in the private sector is subsidized—production of food, automobiles, furniture or electric power.

(The letter referred to above follows:)

UNIVERSITY OF CHICAGO,
DEPARTMENT OF ECONOMICS,
Chicago, Ill., December 11, 1972.

HON. WILLIAM PROXMIRE,
Joint Economic Committee,
U.S. Senate, Washington, D.C.

DEAR SENATOR PROXMIRE: I understand you are holding hearings on the proposed revival of the SST project. I am very pleased indeed to submit herewith a statement for the Record.

The SST issue is often presented as if the question were: Should or should not an SST be built in the United States? That seems to me the wrong question. I favor the building of an SST in the United States, if private enterprise finds it profitable to do so, after paying all costs, including any environmental costs imposed on third parties. On the other hand, I oppose the building of an SST in the United States if that requires governmental subsidies. I oppose governmental subsidization of the SST for exactly the same reasons that I oppose governmental subsidization of the production of food, or of automobiles, or of furniture, or of electric power. I believe in a free enterprise system. A governmental decision to produce an SST largely at its own expense is a step toward socialism and away from free enterprise.

The basic justification for a free enterprise system is that the possibility of profit will lead private individuals seeking their own interests to promote the social interest by producing only those products for which people are willing to pay and producing them at lowest cost. But a profit system can work only if it is also a profit and loss system, only if projects that do not pay are not carried out, and when enterprises make a mistake about a project, they must bear the consequences. If government bails enterprises out, either in advance on the expectation of a loss, or after the event when a loss has been realized, the fundamental justification of a free enterprise system is destroyed.

There are occasions when governmental subsidization or taxation of private activities is justified. Such occasions arise when the activity imposes net benefits or net costs on third parties for which they do not pay or do not receive compensation. For example, there is a strong case for affluent taxes, as a means of requiring the consumers of a product to pay the costs of pollution imposed on third parties in the course of manufacturing that product. There is a case for governmental subsidization of basic scientific research because the research confers benefits on the rest of us that the producers of the research cannot charge for—though I hasten to add that I conjecture that the present level of such subsidization is far greater than can be justified on these grounds.

Despite the enormous amount of propaganda for government subsidization of SST, no valid evidence has been presented that there are net benefits to third parties that they are not required to pay for. The assertions to this effect have in general been logically fallacious. This is true about the alleged benefit from additional employment. The only effect would be to employ people here instead of on more productive activities, since the addition to employment from the SST subsidy would be offset by the subtraction from employment as a result of the extra taxes that would have to be paid to finance the subsidy or the loan funds that would not be available for other uses if they were absorbed to pay the subsidy. Similarly, the alleged benefit to our balance of payments is logically fallacious. That is simply mercantilist confusion. Our benefits from international trade come from imports not exports and there is always a rate of exchange at which these will balance. If at that rate of exchange it is profitable to produce an SST for export, fine; if not, there is no case for subsidizing it.

In the one external effect that it has any even prima facie merit is the possibility that the development of the SST will have some benefits for national defense. But in that case the expenditure on the SST should be considered as part of the defense budget and compared with other means of adding to our military strength.

I therefore conclude that there was no case earlier for subsidizing the production of an SST and that there is none now.

Sincerely yours,

MILTON FRIEDMAN.

Chairman PROXMIRE. Congressman Reuss.

Representative REUSS. Thank you, Mr. Chairman.

Mr. Capron, in your excellent statement, you pointed out that the high technical competence and management skills of a company that might be making SSTs can be transferred to other uses. You say specifically, and I quote from your statement, "We make a mistake when regard these skilled and relatively specialized resources as lacking any versatility: They do not have to be used for building airplanes."

Well, is not Boeing itself a pretty good example of that?

Mr. CAPRON. Yes.

Representative REUSS. I give them high marks for the fact that, after, what to them was a severe blow in 1970 to 1971—when the SST was being cut off—they have since intensified their efforts in housing and mass transportation, air and water pollution, and solid waste disposal. They have shown an excellent will to diversify, a point, it seems to me, which has not gone unobserved by the people who invest in the Wall Street stock market.

Back in 1970 and early 1971, when the SST looked impregnable, Boeing's stock hit lows of 12 and 13. Today, it is selling at 25, and it has not gone below 19 in at least a year. So that Wall Street, at least, seems to have adjusted rather well to diversification of Boeing.

Mr. CAPRON. If I could just suggest, Congressman Reuss——

Representative REUSS. Yes.

Mr. CAPRON (continuing). I think Wall Street also showed their judgment that the Congress was right in not allowing Boeing to get itself involved at this particular juncture in the SST. I do not know that. I am not myself an active investor, but I think that the movement of that stock was really quite interesting to watch at the time you made the decision you did.

Representative REUSS. It is very gratifying for Senator Proxmire—who is an old Wall Streeter—and myself to find that the judgment of the market frequently vindicates our feeling about the war in Vietnam, about the SST, and other matters.

I ask, however, my question: if we now were to revive the SST, is it not likely that Boeing would then transfer its emphasis away from housing, mass transport, water, air pollution, solid waste disposal, and some of the other things it got forced into doing by being forced out of the SST—and go back to concentrating its efforts on the very limited benefits that would insure from an SST?

Mr. CAPRON. Yes, sir. I think they would be forced to do that because this would clearly be a terribly demanding undertaking. It would require all the enterprise of that management if they were going to have any chance of succeeding with it. I think they would just have to give up on the diversifications you point out they have gone into, because they would not have the management capacity to focus on potential new areas while dealing with the SST.

Representative REUSS. I now turn to another aspect of your statement, and I want to make sort of a devil's advocate argument to you on it.

You point out that future traffic in the SST—if American SST's were built—might be less than a lot of SST adherents point out because the surcharge to travel in an SST would be even greater than expected. This is partly due to the fact that there may be cheaper regular non-SST air fares, and you say that while the jet set is often visible it is never very numerous.

Well, would not a member of the Nixon administration argue, with some justice, that both the absolute number and the percentage of jet-set type people able to afford these surcharges has, due to the Nixon economics, increased? After all, the Census Bureau's income figures show that, in the last 2 years, for the first time in 30 years, the share of national income enjoyed by the top quintile—the top 20 percent of American families—has increased. For 30 years, you know, we have grown more egalitarian; while the top fifth has done very well, they have not increased their share of the whole. But under Mr. Nixon, I would think as a result of increasing unemployment, and refusing to do anything meaningful about plugging tax loopholes the share of those at the top has increased.

Well, could this not be a coordinated Nixon program to insure that there are going to be enough jet setters to buy up those seats on the SST if it is built?

Mr. CAPRON. I hope that long before there is an SST, or at least a U.S. SST, that the policies you referred to, which have affected income distribution in the way you describe, have been rather substantially changed. Indeed, I have considerable confidence that in the upcoming session of the Congress some changes, which will reduce the number of potential supersonic flyers from the jet set might be taken.

A little more seriously, with regard to the demand estimates that were part of the administration's case in 1971 I would make two comments:

One, I think there is good reason to view them very skeptically, I think that they made every assumption in the book to get up to this very large number of planes that would be purchased and the percentage of capacity at which they would be operated; these estimates seem to me, and to others more knowledgeable than I am about aircraft operations, to be quite unrealistic.

The other point is that we have to discount way back from 1990, and when you do that, and assume that in 1990 some large number of people might be flying on the SST, we are being asked to pay a very heavy price; in the economist's terms, the present value of any benefits that far ahead, stacked against the very large current costs that we would be asked to pay as taxpayers to develop this plane, make the cost-benefit calculus just look completely unfavorable.

So that even if there are going to be more people in 1990 willing to pay a surcharge to fly on a supersonic transport produced by the United States, I still do not think the case is made.

Representative REUSS. Thank you.

Thank you, Mr. Chairman.

Chairman PROXMIRE. One of the matters that has concerned economists a great deal, and also concerned very powerful economic groups, is the employment argument.

I can remember when Senator Jackson was speaking in favor of the SST, in his summation in the 1 minute he had when he summed up his argument for it, he mentioned George Meany's name three times. The AFL–CIO was all out for the SST, and they have a very informed, intelligent, thoughtful notion of what is good for American labor. They argued tens of thousands of jobs would be at stake eventually in the SST.

As an economist, how would you evaluate and appraise the employment argument for the new SST? If we have a $5.5 billion program here, it is going to put a lot of people to work and it is doing to mean an increase in the prosperity of an important industry and it is going to benefit the economy of a number of cities and States.

Mr. CAPRON. I think that it is always wrong to base judgments on particular projects and programs which the Government is considering by putting major emphasis on the employment effect. That issue should be dealt with by following an appropriate fiscal and monetary policy, and you do not choose among the various ways of spending taxpayers' dollars, it seems to me, by looking at employment effects.

I would add that a dollar is a dollar, and after the first recipient of the Federal dollar, the multiplier effect means that the employment impact of any Federal dollar of expenditure is going to be almost the same. While it is true that there will be differences depending on the labor intensity of the initial direct spending, such a difference is very quickly swamped by the spreading effect of those dollars as they circulate from hand to hand through the economy.

Chairman PROXMIRE. How about the argument that this is a different kind of Federal investment? This would be an investment in prototypes, it would be an investment in research, it would be an investment in the beginning of production. Of course, $5.5 billion would not only be just prototype, but they would support production and get it going so it would stimulate an industry which otherwise might not be operating and would sell, and has in the past sold, an enormous amount abroad. The sale of commercial aircraft has been the principal, favorable international trading factor that we have had. Under those circumstances, what would you think of the argument that we should stimulate this industry when it needs a research breakthrough to make feasible a profitable commercial operation and, therefore, some stimulus would provide more jobs in the long run than if you put the same amount into a technologically static industry of the kind we have been discussing——

Mr. CAPRON. As I said in my statement, I do believe that——

Chairman PROXMIRE (continuing). Such as housing or something like that?

Mr. CAPRON. I do believe Federal support for research and development, and particularly research or applied research, is appropriate in this and in other fields of technology. But I draw a sharp line between that and actually going to the underwriting of a prototype and underwriting actual tooling up and actual commercial production.

I think there are lots of advanced technologies, many that I do not pretend to even understand, which undoubtedly deserve research support, and that out of such efforts, as in the past, new industries will be born which will contribute to employment. They will employ our highly trained manpower, and will also in many cases contribute substantially to our balance of trade by producing goods in which we have a headstart and which are attractive to other nations of the world.

I just want to emphasize again that I draw a really sharp line between the underwriting of a particular commercial product, and general support of basic research and even applied research.

Chairman PROXMIRE. One of the reasons why we are so anxious to get economists to testify in this area is not simply because, after all, your job is to understand the importance to the national interest of allocation of economic resources, but also because you bring to the problem a degree of disinterestedness, a degree of objectivity, I would hope. You are not in the union position or in the management position or in the stockholder position or maybe in a position of having made a political commitment of some kind on the program.

Mr. CAPRON. I qualify fully on those grounds.

Chairman PROXMIRE. Well, on those grounds, how would you assess the overall attitude of the economists? You have mentioned a few of them, you have mentioned Heller, Samuelson, and Arrow and they are among the most distinguished economists. But how would you assess the attitude of the economics profession in general? The ones you have talked to and heard from and heard about, those who have thought about this operation, what proportion would you say of the economists that you know oppose and what proportion would favor a Federal investment in the SST?

Mr. CAPRON. On many issues, Senator, I would have to say I really cannot respond because I have not checked positions, but in this case, since I have had an interest in it going back nearly a decade, and it is a favorite example of a number of economists demonstrating the kind of mistakes we are sometimes tempted to make, I can honestly say that I know of none who favor the supersonic transport, and I would not want to——

Chairman PROXMIRE. Mr. Wallach, distinguished Yale economist, a former member of the Council of Economic Advisers, supports the SST.

Mr. CAPRON. His was one of the most qualified and carefully phrased supports. If I may take just a moment, I happen to have one of his statements here which was printed in the Congressional Record—among those referred to earlier. He may have made other statements with which I am not familiar, but one statement that he did make was very brief. He says, "I continue to believe that the key to the right decision on the SST"—this was in 1971—"is the outlook for the Concorde. If we are sure that the Concorde will not fly commercially, there is much to be said for terminating the SST program."

As I understand Professor Wallach's position, it was very heavily weighted by his concern at that time for the balance-of-payments implications.

Many of us feel that the same argument I made on employment, which was one of Professor Freedman's points, applies as strongly to balance-of-payments considerations. One should not make particular program decisions of this sort on balance-of-payments grounds. Professor Freedman and Professor Wallach often see eye to eye with each other on policy issues.

In the first place, by the time a U.S. SST would be in the air, we have no idea at all what our balance-of-payments situation is going to be.

My own hunch, for whatever it is worth, is that we are not going to face a deficit but rather the opposite in a very short time, within a few years. That may be wrong, but even that is not relevant, it seems to me, to this issue. So I would just suggest that Professor Wallach was hardly to be identified as a wholehearted supporter of the supersonic transport.

Chairman PROXMIRE. I have just one final question.

The purpose of these hearings is to try to develop information that would be useful in determining our transportation policies. In allocating resources in the transportation field, how would you feel the allocation of this amount of money to the SST would compare with other aircraft, mass transportation, or any other allocation of Federal investment that would be in the national interest?

Mr. CAPRON. Well, I have no question that my own set of national priorities would place heavy emphasis in the next decade on mass transportation and, as I mentioned in a parenthetical clause in my prepared statement, I also feel—although I am not expert in this area—that serious consideration should be given to developing, perhaps with some Federal support on the basic research and, a viable alternative—and by that I mean an economically viable one—to the internal combustion engine.

Readings I get from some of my colleagues who have studied the present attempt to clean up the internal combustion engine are not very hopeful; it is inherently a dirty technology, and penalties that are going to be paid to attempt to meet the standards that are currently set for 1975 and 1976 are going to be very heavy in economic terms. So that I think that I would add an alternative to the internal combustion engine to my list of candidates that are worth seriously looking at, particularly if it does turn out that we are going to have a terrible time meeting our proposed standards.

Chairman PROXMIRE. Of course, from the latest information, the latest report I have read in the last couple of days, the problem is going to be very, very serious and a considerable expense not only to the Government but to the automobile companies, and the people who buy automobiles.

Mr. CAPRON. Yes, sir.

Chairman PROXMIRE. The cost could be very great if we are going to meet the standards of the Antiair Pollution Act.

Mr. CAPRON. Yes, sir.

Chairman PROXMIRE. Well, Mr. Capron, I want to thank you very much for an excellent appearance and fine statement. You have been most helpful to us.

Once again I want to thank you, Mr. Lundberg, for your most helpful appearance.

Tomorrow the subcommittee will reconvene in this room at 10 o'clock to hear Andrew Wilson, aviation correspondent of the Observer of London, an expert on the Concorde; Harold S. Johnston, Department of Chemistry of the University of California, who will inform us on one very important element of the environmental impact; David Brower, president, Friends of the Earth; and Gary A. Soucie, president of the Environmental Policy Center.

The subcommittee stands in recess until tomorrow morning at 10 o'clock.

(Whereupon, at 12:05 p.m., the subcommittee recessed, to reconvene at 10 a.m., Thursday, December 28, 1972.)

THE SUPERSONIC TRANSPORT

THURSDAY, DECEMBER 28, 1972

Congress of the United States,
Subcommittee on Priorities and
Economy in Government of the
Joint Economic Committee,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10:05 a.m., in room 5302, Dirksen Senate Office Building, Hon. William Proxmire (chairman of the subcommittee) presiding.

Present: Senator Proxmire.

Also present: William A. Cox and Courtenay M. Slater, economists; George D. Krumbhaar, Jr., minority counsel; and Leslie J. Bander, minority economist.

Opening Statement of Chairman Proxmire

Chairman Proxmire. The subcommittee will come to order.

This morning we conclude our 2-day hearing to assess the supersonic transport, and the advisability of Federal support for it.

A brief word is in order about why we did not cancel these hearings today. Of course, this is the day when we are honoring our former President, Harry Truman, and I have the greatest respect for Mr. Truman. He was a great President and an outstanding leader and a marvelous human being. If he were with us today I am sure his advice would be to go to work, and the reason we have to go to work is that our witnesses on today's schedule have traveled many thousands of miles to be here. Mr. Brower has just returned from Nairobi to be present today. Mr. Wilson has flown in from London in order to testify. And Mr. Johnston and Mr. Soucie have come from California and Connecticut to be here. It would impose a considerable hardship on these witnesses to ask them to return here at some later date, and we are, therefore, going ahead as previously scheduled.

Our first witness today is Mr. Andrew Wilson, the aviation correspondent for the London Observer. Mr. Wilson has followed the development of the Concorde closely since its inception in the early 1960's, and his testimony should bring us up to date on the current status of that program.

We all know that a great element in our decision on the SST has been the British-French Concorde. I suppose, Mr. Wilson, that the principal argument in favor of our going ahead with the SST in spite of all economic arguments and environmental arguments against it has been if we did not proceed the British-French Concorde would proceed and tend to dominate international air traffic, and that has been a matter of the deepest concern and consideration for this country because, as you know, we have a very serious adverse balance of payments and now an adverse balance of trade. Our most favorable element has been the sale of our great commercial planes abroad, and to lose that market would be quite an economic tragedy for this country.

For that reason I think that he viability and the competition offered by the Concorde is of the greatest importance in how we proceed and the timing of our proceeding on our own SST.

We are delighted to have you here. We are deeply grateful to you for coming all the way from London today. Go ahead.

STATEMENT OF ANDREW WILSON, AVIATION CORRESPONDENT, THE LONDON OBSERVER

Mr. WILSON. Thank you.

I think you last heard in some detail about Concorde in 1971, shortly before Congress stopped the funding of the U.S. SST prototypes.

Chairman PROXMIRE. May I just interrupt for a moment to say, Mr. Wilson, I think you are aware of our ground rules, a 10-minute opening statement and then we go to questions.

Mr. WILSON. I will observe that, sir. Thank you.

The status of Concorde was then as follows:

Number under option, 74; customer airlines, 17; projected in-service date, 1974; development cost estimate $2 billion.

The costs had risen fivefold from the original estimate 9 years before, and the entry-into-service date had slipped 6 years. The only figure that had remained anything like constant was the number of options. This had stuck at 74 since 1967.

When work on the SST was stopped those responsible for marketing Concorde expected to increase their sales prospects. But this did not happen. Instead there were a number of negative developments.

After strong resistance—for reasons I will come back to—the British and French state airlines were obliged by their Governments last summer to place orders for nine Concordes. BOAC ordered five and Air France four—a far remove from the eight aircraft on which each held options.

It is true as a "bonus" to the vendors, the Government of China which was not an option holder, signed a "preliminary purchase agreement" for three Concordes. So did the Iranian state airline, Iranair. But these preliminary agreements are not the same thing as firm orders.

Against this—and it is clearly the most significant development—three major airlines (United, Air Canada, and Sabena) have formally and publicly canceled their options. So the present status of Concorde is: Firm orders, nine; preliminary orders, six; options, 54; total, 69.

In other words, the listed prospects, including orders, have diminished by at least five since 1971. And in fact, they have diminished still further because at least 16 of the options still listed are very doubtful. These are the options of Lufthansa, Air India and Qantas, and the residual options of BOAC and Air France.

Before going into the reason for this lack of airline interest, I should like to put the present state of orders into fuller perspective.

Concorde was started in 1962. It was then supposed to cost about $400 million, to enter service in 1967, and to sell to the tune of 400 aeroplanes by about 1990. If it had been an ordinary commercial venture, it would have been canceled long ago. But, of course, it is not a commercial venture. It is a political one.

In 1962 Mr. Macmillan's government entered into an agreement to build an Anglo-French supersonic airliner as a means of winning French support for Britain's application to join the European Economic Community. As you know, this application was finally vetoed—by France. Two years later Mr. Wilson's government tried to cancel the project. But it found the Anglo-French agreement contained no escape clause. To have withdrawn unilaterally would have exposed it to action for damages in international law.

Former members of that government now regret greatly that they did not cancel and accept the legal consequences—which would have been cheaper, in the end, than going on. I, myself, am certain from conversations with those concerned that if the labour government had stayed in office, it would have canceled Concorde in 1971 when decisions had to be taken on production, to which the legal tie with France no longer applied.

However, as I said, Concorde is a political aeroplane, and the new British Government of Mr. Heath decided after much hesitation to go on with it—because so much money had already been spent, and because the government still needed French support over Europe.

I mention this so that you may understand how much you were envied in Britain, and particularly in the British treasury, when you were able to stop work on your own SST without international repercussions.

But, to come back to the present state of Concorde and its terrible unpopularity with the airlines.

There are two chief grounds for the airlines' reluctance to buy it. The first is environmental: nobody knows what restrictions will be put on its operations. The second is a question of purchase price and operating costs.

Leaving aside the upper atmosphere question, Concorde's environmental problems are sonic boom and ground noise.

Since 1963, when Bo Lundberg alerted the public to the nature of the sonic boom by an article in the London Obeserver, Concorde's makers have frequently said that they are proceeding in the assumption that supersonic flying over populated areas will be forbidden.

If sincerely held, this is a wise assumption. Already Canada, Sweden, Norway, Switzerland, and Japan have passed or prepared laws banning supersonic overflying and others are likely to follow.

Even so, many routes advertised as being suitable for Concorde ignore the existence of populated islands and populous strips on the fringes of deserts, which could become serious obstacles to supersonic flight. Among these obstacles are islands in the Caribbean and East Indies, and the populous North African coast.

The problem of the boom, because of its novelty, has tended to overshadow the ground noise problem, which looks like becoming a more immediate matter.

As you may know, there has been great disquiet in Britain, Japan and Australia—to name just three countries—about the ground noise generated by the prototype Concordes. During this year's demonstration flight to Australia a maximum approach noise of 126 effective perceived noise decibels was measured, 19 decibels more than the FAA standard for subsonic aircraft.

The makers are unwilling to discuss the prototype noise figures. Instead they refer to the performance expected from the modified engine to be fitted to the production aircraft. This will have a spade-type silencer and a new form of primary nozzle area control.

The target figures published for this engine are:

Approach, 115 decibels; take-off, 114 decibels; sideline, 111 decibels.

Some authorities have serious doubts as to whether these figures will be attained. A pre-production aircraft incorporating the improvements has not yet started test flying. Nevertheless I will base my remarks on the assumption that the noise targets are reached.

It is officially argued in defense of Concorde that its noise targets are little or no worse than those of the Boeing 707, the Douglas DC–8 and the British VC–10. But this is a totally false and deliberately misleading argument. The 707, the DC–8 and VC–10 are first generation passenger jets. It is they which account principally for the present degree of noise misery around airports. Their standards have long been superseded.

Concorde is supposed to have a service life of 15 years. If it enters service, it will be flying alongside a new generation of big, quiet subsonic jets such as the DC–10 and the TriStar, that were not even dreamed of when it was started. It is with these that it should be compared.

For the DC–10 the noise figures are as follows:

Approach, 105 decibels; takeoff, 98 decibels; sideline, 95 decibels.

In other words, since the decibel scale is logarithmic, the 108-seat Concorde, even if it meets its noise targets, will be twice as noisy as contemporary subsonic aircraft carrying three or four times as many passengers. It will also be markedly noisier than the maximum permitted by the 1970 UK Air Navigation (noise certification) Order—from which, however, Concorde has been extempted in an attempt to preserve its sales prospects.

Even in France, where Concorde enjoys a good deal of licence, the Minister of Transport has felt it political to assure Parisians that Concorde will not be allowed to operate from Orly Airport. And BOAC and Air France are seriously concerned lest their Concordes should be banned by noise regulations from landing at airports in the United States.

I come now to the question of purchase price and operating costs:

The development cost of the Concorde, shared equally by the British and French Governments, has risen 700 percent in 10 years. The whole of this cost, nearly $2.5 billion on the latest official estimate—is likely to come from taxpayers, although a fractional and token payment is supposed to be included in the price of each aircraft sold. The British Government still refuses to give a breakdown of the purchase price, purportedly for commercial reasons.

In addition to the development costs there are also, of course, the costs of starting production; and it may not be generally realized in your country—it is not yet fully realized at home—that for this each government is providing the manufacturers with $840 million in the form of a loan. In the all too possible event that Concorde fails to sell more than a few copies, a large part of this loan could be irrecoverable. So the final cost of Concorde may be substantially in excess of the generally published picture.

But this vast government expenditure, which almost certainly includes a subsidy for production as well as development, has not been sufficient to keep the price at a figure economic to airlines.

In 1962 the price was supposed to be $9.6 million. In 1972 it was quoted by the French manufacturers as $31 million. But when BOAC and Air France placed their orders last summer they had to pay $55 million per aircraft, including the cost of initial spares and equipment. This was a preferential price to first customers. The price to other customers has not been disclosed.

The raising of capital for purchases of this magnitude can present an airline with a problem, particularly if its bankers regard the aircraft in question as a loss maker. In an attempt to anticipate this problem the makers in each country have set up leasing companies; but either the leasing arrangements must be heavily subsidized or the leases will be prohibitively expensive to the customer.

In fact, there is little doubt that the cost of leasing a well-nigh unsellable aeroplane will be borne by the British and French public.

In about 1970 it became clear to the economists of customer airlines that the seat-mile operating costs of Concorde would be at least twice as great as those of the 747. This was inevitable in view of Concorde's heavy fuel requirement and the difference in capacity between the two aircraft.

However you doctor that figure, for example by lumping in an arbitrary figure for indirect costs, you cannot escape the fact that to cover such costs requires exceptionally high load factors, or a substantial fare surcharge, or both.

In 1970, BOAC did extensive calculations with various surcharges up to 30 percent above the standard first-class fare. It found only two routes in its system on which it expected to make a profit with Concorde—the route to South Africa, which carries a high proportion of first-class traffic, and the route to Tokyo across Russia.

The trans-Atlantic route between Britain and America presented, and still presents, great problems because the supersonic Concorde, in order to provide a return on the investment, must make four crossings a day.

There is only one "glamour" flight for Concorde on this route—the morning flight westbound that will deliver passengers in New York ahead of their by-the-clock departure time in London.

The other flights available are no great gain because of the inconvenient arrival and departure times. This applies particularly to eastbound night flights.

Because of night landing restrictions at Heathrow Airport, London, Concorde would not leave New York until about 10 p.m., and would deposit passengers in London after only 3 and a half hours flight at 6:30 a.m., with little sleep and no hotel ready to receive them.

The fourth route studied by BOAC—Britain to Australia—was found to be a poor proposition because of the frequency of refueling stops, which erode Concorde's flight speed advantage. BOAC now thinks of flying this route with subsonic 747's fitted with first-class sleeping bunks and making only one stop en route.

Because of these findings, and of problems of inflexibility arising from the mixture of subsonic and supersonic fleets, BOAC finally placed orders only after the grant of what, despite all denials, is a government operating subsidy.

This subsidy arises from the grant to the airline of $324 million public dividend capital; that is to say, capital on which no interest is due until a certain level of profit is reached. BOAC is not expected to make this level of profit for a considerable period, so that $324 million is really an interest-free loan—or rather an interest-free investment, since the loan is unlikely to be recoverable if the airline goes into deficit.

Interest on such a sum, if raised on the market, would be at least $38 million annually. So, this is the extent of the subsidy to be paid for operating Concorde in addition to all the other sums I have mentioned as being paid by the British taxpayer.

Chairman PROXMIRE. If you could bring your remarks to a close, we would appreciate it.

Mr. WILSON. I will do so within 1 minute if I may take just that.

Chairman PROXMIRE. All right.

Mr. WILSON. The Anglo-French strategy for selling Concorde is now nakedly one of blackmail. It is hoped that when BOAC and Air France fly their Concordes—at an expected loss of $48 million a year, in the case of BOAC—other airlines will feel obliged to by Concorde, too, or lose first-class traffic.

As I have indicated during this testimony, there are fallacies in this hope, as the British Government itself is well aware, I hope nobody here is taken in by the manufacturers' talk of selling 200 or more Concordes—the figure that was quoted in the heyday of its hopes. The current hope in the responsible Government department in London—and I am speaking of its optimists—is that 35 Concordes will be sold. Some other officials are prepared for the total not rising much above the nine orders for BOAC and Air France.

I also hope nobody is taken in by talk of an improved or "Mark II" Concorde. Not a penny of expenditure has been authorized for such a plane; and after the experience of the Mark I Concorde, no British (or, I think, French) Government is going to sanction the vast sum needed for a major redesign.

I think I have said enough to indicate that I do not think Concorde is any threat to the U.S. aircraft industry. It has weakened the competitive position of the British industry by devouring resources much needed for other projects.

Thank you, sir.

Chairman PROXMIRE. Thank you very, very much for a fine statement, a very helpful statement, Mr. Wilson.

When I read this over last night, I was particularly struck and startled by the figures that you gave on the per copy cost. I think there is a mistake in your text which you corrected when you delivered. You said $65 million in the text, you said $55 million per copy now; that would be shocking.

Mr. WILSON. $55 million.

Chairman PROXMIRE. That would be shocking. I think even that is higher than it would be if you did not allow—as I think you do—for expenses for hangar and maintenance facilities, pilot and crew training, and other things not normally included in citing the price of a plane. The figure we have from the Library of Congress is $33.8 million per copy, not counting spares; 20 percent more for spares would bring it to a little over $40 million. Would you agree with that, or would you feel that figure is too low?

Mr. WILSON. That figure is too low on the basis on which BOAC and Air France placed their orders.

Chairman PROXMIRE. Yes, I am just talking about the BOAC and Air France.

Mr. WILSON. Yes.

Chairman PROXMIRE. But you called that preferential, meaning it was a lower price than the makers could probably afford to sell it for if they sold it in any quantity to airlines. Is that right?

Mr. WILSON. Yes. I think this is probably a loss-making price, and I think a loss-making price is probably being offered to Pan American, the third customer in line.

Chairman PROXMIRE. So that Pan American might be able to get it at $40 million?

Mr. WILSON. Yes. There are even suggestions that Pan American, whose orders are very desperately needed, would be offered a slightly lower price than that priced by BOAC and Air France.

Chairman PROXMIRE. You also mentioned the interesting prospect of a leasing scheme to cut the financing problem involved with the airlines in acquiring the Concorde. It would be a very considerable problem, because $40 million even for a very large American corporation is a tremendous amount to invest in one aircraft, especially when that aircraft is not as large as the 747, costs twice as much, and revenues from it would be less than from the 747. The leasing arrangement might disguise the size of the subsidy of the purchase price.

Then you state an operating subsidy will be granted to the British and French carriers in the form of interest-free loans? Is it possible that a farm of this scheme will be used to induce foreign carriers to buy, and that we may have many more Concordes flying than we now expect?

Mr. WILSON. I am sure that loans and leases are among the contingency plans prepared by the British and French Governments in case they cannot sell the aircraft directly.

Chairman PROXMIRE. Why would that not be effective—you say blackmail, which would be a little strong. It seems to me they might be desperately driven to that kind of action. If the British and French airlines have supersonic planes, and if this catches the public fancy, and if people in any numbers are excited about flying it from New York to Paris, or New York to London, or over the Pacific Ocean, then it seems to me the pressure will be very great on the large American airlines and other airlines to buy Concordes, also, even though all the arguments that you make are logical and economically irrefutable.

Mr. WILSON. The market research done up to now by the airlines in Europe indicates that not large numbers, but only a limited number of people, would want to take advantage of this supersonic facility.

Chairman PROXMIRE. We really do not know that, do we? That is a matter of estimate; it is a subjective matter. It might very well—it might conceivably—catch the public fancy in a way that we cannot really foresee.

90-912 O - 73 - 7

Mr. WILSON. It is, as you say, a subjective matter which involves various unknowns. Nevertheless, it has been gone through with the greatest possible thoroughness by the airline economists involved. They have studied all kinds of possibiilties, and their conclusions have led to a drop in orders by European airlines.

Chairman PROXMIRE. United was the largest airline to drop its options and they argued their routes are, by and large, domestic; they have very few overseas routes, their biggest route is to Hawaii and, of course, they would be less interested than Pan American or TWA or some of the others that have major overseas routes.

Mr. WILSON. Yes. United and some others have been in a special position because of their overland routes.

Chairman PROXMIRE. So their cancellation would not have been quite as significant as if Pan American or TWA dropped their options?

Mr. WILSON. If Pan American or TWA should not take up their options the effect would be very considerable, perhaps catastrophic for sales prospects.

Chairman PROXMIRE. Do you see any serious prospect that the competitive wedge of nine Concordes flown by BOAC and Air France will succeed in stampeding other carriers to overbuy the Concorde?

Mr. WILSON. I think these nine aircraft, which have been ordered as firmly as possible, though there are some conditions which would still allow the airlines to get out, are capable of being operated as a kind of monopoly. I even think it possible that on the North Atlantic route such limited numbers as will be flown by Air France and BOAC might make a marginal profit. But again, market research indicates that if another airline or airlines were to come into the operation, that that profit would disappear on the North Atlantic, which has proved a very disappointing route for Concorde.

Chairman PROXMIRE. On the other hand, there is some indication that there will be a restriction in scheduled service and an increase in charter and shuttle-type services at much higher rates of seat occupancy. The Chairman of the Civil Aeronautics Board recently proposed a move in that direction. Now, it seems to me, that that kind of action would reduce fares, of course; that would be the purpose of it, I presume. We would have more people traveling per plane. The lower subsonic fares would put the Concorde at a further disadvantage, because it needs higher fares desperately in order to have a payoff, is that not correct? So that to the extent we move in the direction of shuttle-type service and charter service, this would be damaging to the prospects of selling Concordes, would it not?

Mr. WILSON. Very damaging. It has already happened on the route from Britain to Australia, where in the last 12 months fares have been cut by some 30 percent.

Chairman PROXMIRE. Do you see any prospect of an arrest of this downward trend of rates—of course, all of us as travellers like to see a downward trend—but do you see any prospect of arresting this downward trend of rates, as I say, as a serious economic problem for the Concorde or for any SST?

Mr. WILSON. I find it difficult to forecast when the trend might level off. But even if it merely continues on its present line for another couple of years, I think the differential between ordinary fares and the supersonic surcharge is going to be much more serious for the Concorde than the manufacturers ever imagined.

Chairman PROXMIRE. Now you note in your statement that the French Ministry of Transport has banned the Concorde from landing at Orly Airport. Isn't the noise problem just as severe at La Bourget, the other Paris airport?

Mr. WILSON. Well, as you know, the French are building another airport, Paris-Nord.

Chairman PROXMIRE. How can that serve Paris efficiently if it takes you much longer to get from the airport to the city? It does not make much sense to save a couple of hours in flight time and spend that time sitting in some kind of a miserable bus.

Mr. WILSON. Indeed. Any extension of the journey time erodes the advantages of a supersonic flight, and because of the great noise problem there is a tendency in Britain, as well, to try to push Concorde further from the city center. Concorde may finally be excluded from Heathrow and regulated to flying from a new coastal airport being constructed for the London area at the very great cost of $600 million.

Chairman PROXMIRE. What you are saying is the sideline noise factor requires the airports for the supersonic transports be placed, whatever the expenses involved, farther away from the city so that the noise pollution willl be a lesser factor.

Mr. WILSON. Certainly, if you are not to inflict the noise on the population.

Chairman PROXMIRE. When you do that you lose part of the one very significant advantage the Concorde would have or any SST would have, which is a time advantage, because it takes you so much longer to get from the airport to the city; is that right?

Mr. WILSON. Yes.

Chairman PROXMIRE. You inform us that the Concorde noise problem remains quite serious at best. Has the aircraft been certified to serve any countries besides Britain and France? Have any countries indicated refusal to permit it to land?

Mr. WILSON. I am only aware of legislation passed in the five countries banning supersonic over-flying. We are not aware in the United Kingdom of any specific ban because of the ground noise problem as yet.

Chairman PROXMIRE. We discussed, in the staff this morning, whether or not we might ask you this question, and it seems to me that it is a useful question to ask. In questionnaires that I have sent out in my State, and I think I have a typical State, and that others have sent out, the support for the supersonic transport in this country is very weak. It runs 8 to 1, 9 to 1, 10 to 1 against it, against having the Federal Government subsidize a program which would bring on an SST. Of course, the majority of people have occasionally been wrong in the past, they may be wrong on this one, but that is an element in public policy, certainly one that we should consider in a democracy, at any rate.

If a referendum were held in Britain tomorrow, do you have any hard knowledge on the basis of any kind of a survey or any kind of questionnaire, or any feeling as a newspaperman, sensitive to public attitudes, of what the attitude would be in Britain tomorrow toward proceeding with the Concorde?

Mr. WILSON. I have no hard knowledge based on questionnaires or polls, which have not been taken in my country on this point. I have an instinct as a newspaperman that a majority, a very recognizable majority, would be against proceeding with the Concorde on a variety of grounds.

Chairman PROXMIRE. They do not feel the prestige of Britain is to tied to the Concorde?

Mr. WILSON. No. But those who support the aircraft do so very much for this reason, they feel the prestige of British engineering is heavily involved.

Chairman PROXMIRE. Now for some reason it is hard for me to understand these national psychologies, if there are such things. For some reason the French have been hung up on the prestige kick to the extent of having great investments in nuclear and space activities, and so forth, that may or may not be wise; but the French seem to have been pushing this harder. Maybe it is the aura of De Gaulle.

Do you have any obsevations with respect to the public opinion supporting this in France?

Mr. WILSON. Yes, there is a difference in national temperament reflected in these differing approaches. Also, because of the system of government that France has enjoyed during the life of Concorde, there has been very much more publicity from official sources in favor of the aircraft, and less opportunity, I think, for public criticism.

Chairman PROXMIRE. So that you would say that in France the public sentiment is probably more favorable than in Britain but you cannot say whether a majority would favor it even in France.

Mr. WILSON. No. There is, of course, a degree of opposition in France to the aircraft which is not always publicized.

Chairman PROXMIRE. Supposing New York or Massachusetts, where landing is important, supposing they were to impose noise restrictions for their airports, noise restrictions which would make it impossible for the Concorde to land. It has been suggested that if this is done, Britain would retaliate and prohibit our jets from landing at Heathrow. Do you think this is likely, and what form might such retaliation take? How about the French, would they retaliate, too?

Mr. WILSON. I think there is no serious possibility of this retaliation, because the United Kingdom very much needs the arrival of visitors from the United States. The British Airports Authority derives geat benefit from the landing fees paid by your aircraft at the London airports.

The one thing that might happen is that the British Airports Authority could follow up an idea which it is currently discussing for fixing the landing fees of aircraft according to the noise they create. In that case very noisy aircraft like the Boeing 707 would be subject to higher landing charges. These could be avoided only by landing at airports farther from the center of London. But I do not think this could be regarded as retaliation for an American ban on the Concorde.

Chairman PROXMIRE. How about retaliation from the French?

Mr. WILSON. The French need air traffic from the United States as much as we do. One of the great anxieties or airport authorities in both countries has always been that another country might filch the bulk of the North Atlantic traffic and so deprive Britain or France of the economic advantage of being a gateway airport country to Europe.

Chairman PROXMIRE. As a well known journalist, and as one who is far more familiar than most of us are with respect to the British position vis-a-vis the Common Market, and the role that this consideration played in Britain's continuing with an investment which its leadership might have felt ill-advsed and uneconomic, do you think there is any prospect at any time in the future, any point along the production schedule, when Britain could get off this road to economic disaster, could finally say "no" before proceeding with the production of a substantial number of Concordes. Can they get off now that the Common Market question is not quite as delicate?

Mr. WILSON. I think that with political decency we could get off in the next 12 months—I am speaking now of our relationship with France. But I think that because of domestic political factors, the British Government is not yet ready to acknowledge defeat on the Concorde, that it will make a consistent effort for some time yet.

Chairman PROXMIRE. Is this is a live issue between the two parties, between the Labor Party and Conservative Party with the Labor Party opposing the Concorde now, or is it just that some of the leaders feel if they were in power they would have dropped it before?

Mr. WILSON. It is true on balance. I think, that whereas a Labor Government would now be ready to cancel, the Conservative Party is committed to continuing. But the issue cuts a little across party lines because, of course, the trade unions have an interest in seeing production continue, and this is reflected in the views of some Labor Party Members of Parliament.

But if you take those responsible in a shadow capacity for thinking about the economic problems of Britain in the Labor Party leadership, I think, I am certain, that you will find a consensus that the Concorde is a waste which must be terminated.

Chairman PROXMIRE. All right. Then, let me come to that question and what I am obviously driving at. What prospect, if any, is there that this program may be aborted either by England or by France or in some other way short of completion of a sizeable number of planes?

Mr. WILSON. There is, I would say, a clear prospect that it might be aborted within the next 2 years but certainly not within the next year.

I think that the Government must allow a further period in which customer airlines can place orders. After all, the options of many airlines are still running, and the Government is bound to see if any more customers come home, as they may well do. I would personally not be surprise to see a number of more orders picked up. I think that Japan Airlines will be one customer. But when it is perceived that the orders will not rise above a certain figure, then the program will be terminated.

Chairman PROXMIRE. I have just one other question before we proceed to the next witness. Despite the deficiencies— both economic and environemenal—the real threat seems to be in a second generation Concorde. I think you, Mr. Lundberg, and others have made a very convincing argument that the present Concorde just does not have the seating capacity. does not have the range, has an exececessive fuel consumption, has all kinds of problems with respect to competition with the 747. You may sell some but not many. But the second generation Concorde is something that is still haunting many in this country who are concerned that Britain and France have the momentum now, they have some know-how now. They can move into the second generation field. Now you dismiss that in your statement with considerable emphasis. You say there is no prospect of a second generation because, one, you are not going to get into it again; the cost would be much too great. you just cannot see it. How can you be so sure about that?

Mr. WILSON. I am influenced in this by the judgment of others more expert that I. The reason I am so certain is that it is not simply a question of stretching an aircraft as you might stretch the design of a subsonic aircraft to include more passengers. To increase substantially the capacity of Concorde, to increase it to a point which might come a little nearer to its being an economic airplane, would mean a major dedesign. This is something that is going to cost some hundreds of millions of pounds, and the risks which will be entailed are just too great.

Chairman PROXMIRE. Supposing this becomes more of a Common Market operation; supposing you have West Germany, with its great resources and its fine know-how and great capability, entering a three-country consortium, would this be a possibility?

Mr. WILSON. Moves have been made in the past, and not so remotely, to interest the Germans in some participation, and their answer has always been, "No."

Our Common Market partners are acutely aware of the risks in the supersonic development.

Chairman PROXMIRE. Is there any interest in the possibility of having a joint American-British-French-German combination, a real international free world effort to come along with an SST?

Mr. WILSON. Yes. This is a proposal which, at least in relation to cooperation by Britain and France on one side and America on the other, has been made on a number of occasions, notably by Sir George Edwards, head of the British Aircraft Corp., and I have no doubt that it may be made again in relation to a second generation supersonic aircraft. But I see no evidence that it will lead to anything you could call a Mark II Concorde. I also see considerable opposition to finding funds for such a venture in view of all our other needs in the United Kingdom.

Chairman PROXMIRE. So much of this is a matter of national prestige, if you dilute it by bringing in everybody—it is almost like some people saying the kiss of death for our space program would be to join with the Soviet Union. It makes a lot of sense economically and technologically, but prestige and competition add a lot of force in both space and the SST——

Mr. WILSON. Dilution of the national effort would certainly remove part of the impetus which has been behind Concorde in Britain and France, the part which has been a matter of national prestige.

Chairman PROXMIRE. Thank you very much, Mr. Wilson, for your most helpful analysis, and we are so grateful to you for coming from London to give us this information; most useful, and I will call it to the attention of other committee members and the Members of the Senate and the House.

Thank you, sir.

Mr. WILSON. Thank you, Senator.

Chairman PROXMIRE. I had previously planned to have a panel involving our three remaining witnesses but I have decided, in view of the sharp differences in the nature of their testimony, that I will have

Mr. Harold Johnston proceed first by himself and then we will have our final two witnesses appearing as a panel.

Mr. Johnston is an unusual witness in these hearings. As you know, Mr. Johnston, we invited the proponents, administration proponents that we could identify, but they refused to appear. We have had a number of opponents.

I understand you are in neither category, you do not appear as an advocate or as an opponent of the SST. I wish you did one way or the other, but I understand your position, and it is most valuable to us to have a man of your technical competence and professional reputation to appear.

I understand you are a member of the Department of Chemistry at the University of California at Berkeley, and you are one of the world's foremost authorities on the chemistry of the upper atmosphere, you have written extensively about this work, and you are currently participating in the Department of Transportation's Climactic Impact Assessment program, which, among other things, is designed to assess the impact of SST exhaust emissions on the upper atmosphere.

It is hard to say for sure, but I think the killing blow against the SST last year was the revelation, which was joined in by both meteorologists and skin cancer specialists, that it was conceivable—they could not give us the odds—but it was conceivable that a large fleet of SST's could have some effect on the radioactivity on earth, and increase the incidence of skin cancer by depleting the ozone. This is a pretty complicated argument for a lot of people but, as I say, it became one that a number of Senators became aware of, and it may have tilted the balance. So we are interested in hearing about this.

The proponents of the SST say it is baloney, nonsense, and that the weather up there has far more effect, and so forth. Now we would like to hear from a man who is a world expert on atmospheric chemistry, and is not coming to us as a proponent, or opponent, of the SST, but just to enlighten us.

Go ahead.

STATEMENT OF HAROLD S. JOHNSTON, PROFESSOR OF CHEMISTRY, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF.

Mr. Johnston. Mr. Chairman, the probable effect of supersonic transports on the earth's ozone shield is a complex technical subject involving chemistry, meteorology, geophysics, mechanical engineering, biology, and other fields. The present report is primarily devoted to the chemistry and photochemistry of the problem.

Chairman Proxmire. As you know, Mr. Johnston, we do have a 10-minute rule on time.

Mr. Johnston. Beg your pardon.

Chairman Proxmire. We have a 10-minute rule on time.

Mr. Johnston. The chemistry itself is detailed and can easily involve a large number of reactions. Certain important features, however, are so large that it should be possible to state them in relatively simple terms. I shall present the case, as I see it, at three points in time: first, the present, second, 2 years ago, and third, 2 years from now. In this report, I shall try to state the case as simply as possible. At the end of this summary statement, I give references to my technical articles on this subject.

For the present status—this is a slightly involved argument—let us see if we can build it up.

(1) THE PRESENT STATUS

Stratospheric ozone is produced from sunlight and oxygen. It is destroyed by several chemical reactions and removed from the stratosphere by several modes of atmospheric motions. The ozone of the world is in dynamic balance between production and loss mechanisms. Only about 20 percent of the loss of ozone, however, is due to reactions of pure air and to air motions; the other 80 percent loss of ozone is caused by "something else," something other than pure oxygen and nitrogen. The necessity for "something else" has been recognized by atmospheric scientists for more than 10 years.

During the period 1965 to the summer of 1971, it was thought that this discrepancy was due to reactions based on water in the stratosphere. Articles by Crutzen (1970), and Johnston (1971), suggested that the ozone balance is caused by natural oxides of nitrogen (NO_x) in the stratosphere. Well-established reactions of the oxides of nitrogen are very powerful catalysts for ozone destruction. At the Arosa Symposium on Ozone, in August 1972, it was the consensus of the international group of ozone scientists that the oxides of nitrogen are very important in the natural ozone balance. There is still reason to believe that water vapor is of importance in the upper half of the stratosphere.

The natural source of nitrogen oxides in the stratosphere has recently been recognized and evaluated by several different groups. There is an uncertainty in the estimate of the rate of natural injection of NO_x into the stratosphere; the various investigators gave as an average range 1.7 to 7.7 (in arbitrary units) for the worldwide natural source of NO_x.

Point No. 2: We know the natural source, within limits.

The artificial source of NO_x from 500 supersonic transports has been estimated by several different investigators. There is an uncertainty in these calculations based on different estimates of percentage NO_x in the exhaust, and the Concorde burns only about one-third as much fuel per hour as the American SST. The range of current estimates of the artificial injection of NO_x from the SST is between 2.4 and 7.5 in the same units as quoted for the natural source. Thus, estimates of the artificial source of NO_x from 500 SST cover about the same range (2.4 to 7.5) as the natural source (1.7 to 7.7). The natural source of NO_x sets the worldwide level of ozone at about half the value it would have without NO_x, and, as such, it is a very active natural ingredient. According to our present understanding, commercial fleets of SST promise more or less to double a very active natural ingredient in the stratosphere.

Now, another current topic follows: Following the proposal by Foley and Ruderman that atmospheric nuclear bomb tests introduced significant quantities of nitric oxide into the stratosphere, we have carried out a detailed examination of the total-ozone data for the world, which are available only for the period 1960 to 1970.

These data appear to show a statistically significant decrease of stratospheric ozone during the period of intense nuclear bomb testing, 1960–62, and a larger, statistically significant increase of total-ozone, 1963–70, after cessation of large-scale atmospheric nuclear testing. Although these trends may have other explanations, their location, and timing, are consistent with the distribution of carbon–14 and strontium–90 in the stratosphere and, thus, presumably with bomb-produced nitric oxide. The magnitude of the ozone decrease and increase, about 5 percent, is consistent with what one expects from injections according to Foley and Ruderman's model, if consideration is given to the uncertainty with which those quantities are known. It appears that nuclear tests between 1952–62 injected nitric oxide into the stratosphere at a rate comparable to normal operation of between 20 and 100 American SST's during the same 10-year interval, and there was an observed decrease of ozone, especially in the Northern Hemisphere. The well-established increase of global ozone over the period 1963–70 could very well be the world returning to normal after the perturbation by nitric oxide injected by nuclear bomb tests, 1952–62.

(2) THE STATUS 2 YEARS AGO

The U.S. Department of Commerce panel on supersonic transport environmental research at Boulder, Colo. in March 1971, presented three things: Presented an estimate of the natural NO_x concentration in the stratosphere, the NO_x increment expected from full-scale SST operation, and a computational procedure. I used their data and computational procedure, corrected a mistake they made, and found the ozone shield to be reduced by a factor of two. A more realistic data base is needed than that issued by the panel. However, it then represented the judgment and understanding of governmental agencies and SST industries. I deplore one aspect of the panel's final report—May 1972—which omitted their own data presented a year earlier, which concealed the range of uncertainty that still exists, and which within the ranges of uncertainty appeared to quote only the extreme values in the direction of favoring the SST. To put it bluntly, they hid the bad news.

The full range of probabilities needs to be kept clearly in view. For the sake of balance, it is important for the Congress and the public to maintain an informed, detailed interest in this problem.

(3) STATUS 2 YEARS FROM NOW

With respect to the case for environmental harm from the SST, a good analogy can be made between a grand jury and a trial jury. A grand jury decides whether there is enough evidence to require a careful, balanced, detailed trial. A "true bill" by a grand jury does not prove guilt, nor must guilt be proven before a "true bill" should be issued. In 1971 and even today, the ozone-depletion case against the SST has the character of a "true bill" returned by a grand jury. There is strong evidence that NO_x from the SST exhaust could seriously reduce stratospheric ozone. A careful, quantitative, impartial "trial by jury" is strongly indicated.

The Department of Transportation has inaugurated a crash 3-year program of research in its climatic impact assessment program—CIAP—concerning the environmental impact of the SST. There are about 50 different research projects on all aspects of the problem, including biological effects of increased ultraviolent radiation. This program is engaged in measuring the actual distribution of NO_x in the stratosphere, in measuring the actual emissions from SST engines under simulated stratospheric conditions, in measuring in the laboratory optical and chemical properties to close gaps in needed information, and in supporting a wide range of calculations of atmospheric motions. This 3-year—1972–74, inclusive—program constitutes the "trial by jury," which the considerations of 1971 called for. There is a committee of the National Academy of Sciences-National Research Council that is advisory to CIAP and that will follow the program in detail. It is the intention of CIAP freely to publish all of its findings and to earn the credibility and support of the international scientific community.

During the first year of CIAP, relatively little new, hard data on the subject have been presented. Significant new data and calculations are expected during the calendar year 1973. It will probably be early in 1974 before the new data base is sufficient to provide a verdict that could be widely believed. The goal of CIAP is to characterize the properties, resources, and limitations of the stratosphere as a region for transportation. I hope that the Congress will support this program and give it continuing sympathetic and critical scrutiny.

Finally, as a summary, of the summary, the environmental warnings that were published in 1971 about the impact of the SST on the ozone shield are responsible, conservative statements based on data then available. A range of effects was always indicated. After 2 years of scrutiny of the case by four big hostile governments, no substantive flaws have been demonstrated.

Chairman PROXMIRE. No substantive what?

Mr. JOHNSTON. Flaws. At present the U.S. Government has under way research programs designed to narrow the range of uncertainty. Until results come in from these research programs we are left with a broad range of probable effects, one extreme of which entails very serious environmental hazard.

Thank you, Mr. Chairman.

(The prepared statement of Mr. Johnston follows:)

PREPARED STATEMENT OF HAROLD S. JOHNSTON

THE PROBABLE EFFECT OF SUPERSONIC TRANSPORTS OF STRATOSPHERE OZONE

The probable effect of supersonic transports (SST) on the Earth's ozone shield is a complex technical subject involving chemistry, meteorology, geophysics, mechanical engineering, biology, and other fields. The present report is primarily devoted to the chemistry and photochemistry of the problem. The chemistry itself is detailed and can easily involve a large number of reactions. Certain important features, however, are so large that it should be possible to state them in relatively simple terms. In this report, I shall try to state the case as simply as possible and give references to the detailed, technical articles. I shall present the case, as I see it, at three points in time: (I) the present, (II) two years ago, and (III) two years from now.

I. PRESENT STATUS OF THE EXPECTED EFFECT OF OXIDES OF NITROGEN ON STRATOSPHERIC OZONE

A. The Ozone Balance in the Stratosphere

In 1930 Sydney Chapman proposed a mechanism involving pure air species and sunlight that explained the natural balance, formation and destruction, of ozone in the stratosphere. Sunlight converts ordinary oxygen, O_2, into two very reactive forms: atomic oxygen, O; and ozone, O_3. At twenty kilometer elevation ozone is a few parts per million and oxygen atoms are a few parts per million million. The highly reactive "odd oxygen" is re-converted to normal oxygen in a chemical reaction:

$$O+O_3 \rightarrow O_2+O_2$$

The wavelength of sunlight that forms ozone from oxygen is below 242 nanometers (nm). Ozone itself strongly absorbs radiation below 300 nm, and this absorption is the only effective shield of the surface of the earth against the harsh radiation between about 250 and 300 nm.

In the early days of Chapman's mechanism, the intensity of ultraviolet radiation above the atmosphere was calculated from the temperature of the surface of the sun. Optical and chemical properties of O, O_2, and O_3 were measured in the laboratory. There was reasonable agreement between many aspects of the calculated and observed quantities of stratospheric ozone. However, it was noticed very early that the distribution of ozone with elevation and with latitude was strongly modified by atmospheric motions. Much ozone in the lower stratosphere is brought there by vertical eddy diffusion and by vertical components to certain winds. The ozone in polar and near polar regions is largely brought there by horizontal eddy diffusion and by north-south components of winds.

Early rocket flights in the late 1940's and 1950's measured the solar intensity above the atmosphere. Laboratory data on the properties of O, O_2, and O_3 in the 1950's was more precise and in some cases different from that of the 1930's. Dütsch (1961) pointed out that the new data appeared to indicate that ozone was produced much faster from sunlight that it was destroyed, according the Chapman model. Dütsch stated that the laboratory workers themselves were not in agreement and that the conflict might not be real; he advised workers in the field to watch the situation. By 1965 the laboratory measurements on the optical and chemical properties of oxygen species (O, O_2, O_3) and the rocket-observed solar intensity had become sufficiently well established that there was little doubt that there was a major conflict between observed ozone data of the world and the expectations of the "pure air" model, even when corrected for air motions. Hunt (1965) wrote of "the need for a modified photochemical theory of the ozonosphere". Ozone appeared to be formed much faster than it is destroyed. Hunt (1966) pointed out that if two reasonable, but never observed, chemical reactions involving free radicals based on water (H, HO, HOO, abbreviated as HO_x) were sufficiently fast, then the ozone balance could be explained in terms of these "water reactions". For the period 1965–71 (these "water reactions" were almost universally regarded as the major factor in the natural ozone balance. Meanwhile, chemists tried without success to observe and measure the rates of these elusive "water reactions".

When it was pointed out that the SST would probably increase the water content of the stratosphere by 10 per cent on a worldwide scale and perhaps double the water concentration at latitudes of high traffic density, then it followed at once that the SST might significantly perturb the ozone of the stratosphere. Some of the cases that were presented in 1970 and early 1971 involved long lists of reactions and elaborate computer programs. The basic argument, however, is very simple: if natural water accounts for most of the natural destruction of ozone in the stratosphere (as almost everyone in the field believed), then a 10 to 100 per cent increase in stratospheric water content would probably reduce stratospheric ozone.

Crutzen (1970) and Johnston (1971) pointed out that the oxides of nitrogen (NO_x stands for NO and NO_2) are much more potent catalysts than HO_x for the destruction of stratospheric ozone. The mechanism is a simple two-step cycle

$$NO+O_3 \rightarrow NO_2+O_2$$
$$O+NO_2 \rightarrow NO+O_2$$

$$\text{net: } O+O_3 \rightarrow O_2+O_2$$

The net reaction is the same as that of the Chapman mechanism, but the rate constant for the rate-determining step ($O+NO_2 \rightarrow NO+O_2$) in the catalytic cycle is 10,000 times greater at 220°K than the direct reaction ($O+O_3 \rightarrow O_2+O_2$).

Let me now review a current calculation of the magnitude of the failure of the "pure air" reactions (Johnston and Whitten, 1972). The computational method is indicated by Figure 1. Actual, average, world-wide distributions of zone and of temperature are taken. The atmosphere of the world up to 50 kilometers elevation is divided into 43,200 volume elements. The distribution of solar radiation in each cell is calculated in terms of all substances above it, which screen the sun; all hours of day and night are included by the orientations of various parts of the Earth toward the sun. The concentration of oxygen atoms in each cell was calculated according to the Chapman model. The rate of ozone formation and the rate of ozone destruction was calculated in each of the 43,200 cells. The sum of the rate of formation of ozone over the entire stratosphere per second was found. The sum of the rate of transport of ozone from the stratosphere to the troposphere has been evaluated many times by atmospheric scientists, and we accept a typical upper value of this quantity, for instance, that of Brewer and Wilson (1968). Transport of ozone from one part of the stratosphere to another does not matter to this calculation of total world-wide rates, and thus the most difficult aspect of the general problem of stratospheric ozone is eliminated from this special case. In units of 10^{29} molecules of ozone per second for the world, the balance sheet for instantaneous ozone rates as of January 15, for example, is:

Global rate of ozone formation	500
Transport to troposphere	—6
Chemical loss in "pure air'	—86
Loss to "something else"	408

Similar calculations for other times of year give much the same result. "Something else" in the stratosphere destroys ozone four times faster than the reactions of the Chapman mechanism and transport to the troposphere together.

The appendix to this report demonstrates the experimental data upon which this calculation is based. The figures given there show experimental results by various authors. The experimental error is indicated by the scatter of points. Each figure includes a heavy line which is what one must have if the five-fold discrepancy is, after all, to be explained in terms of the Chapman mechanism. Although there is experimental scatter in each of the quantities, it appears very unlikely that the discrepancy between ozone formation and destruction as calculated above is due to experimental error in the background data.

At present it is not possible to prove what causes this large ozone inbalance. There are only two mechanisms that appear to be important, the free radicals based on water and the oxides of nitrogen. The key rate constants for the water reactions are not known. The distribution of the oxides of nitrogen in the natural stratosphere is not known. The difficulty of proving the case is brought out by this diagram.

Mechanism	Key substance	Concentration in the atmosphere	Chemical rate constants
O, O_3	O_3	Known	Known.
HO_x	H_2O	do	Unknown.
NO_x	NO_2	Unknown	Known.

To clinch the answer to these questions, we must have measured concentrations of the oxides of nitrogen in the natural stratosphere, and we must have measured rate constants for the chemical reactions based on water.

With present estimates of these qualities (distribution of NO_x, rate constants for HO_x) it appears that the "something else" is almost exclusively the oxides of nitrogen in the lower half of the stratosphere and about equally NO_x and HO_x in the upper half of the stratosphere (These estimates are subject to revision as more data are obtained).

To a first approximation, the ozone concentration is reduced as the square root of the rate of destruction. Thus the presence of "something else" has reduced the ozone of the world to about one-half the value it would otherwise have.

The key test of the effect to be expected from the SST is to compare the natural source of NO_x in the stratosphere and the artificial source to be expected from 500 SST under normal operating conditions. The principal source of natural NO_x in the stratosphere has recently been identified. Nitrous oxide, N_2O ("laughing gas") is produced in small amounts from soil bacteria under anaerobic conditions. This gas is inert in the troposphere; it resembles carbon dioxide in many ways.

Nitrous oxide slowly penetrates the stratosphere, where it is fairly rapidly destroyed by ultraviolet radiation to give inert nitrogen, N_2, and eventually oxygen, O_2. However, about 10 per cent of it reacts with an especially reactive form of atomic oxygen (O, ^1D) to produce nitric oxide, NO. This source of stratospheric nitric oxide appears to have been discovered by Crutzen (1971) and confirmed by Nicolet and Vergison (1971) and by McElroy and McConnell (1971). The estimates of nitric oxide formation from this mechanism vary because of uncertainties in the calculated atmospheric motions and in the chemical constants. The range of natural input of NO_x into the stratosphere by each investigator is given in the table below. Also given is the range of estimates of the artificial input of NO_x from the SST. These estimates have a range of uncertainty, largely dependent on the fraction of NO_x in the exhaust of the SST as it operates in the stratosphere. The best way to express the exhaust emission is in terms of grams of nitric oxide emitted per kilogram of fuel burned. This number varies with vehicle load, flight mode, ambient temperature, etc. Estimates of this quantity have varied: 42 g NO/kg fuel, SCEP, 1970; 15, Johnston, 1971; 12.5, Concorde, 1972; 7, Forney, 1972. The range of global NO_x emission from SST is given in the table below.

TABLE 1.—COMPARISON OF NATURAL AND ARTIFICIAL SOURCES OF NITRIC OXIDE IN THE STRATOSPHERE

[In units of 10^{26} molecules per second for the world]

Calculated natural flux:	Reference
1.5 to 7.5	Crutzen (1971).
2.5 to 12.5	Nicolet and Vergison (1971).
1.2 to 3.3	McElroy and McConnell (1971).
1.7 to 7.7	Average.

Estimated artificial flux	500 SST type	Reference
2.4	Concorde (1985)	Aust. Acad. Sci.
3.5	U.S.	Forney (1972).
7.5	U.S.	Johnston (1971).
21.0	U.S.	SCEP (1970).

On a world wide basis the average estimates of the natural source of NO_x in the stratosphere is 1.7 to 7.7 (in the units of the table above). The range of estimates for the artificial flux as contributed by 500 SST is 2.4 to 21 in the same units. For the lowest estimate of artificial flux 2.4, it makes a big difference whether the natural flux is 1.7 or 7.7. For the highest estimate of artificial flux, 21, which was the number apparently accepted by U.S. planners of the SST in 1970, the artificial flux is much greater than all estimates of natural flux. In general, it appears that NO_x is a very active ingredient in the natural stratosphere, and full scale operation of SST promises more or less to double this very active natural ingredient.

B. Nitric Oxide Injected into the Stratosphere from Nuclear Bomb Tests

The case given above is based on calculations and the extrapolation of laboratory data to the upper atmosphere. There is, of course, a chance that these calculations are incomplete; it could be that the most important factor is not yet recognized. Many people wish to carry out a direct experiment, to inject nitric oxide into the stratosphere, and to observe the effect. Such experiments face overwhelming obstacles. The residence time of pollutants in the stratosphere is measured in months and even years, depending on latitude and elevation. The time for the oxides of nitrogen to destroy half the ozone in the lower stratosphere is also a matter of months or years. An injection experiment would have to be massive enough to be tracked for at least a year if it is to be meaningful in the problem.

On the other hand, Foley and Ruderman (1972) have recently pointed out that atmospheric nuclear bomb tests produced nitric oxide from air ($N_2+O_2 \rightarrow NO+NO$) in amounts comparable to that from fleets of SST. Johnston, Whitten, and Birks (1972) have extended these calculations and have made extensive statistical analyses of the observed ozone data for the world. A large nuclear bomb (one megaton or more equivalent of chemical high explosive) fired in the lower atmosphere produces a hot cloud that rises and spreads out in the stratosphere. The amount of nitric oxide produced by the bombs has an uncertainty of at least a factor of six. This uncertainty arises from lack of definition of the detailed history of the hot cloud as it rises, mixes with surrounding air, and cools. High yield nuclear bomb tests occurred in the atmosphere between 1952 and 1962. There was an especially intense period of testing in 1961–62. Within the factor of six uncertainty in yield of oxides of nitrogen, the nuclear tests 1952–1962 were comparable to the normal operation (NO at 15 g per kg of fuel) of the following number of SST: SST (10 year average) = 18 to 103.

Since there was an intense rate of testing in 1961–62, an alternative way to state the number of SST is that they started at zero in 1952 and increased linearly with time for ten years reaching a maximum of 36 to 206 in 1962, and then all flights stopped.

It is probable that nuclear bomb tests constituted a massive injection of the oxides of nitrogen into the stratosphere. Although nitric oxide from the bombs was not measured, very extensive analyses were made of strontium-90, excess carbon-14, and other radioactive products from the bombs (Health and Safety Laboratory Reports of the Atomic Energy Commission). The timing and location of artificial nitric oxide from the nuclear bombs can be estimated from the observed distributions of strontium-90 and excess carbon-14. The total global burden of these substances is given by Figure 2. The global distribution of crabon-14 carried forward from tests in the 1950's is given by Figure 3. The distribution of carbon-14 at the time of its maximum amount is given by Figure 4, the amount one year later is given by Figure 5, and the amount four years later is given by Figure 6. Relatively little carbon-14 entered the southern hemisphere. Most of the bomb debris, and thus presumably the artificial NO_x, was produced and remained in the northern hemisphere.

The total column of overhead ozone can be measured from the ground by straightforward optical methods. Such data are available from one or two research stations over a period of about 40 years. A large number of such stations were manned during the International Geophysical Year of 1958. A large network of such stations was subsequently set up. Since January 1960 the detailed day-by-day and month-by-month measurements of ozone from numerous stations (over 30 in 1960, over 90 in 1970) have been published as *Ozone Data for the World*, Meteorological Branch of the Department of Transport of Canada. In terms of number of daily observations and monthly averages, all of these data have been analyzed by Johnston, Whitten, and Birks (1972). The history of global stratospheric strontium-90 and excess carbon-14 (Figure 2) indicates that one should expect a *decrease* of ozone between 1960 through 1962 during the period of intensive bomb tests and an *increase* of ozone after the tests ceased in 1962. Table 2 lists all stations that had as many as 30 months of observations out of 36 for the period 1960–62, inclusive. For each station the average linear trend b (per cent per decade) and twice the standard error of estimate 2σ are listed. As in most meteorological or climatological variables, there is a large variation of results. Some stations show an increase and some a decrease. For the period 1960–62, 23 out of 30 stations showed a decrease of ozone. The net decrease was three per cent for the interval. For the period 1963–70, 22 out of 27 stations showed an increase of ozone. The net increase after the cessation of bomb tests was six per cent. These figures suggest that the increase of ozone, 1963–70, corresponded to the world returning to normal both from the intensive series of tests in 1961–62 and from the long preceding series 1952–1959. Such an interpretation is consistent with the levels of strontium-90 and carbon-14 shown in Figure 2. These trends are relatively small effects superimposed on the random and seasonal variations of the ozone column; examples of the data are given for two stations in Figure 7.

The various stations were averaged together in geographical bands in Table 3 (The stations were weighted inversely proportional to the square of the standard error of estimate). Table 3 shows that the northern hemisphere had a much greater decrease 1960–62 and increase 1963–70 than the southern hemisphere. The region of greatest change was north of 50°N latitude, Figures 3 to 6. It will be recalled that the massive Russian tests of 1961–62 were at 75°N.

Atmospheric data are subject to fluctuations and trends over a wide range of time scales. The ozone decrease (1960–62) and increase (1963–70) could be due to some natural trends. The failure to occur in the southern hemisphere tends to exclude a large number of plausible explanations for a natural trend; but even so, a natural explanation remains possible. However, the *Ozone Data for the World* taken at face value give statistically significant (95% confidence level) decreases and increases, qualitatively consistent with expectations from the timing and location of nuclear bomb tests.

The magnitude of these changes appears to be a 2 to 4 per cent decrease during the period of intense testing (1961–62) and a 5 to 6 per cent increase after conclusion of a decade (1952–62) of large atmospheric tests. It was noted above that the decade of testing corresponded to between 18 and 103 SST. If 18 American SST (as conceived in early 1971) would have reduced the ozone of the northern hemisphere by 5 or 6 per cent, the effect of NO_x on stratospheric ozone is substantially larger than that estimated by Johnston in 1971. If 100 American SST would have reduced the ozone of the northern hemisphere by 5 or 6 percent, the effect of NO_x on stratospheric ozone is somewhat less than that estimated in 1971.

II. STATUS OF PROBABLE ENVIRONMENTAL IMPACT OF SST AS OF WINTER 1971

The understanding of the U.S. Government about the probable environmental impact of the SST as of early 1971 is given by two sources: (1) *Technical Information for Congress*, Report to the Subcommittee on Science, Research, and Development of the Committee of Science and Astronautics, U.S. House of Representatives, Ninety-Second Congress, U.S. Government Printing Office, "The Supersonic Transport", Chapter 3, pages 685–748 (revised April 15, 1971); (2) Presentation by Department of Commerce Panel on Supersonic Transport Environmental Research, Boulder, Colorado, March 18 and 19, 1971.

The *Technical Information for Congress* discussed the role of water in reducing ozone, but it was not aware of the problem with the oxides of nitrogen.

The presentation by the Department of Commerce Panel on Supersonic Transport Environmenal Research devoted most of its time to the water problem and to its possible effect on stratospheric ozone. A small amount of attention was given to the problem of oxides of nitrogen. A wide range of scientists had been invited to Boulder to hear the presentation of the case concerning SST environmental effects. The Panel gave out information concerning stratospheric NO_x before and after SST operation; and this information appeared to be the current understanding of government and industry concerning the SST. Park and London (1971) estimated the background concentration of NO_x in the natural stratosphere. Their distribution gave sensible continuity with the mesosphere above and the troposphere below. The average NO_x mole fraction (ratio of molecules of NO_x to all air molecules) in the stratosphere was 5 parts per billion, ppb. Park and London estimated that full SST operation could increase the NO_x in the stratosphere by 22 ppb. The Panel issued pages from the report Study of Critical Environment Problems (SCEP) as a part of its information. The SCEP report estimated that the SST would increase stratospheric NO_x by 6.8 ppb on a world-wide basis and up to 68 ppb in a zone of high traffic density. These increases were stated to be "negligible". Park and London presented calculations of stratospheric photochemistry using the "steady-state" model of a static stratosphere. This computational procedure was accepted and sponsored by the Panel.

If one takes Park and London's distributions for NO_x before and after SST operation, if on uses the steady-state method used at the meeting of March 1971, and if one employs the best current estimates of the rate constants and solar flux, then one finds a factor of two reduction in the vertical ozone column. If one takes Park and London's background distribution of NO_x and increases it by the SCEP "local maximum", one finds about a three-fold reduction of ozone. In commenting on the data presented to us at Boulder, I stated in June 1971: "If NO and NO_2, *as such*, build up in the stratosphere to the expected [SCEP; Boulder, March, 1971] concentrations from SST operation, the ozone shield *would* be reduced by a large amount, about a factor of two." This statement about the consequences if the real world had the properties given by the Panel was immediately followed by several qualificatons about what the real world might be: "If NO and NO_2 are converted to nitric acid (or other inert molecules) at a rate faster than indicated by current knowledge, then the effect of NO_x from the SST exhaust would be less than expected above."

The Department of Commerce Advisory Panel presented the facts about NO_x from the SST as it understood them in March 1971. It was pointed out by Johnston (1971) and by Westenberg (1971) that the quantities of NO_x that they accepted as negligible would in fact cause a major reduction of the ozone shield. The history of the subject since that time has included sharp downward revision of the estimate of NO_x in the SST exhaust, attacks on the use of the photochemical "steady-state" method, and the assertion that atmospheric motions would always act in the direction to reduce the impact of the SST. When the

Department of Commerce Advisory Panel published its report in May 1972, there was a strong tendency to "hide the bad news." At Boulder in March 1971 the Panel gave a range of estimates of the increase of stratospheric NO_x by the SST, 6.8, 22, and 68 ppb; in the published report (page 11) a single number is given, 1 ppb, with no mention of a range of uncertainty. At the Boulder meeting, the Panel gave 5 ppb as the NO_x background in the stratosphere; in the report (page 11) a single figure of 100 ppb was quoted (However, their figure of 100 ppb appears to be in error by a factor of 10; the authors, Hale and Pontano, stated that NO plus NO_2 was about 10^{10} molecules cm^{-3} somewhere between 22 and 30 kilometers. Air concentration is about 4×10^{17} at 30 kilometers, 8×10^{17} at 25 kilometers, and 2×10^{18} at 20 kilometers. A concentration of 10^{10} molecules cm^{-3} is respectively 25, 12, and 5 ppb at these elevations. These mole fractions are close to the estimates made by Johnston and by Crutzen in 1971 and are far below the value of 100 ppm given by the Panel report).

There seems to be a tendency of many workers in this subject (for example, the Department of Commerce Advisory Panel) to believe that large effects from the SST are *a priori* impossible; they tend not to believe evidence, even their own, that indicates a real environmental threat of the SST; they tend to look over the wide range of possible results and to seize the extreme most favorable to the SST. There seems to be a tendency to "hide the bad news." For this reason, I believe it is important for the Congress and the public to retain an informed, detailed interest in this problem.

III. FUTURE STATUS OF OUR UNDERSTANDING OF THE PROBABLE ENVIRONMENTAL IMPACT OF THE SST

With respect to the case for environmental harm from the SST, a good analogy can be made between a grand jury and a trial jury. A grand decides whether there is enough evidence to require a careful, balanced, detailed trial. A "true bill" by a grand jury does not prove guilt, nor must guilt be proven before a "true bill" should be issued. In 1971 and even today, the environmental case against the SST has the character of a "true bill" returned by a grand jury. There is strong evidence that NO_x from the SST exhaust could seriously reduce stratospheric ozone, but in every case the evidence can be matched by a possibility that the SST would have little or no effect. That the evidence might possibly have another interpretation does not eliminate the evidence. A careful, quantitative, impartial "trial by jury" is strongly indicated.

The Department of Transportation has inaugurated a crash three-year program of research in its Climatic Impact Assessment Program (CIAP), concerning the environmental impact of the SST. There are about 50 different research projects on all aspects of the problem, including biological effects of increased ultraviolet radiation. This program is engaged in measuring the actual distribution of NO_x in the stratosphere, in measuring the actual emissions from SST engines under simulated stratospheric conditions, in measuring in the laboratory optical and chemical properties to close gaps in needed information, and in supporting a wide range of calculations of atmospheric motions. This three year (1972–74, inclusive) program constitutes the "trial by jury", which the considerations of 1971 called for.

The CIAP is engaged in the preparation of six books: The Natural Stratosphere (1974), Engine Emissions, The Perturbed Troposphere, The Perturbed Stratosphere and Biological Effects. These volumes are to include current scientific information, new information developed by CIAP, and new information developed by the scientific community on these topics. There is a committee of the National Academy of Sciences-National Research Council that is advisory to CIAP and that will study the six volumes in detail. It is the intention of CIAP freely to publish all of its findings and to earn the credibility and support of the international scientific community.

Although it is very unlikely that all problems concerning the effects of stratospheric pollution will be solved by the end of 1974, there is good reason to believe that the major uncertainties will be removed. As I see it, the major data needed to solve the ozone problem are: (1) measurement of the amount and distribution of the oxides of nitrogen in the normal stratosphere; (2) the measurement in the laboratory of certain optical and chemical constants, especially those related to the water reactions and to the higher oxides of nitrogen; (3) an understanding of the long-term distribution, the residence time, and the removal mechanisms of SST exhaust products in the stratosphere; and (4) most difficult of all, an exhaustive examination of all corners of the problem to be sure that no major effect has been overlooked. The first three problems listed above are finite and definable. In an objective, physical problem of this sort, if the problem can be defined, it should be able to be solved. It may or may not require more resources and time than CIAP have allocated. The fourth problem, of course, is open ended. However, it is being consciously, systematically explored.

During the first year of CIAP, relatively little new, hard data on the subject has been presented. Significant new data and calculations are expected during the calendar year 1973. It will probably be early in 1974 before the new data base is sufficient to provide a verdict that could be believed and used by almost all in the field. The goal of CIAP is not—or should not be—to prove to the 99 per cent confidence level that the SST is and always has been safe. The goal is to characterize the properties, resources, and limitations of the stratosphere as a region for transportation. I hope that the Congress will support this program and give it continuing sympathetic and critical scrutiny.

TABLE 2.—STATIONS WITH AT LEAST 30 MONTHS OF OBSERVATION IN THE PERIOD 1960–62, AND IN 1963–70

[k, ozone increase per decade, percent]

Station	1960–62			1963–70		
	Number of observations	β	2σ	Number of observations	β	2σ
Aarhus, Denmark	36	−12.7	14.9	92	−8.9	7.6
Abustamani, U.S.S.R.	35	−36.1	34.0	29		
Ahmedabad, India	36	+12.3	11.3	82	+8.0	3.7
Alma Ata, U.S.S.R.	30	−9.1	23.5	91	+25.9	11.5
Arosa, Switzerland	36	−5.8	18.4	90	+4.6	5.0
Aspendale, Australia	36	−3.7	17.7	92	−4.3	2.4
Brisbane, Australia	36	−4.3	11.7	92	+1.2	2.4
Camborne, United Kingdom	36	−11.8	19.2	38	+17.2	9.2
Cagliari-Elmas, Italy	36	−3.4	12.5	92	+13.5	4.2
Edmonton, Canada	36	−16.0	13.6	92	+3.3	4.3
Eskdalemuis, United Kingdom	36	−32.8	23.3	7		
Fort Collins, United States	31	−5.8	9.6	36	+18.0	12.8
Kagoshima, Japan	36	+55.9	19.3	92	0	4.8
Karadag, U.S.S.R.	31	−89.3	22.6	36	+6.9	37.4
Kiev, U.S.S.R.	31	−11.4	29.8	92	+9.5	8.4
Kodaikanal, India	36	−.6	8.4	90	+12.4	1.9
Leningrad, U.S.S.R.	30	−7.0	29.3	84	+12.8	8.4
Lerwick, United Kingdom	36	−26.7	15.9	79	+7.5	4.7
Marcus Island, Japan	36	−38.8	16.1	6		
Messina, Italy	36	−32.5	11.3	92	+8.2	3.2
New Delhi, India	36	+15.0	16.1	92	−5.6	3.3
Oxford, United Kingdom	36	−18.2	17.9	92	+6.8	4.5
Port-Aux-Francaise	30	+2.0	24.8	70	+29.0	19.0
Quetta, Pakistan	36	−7.0	17.0	37	+4.5	10.1
Resolute, Canada	35	−32.1	19.1	83	+4.1	6.2
Sapporo, Japan	36	+1.0	16.6	92	+4.1	3.2
Tateno, Japan	36	+10.7	16.7	92	−.9	4.2
Toronto, Canada	36	−11.6	18.8	88	+1.7	4.4
Tromso, Norway	30	+11.1	31.0	64	+10.6	7.8
Vigna di Valle, Italy	36	−15.2	14.6	90	+4.1	4.4
Average per decade, percent		−10.8			+7.2	
Percent in interval		−3.3			+5.8	

TABLE 3.—GEOGRAPHICAL VARIATION OF OZONE CHANGES FOR THE 2 TIME INTERVALS 1960–62, 1963–70

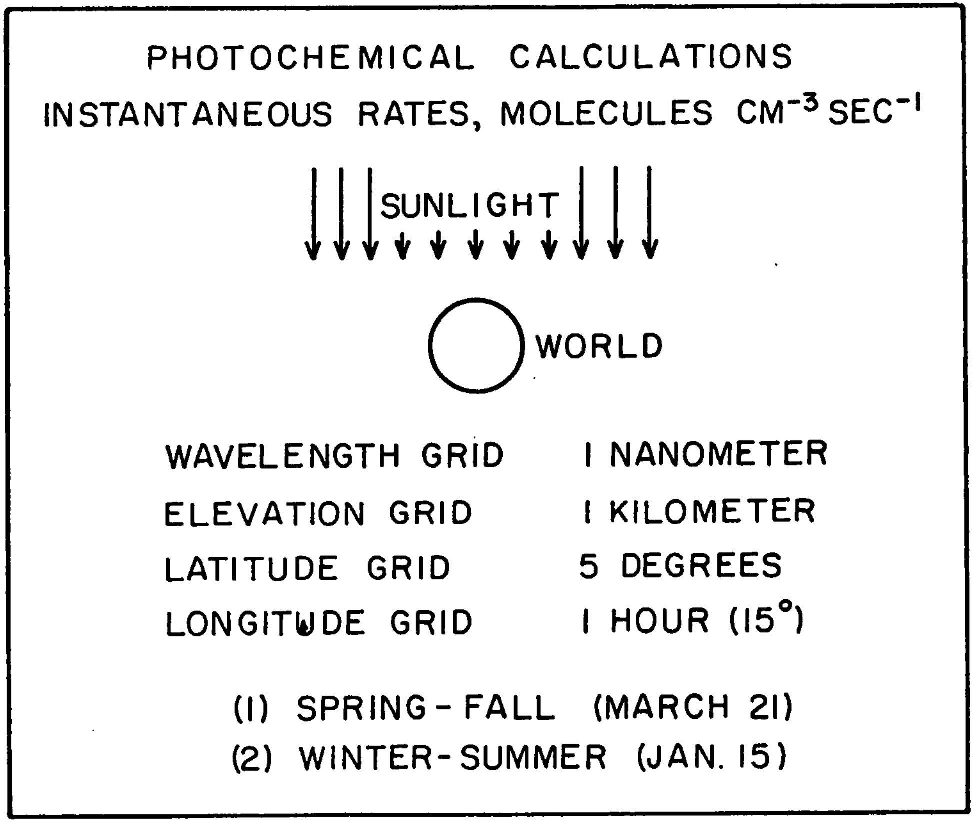
Latitude	Time period	Percent increase per decade	2σ	Number of stations	Number of measurable days
50N–90N	1960–62	−12.6	10.6	20	11,000
	1963–70	+7.6	3.2	28	47,000
	1960–70	+6.5	2.4	29	57,000
0–90N	1960–62	−7.6	7.0	42	28,000
	1963–70	+5.6	1.5	74	129,000
	1960–70	+5.3	1.2	76	156,000
0–90S	1960–62	−3.6	18.8	9	4,200
	1963–70	−1.2	3.1	15	19,000
	1960–70	+.2	2.3	17	23,000
All stations	1960–62	−7.1	6.5	51	32,000
	1963–70	4.6	1.4	89	147,000
	1960–70	4.5	1.2	93	178,000

90-912 O - 73 - 8

Titles to Figures

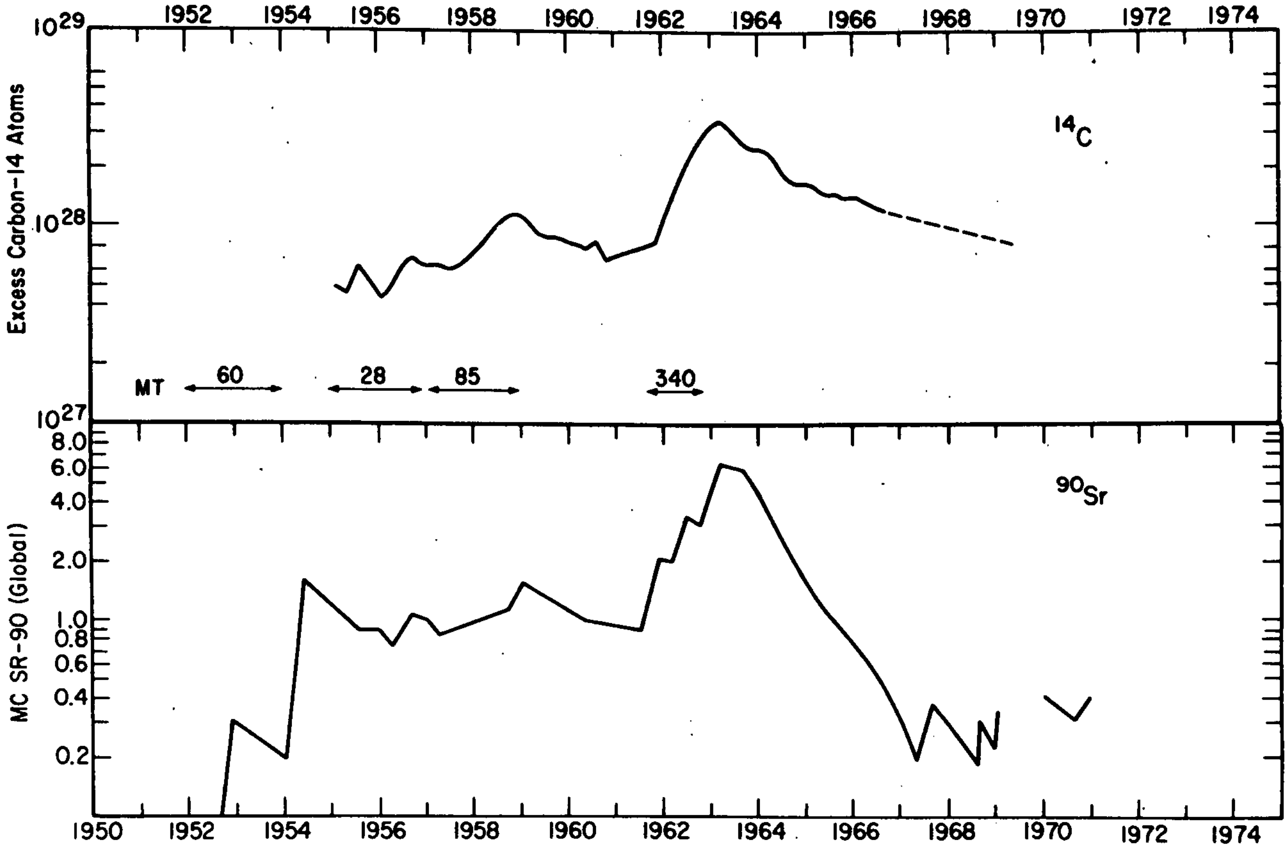
Figure 1. Method of computation of instantaneous, global rates of ozone formation and destruction.
Figure 2. The variation with time of total stratospheric inventory of strontium-90 and carbon–14, with periods and yields (MT) of nuclear explosives.
Figures 3–6. Contour maps of zonal average, excess carbon-14 in the stratosphere in uits of 10^5 atoms of carbon–14 per gram of air.
Figure 7. Total ozone column and monthly deviations (method of Komhyr et al, 1971) for Marcus Island and for Bolshaya-Elau.

FIGURE 1



XBL728-6775

FIGURE 2



1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
10^{29}
10^{28}
10^{27}
Excess Carbon-14 Atoms
^{14}C
MT
60
28
85
340
8.0
6.0
4.0
2.0
1.0
0.8
0.6
0.4
0.2
MC SR-90 (Global)
^{90}Sr
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974

FIGURE 3

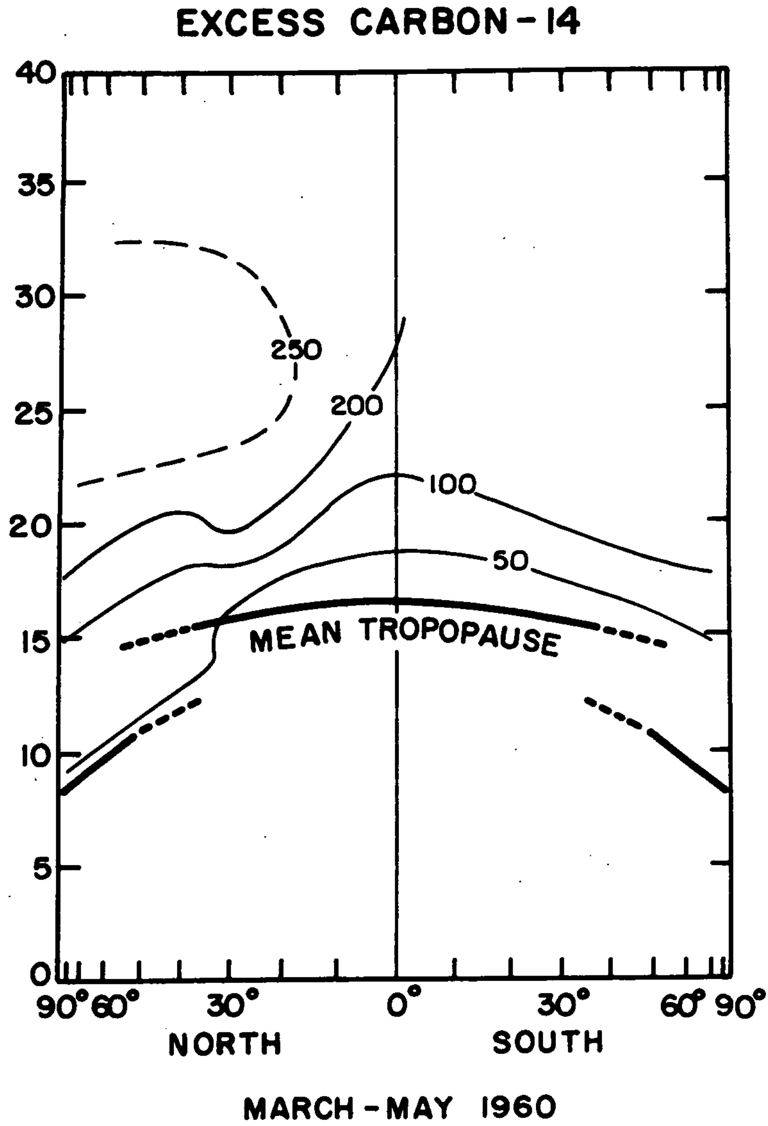

EXCESS CARBON-14
40
35
30
25
20
15
10
5
0
Km
250
200
100
50
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH-MAY 1960

FIGURE 4

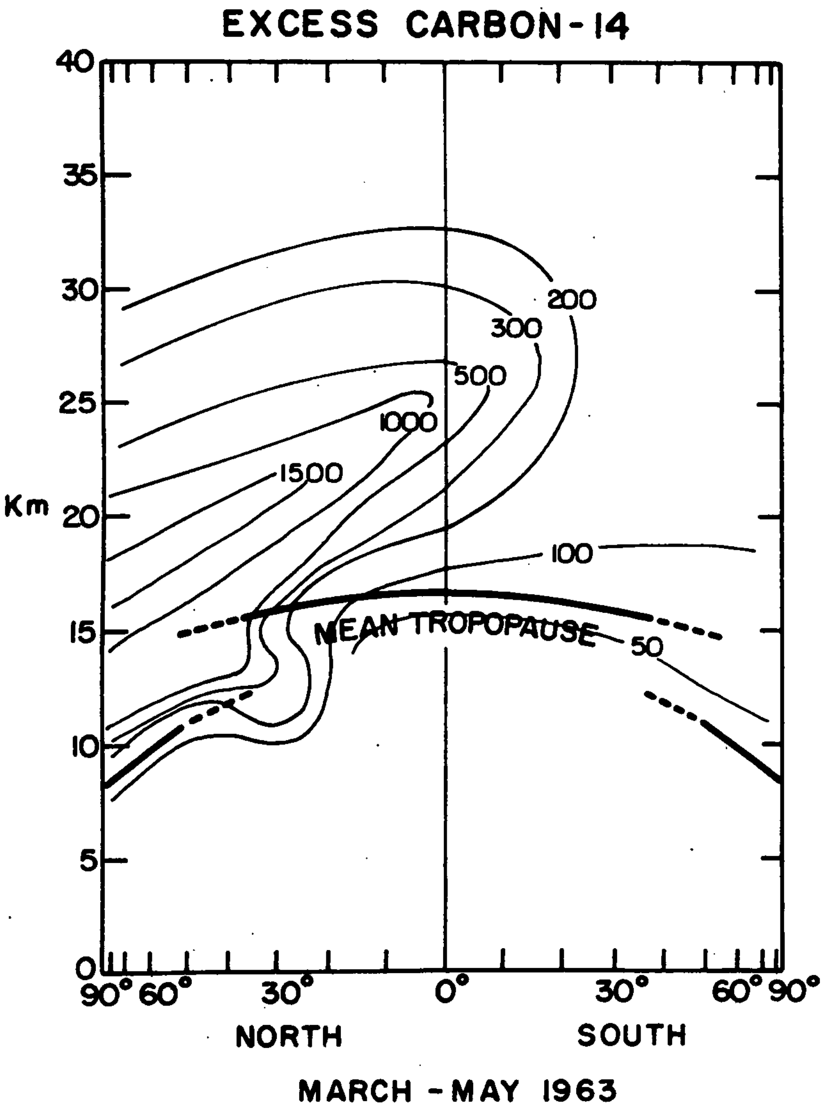

EXCESS CARBON-14
40
35
30
25
Km
20
15
10
5
0
200
300
500
1000
1500
100
MEAN TROPOPAUSE
50
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH - MAY 1963

FIGURE 5

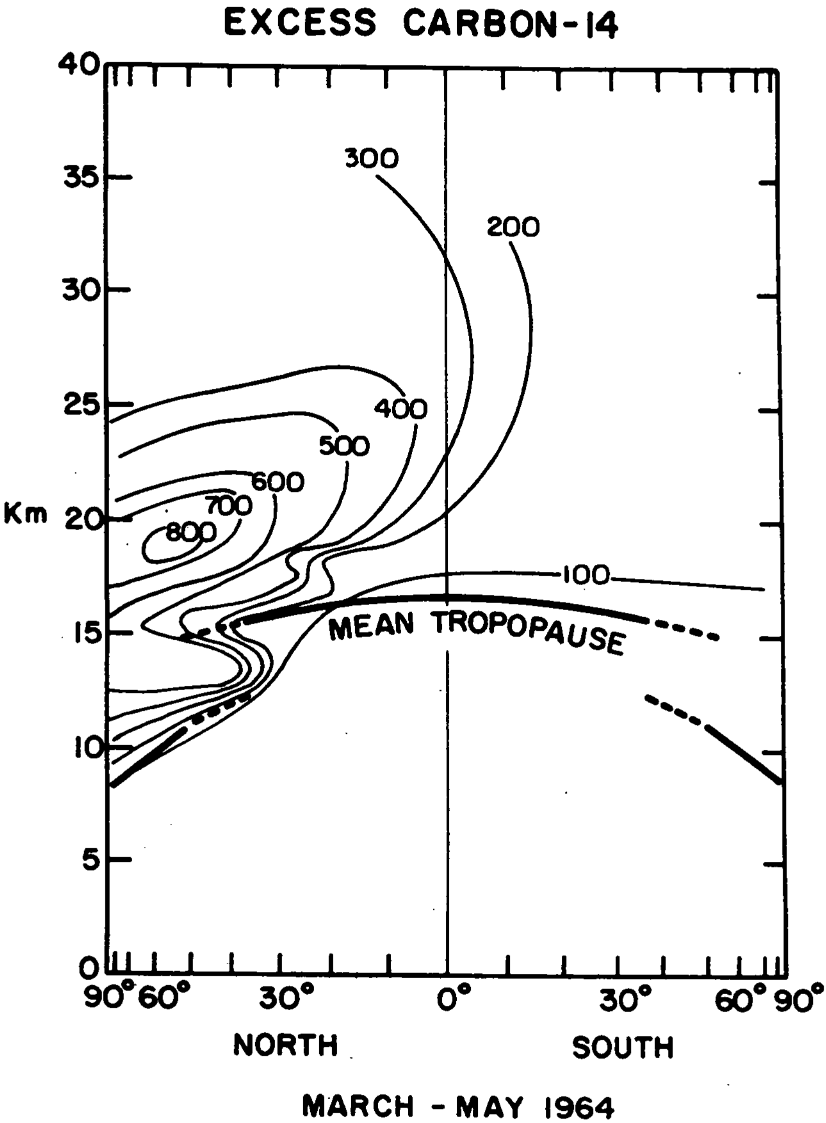

EXCESS CARBON-14
Km
40
35
30
25
20
15
10
5
0
300
200
400
500
600
700
800
100
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH - MAY 1964

FIGURE 6

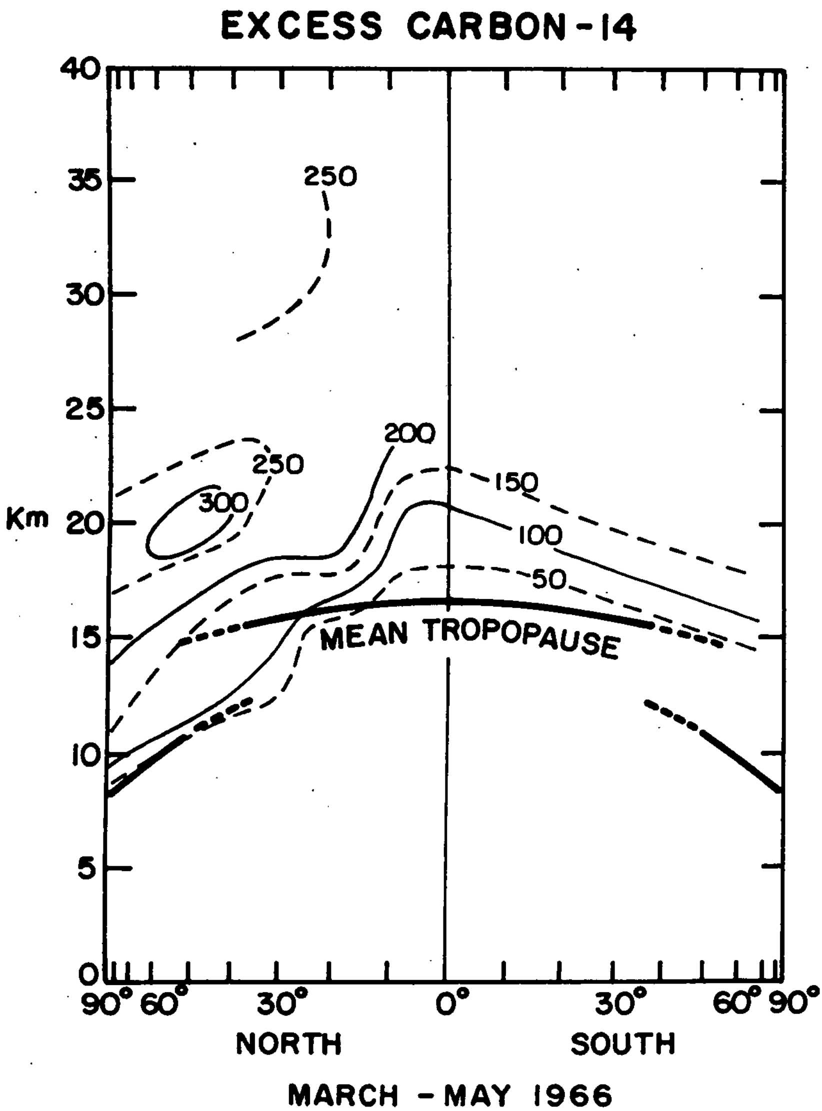
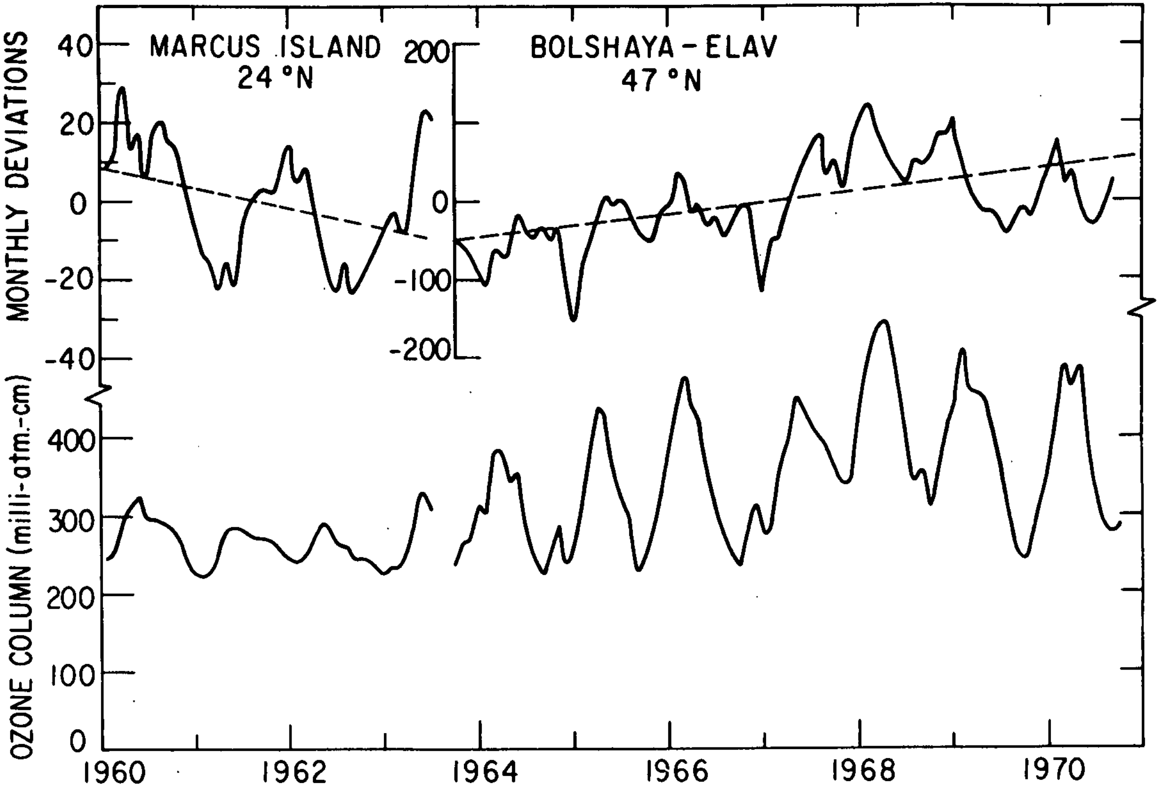

EXCESS CARBON-14
40
35
30
25
Km 20
15
10
5
0
250
200
250
150
300
100
50
MEAN TROPOPAUSE
90° 60° 30° 0° 30° 60° 90°
NORTH
SOUTH
MARCH - MAY 1966

FIGURE 7


MARCUS ISLAND
24 °N
BOLSHAYA - ELAV
47 °N
MONTHLY DEVIATIONS
OZONE COLUMN (milli-atm.-cm)
40
20
0
-20
-40
200
0
-100
-200
400
300
200
100
0
1960
1962
1964
1966
1968
1970

REFERENCES

Atmospheric Effects of Supersonic Aircraft, Australian Academy of Sciences Report Number 15, 1972.

Brewer, A. W. and Wilson, A. W., *Roy. Meteorol. Soc. Quart. Jour.*, 94, 249 (1968).

Chapman, S., *Memoirs of the Royal Meteorological Society*, 3, 103 (1930) ; *Philosophical Magazine*, 10, 369 (1930).

Crutzen, P. J., *Quarterly Journal of the Royal Meteorological Society*, 96, 320 (1970) ; Jour. Geophys. Res., 76, 7311 (1971) ; *Ambio.*, 1, 41 (1972) ; "Gas Phase Nitrogen and Methand Chemistry in the Atmosphere", Ozone Symposium, Arosa, Switzerland (1972).

Dutsch, H. U., Atmospheric Ozone and ultraviolet radiation. *World Survey of Climatology*, Vol. 4, D. F. Rex, Ed., Elsevier Publishing Company, Amsterdam-London-New York, 1969, pp. 383–432; "Chemical Reactions in the Lower and Upper Atmosphere", International Symposium, Stanford Research Institute, p. 85 (1961).

"Environmental Aspects of the Supersonic Transport", Report of the Panel on Supersonic Transport Environmental Research, U.S. Department of Commerce, 1972.

Foley, H. M. and Ruderman, M. A., "Stratospheric Nitric Oxide Production from Past Nuclear Explosions and Its Relevance to Projected SST Pollution", Paper p. 894, Institute for Defense Analyses, JASON, 400 Army-Navy Drive, Arlington, Virginia, pages 1–25, 1972.

Forney K., private communication (1972).

Glasstone, S., The Effects of Nuclear Weapons, U.S. Atomic Energy Commission, U.S. Government Printing Office, p. 486 (1964).

Hale, L. C. and Pontano, B. A., *Transactions of the American Geophysical Union*, 52, 869 (1971).

Hunt, B. G., *J. Atmospheric Sci.*, 23, 88 (1965) ; *Jour. Geophys. Res.* 71, 1385 (1966).

Johnston, H. S., "Catalytic Reduction of Stratospheric Ozone by Nitrogen Oxides", Lawrence Radiation Laboratory Report, UCRL–20568, Berkeley, California (June 1971) ; *Science*, 173 (1972) ; "Laboratory Chemical Kinetics as an Atmospheric Science", Survey Conference on Climatic Impact Assessment Program, Cambridge, Mass., Lawrence Berkeley Laboratory Report, LBL–497 (1972).

Johnston, H. S. and Whitten, G., "Instantaneous Photochemical Rates in the Global Stratosphere", Ozone Symposium, Arosa, Switzerland, 1972.

Komhyr, W. D., Barrett, E. W., Slocum, G., and Weickmann, H. K., "Atmospheric Ozone Increase during the 1960s", *Nature*, 232, 390 (1971).

McElroy, M. B. and McConnell, J. C., *J. Atmospheric Sci.*, 28, 1095 (1971).

Nicolet, M. and Vergison, E., *Aeronomica Acta*, 90 (1971).

Ozone Data for the World, Department of Transport, Meteorological Branch in Cooperation with the World Meteorological Organization. 1960–70.

Park, J. and London, J., "The Photochemical Relation Between Water Vapor and Ozone in the Stratosphere", Extended Abstract. Presented by Department of Commerce Advisory Board for SST Environmental Effects, Boulder, Colorado, Mar. 18, 1971).

Study of Critical Environmental Problems (SCEP), Man's Impact on the Global Environment (The MIT Press) Cambridge, Mass., 1970).

Technical Information for Congress, Report to the Subcommittee on Science, Research and Development of the Committee of Science and Astronautics, U.S. House of Representatives, Ninety-second Congress, U.S. Government Printing Office, "The Supersonic Transport", Ch. 3, pp. 685–748 (revised April 5, 1971).

Telegades, K., "The Seasonal Stratospheric Distribution of Cadmium-109, Plutonium-238, and Strontium-90", Health and Science Laboratory Report-184. U.S. Atomic Energy Commission, pp. 53–118, 1967; "The Seasonal Stratospheric Distribution and Inventories of Excess Carbon-14 from March 1955 to July 1969", Health and Safety Laboratory Report–243. U.S. Atomic Energy Commission, pp. 3–86, 1971.

Westenberg, A. A., *Effect of NO_x on Stratospheric Ozone*, Technical Memorandum TG1186, The Johns Hopkins University, Applied Physics Laboratory, March 1972.

APPENDIX: EXPERIMENTAL BASIS FOR CALCULATIONS OF OZONE IMBALANCE IN "PURE AIR"

According to the Chapman mechanism the differential equation for ozone formation and destruction is:

$$\frac{d([O_3]+[O])}{dt}=2j_a[O_2]-2k_e[O][O_3]$$

The steady-state concentration of oxygen atoms is

$$[O]=j_c[O_3]/k_b[M]\ [O_2]$$

Thus the differential equation takes the form

$$\frac{d([O_3]+[O]}{dt}=2j_a[O_2]-\frac{2j_c k_e[O_3]^2}{k_b[M][O_2]}$$

The rate of ozone formation is given by the rate of photolysis of molecular oxygen, and it depends on one photochemical function j_a. The rate of ozone destruction depends on j_c, k_e, and k_b. The photolysis functions j_a and j_c are determined by light intensity above the atmosphere $I_0(\lambda)$ and by the absorption cross sections for O_2 and for O_3. This appendix gives the experiment basis for each component in the calculation. Figure 8 gives a standard ozone distribution. Figure 9 gives a standard temperature distribution for the same time. Figure 10 gives the intensity of ultraviolet radiation above the atmosphere, and the heavy line shown for below the data points represents what the light intensity would have to be to give a global ozone balance with the Chapman mechanism. Figures 11 and 12 show the light-absorption cross sections of oxygen and of ozone as measured in the laboratory, and the heavy lines—far outside the range of data—again indicate what would be required to give an ozone balance with "pure air". Figures 3 and 4 give similar information for the two rate constants k_b and k_e. In all cases there is a curve, outside the data points, which represents how far one must go to obtain an ozone balance with the Chapman model.

TITLES TO FIGURES IN APPENDIX

Figure 8. Zonal average temperature °K (March 22) as a function of latitude and altitude. The tropopause is indicated by the dashed line. —90 to 0, northern hemisphere; 0 equator; 0 to +90, southern hemisphere.

Figure 9. Concentration of ozone, molecules cm^{-3}, average observations. $5(E12)=5\times10^{12}$.

Figure 10. Observed ultraviolet intensity of sunlight above the atmosphere. Heavy line, the value the intensity must have to bring agreement between ozone formation and destruction rates with the Chapman model.

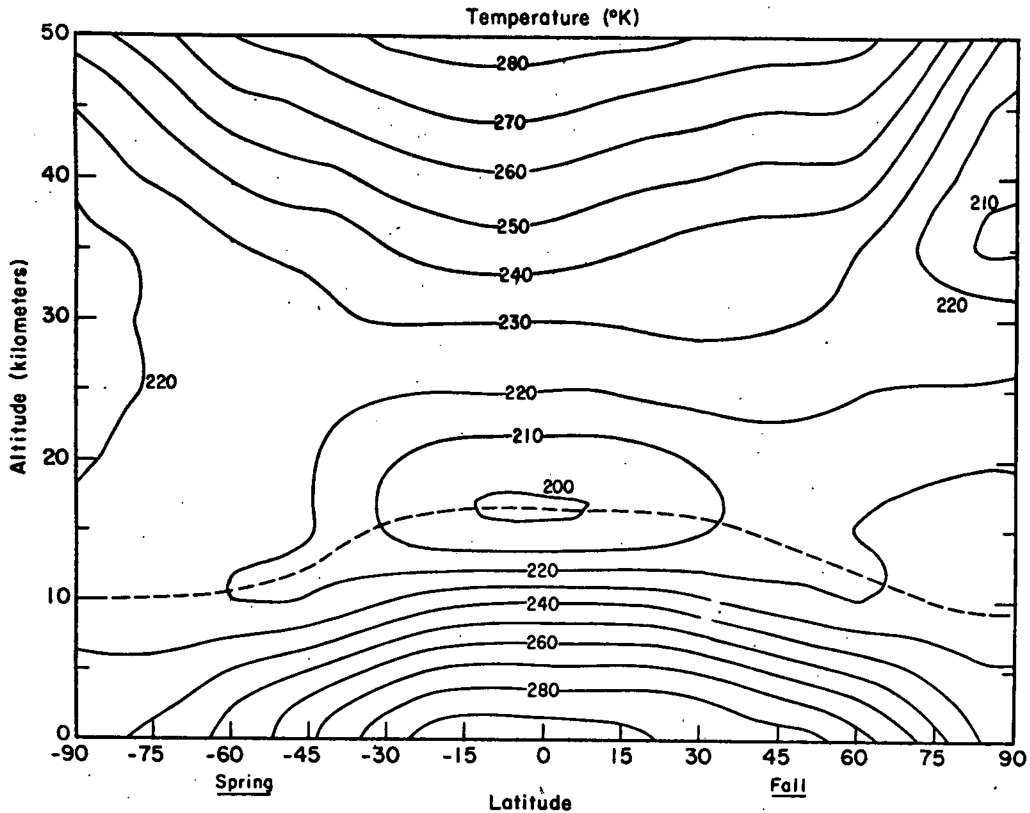
Figure 11. Ultraviolet light absorption cross section for oxygen, and curve required to reconcile Chapman mechanism with observed ozone.

Figure 12. Same as 11, for ozone.

Figure 13. Observed rate constants for reaction *b*. Heavy line, curve required to reconcile Chapman mechanism with observed ozone.

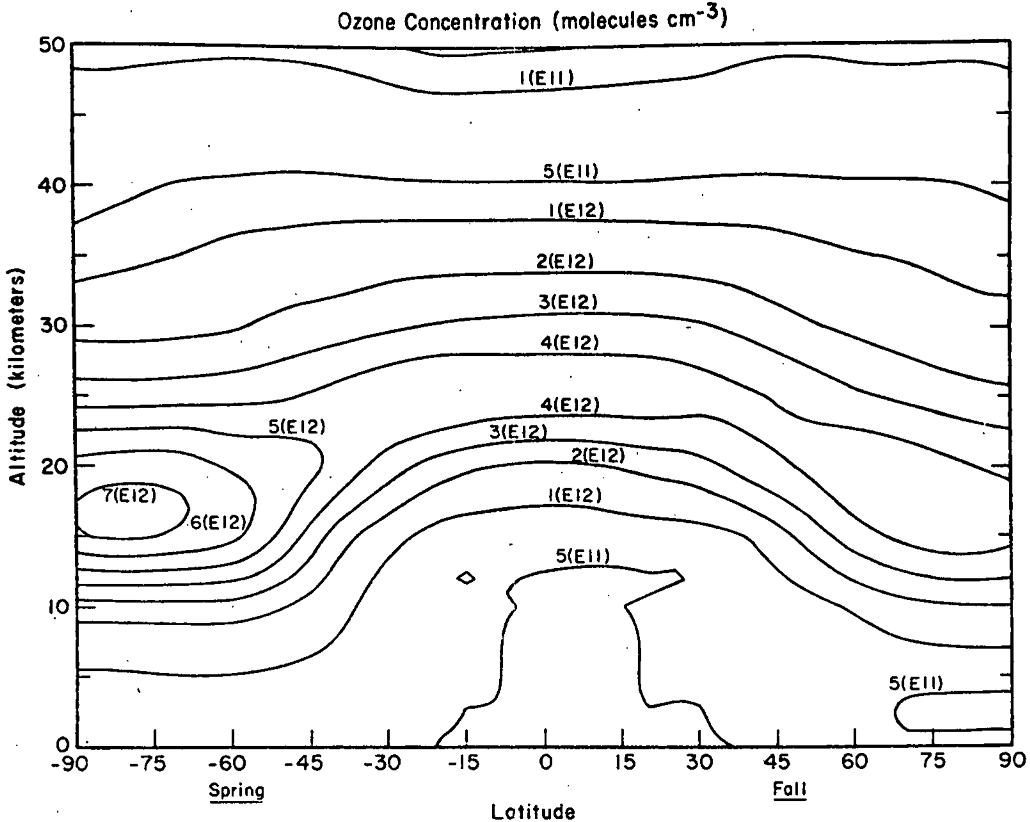
Figure 14. Same as 13, for reaction *e*.

FIGURE 8



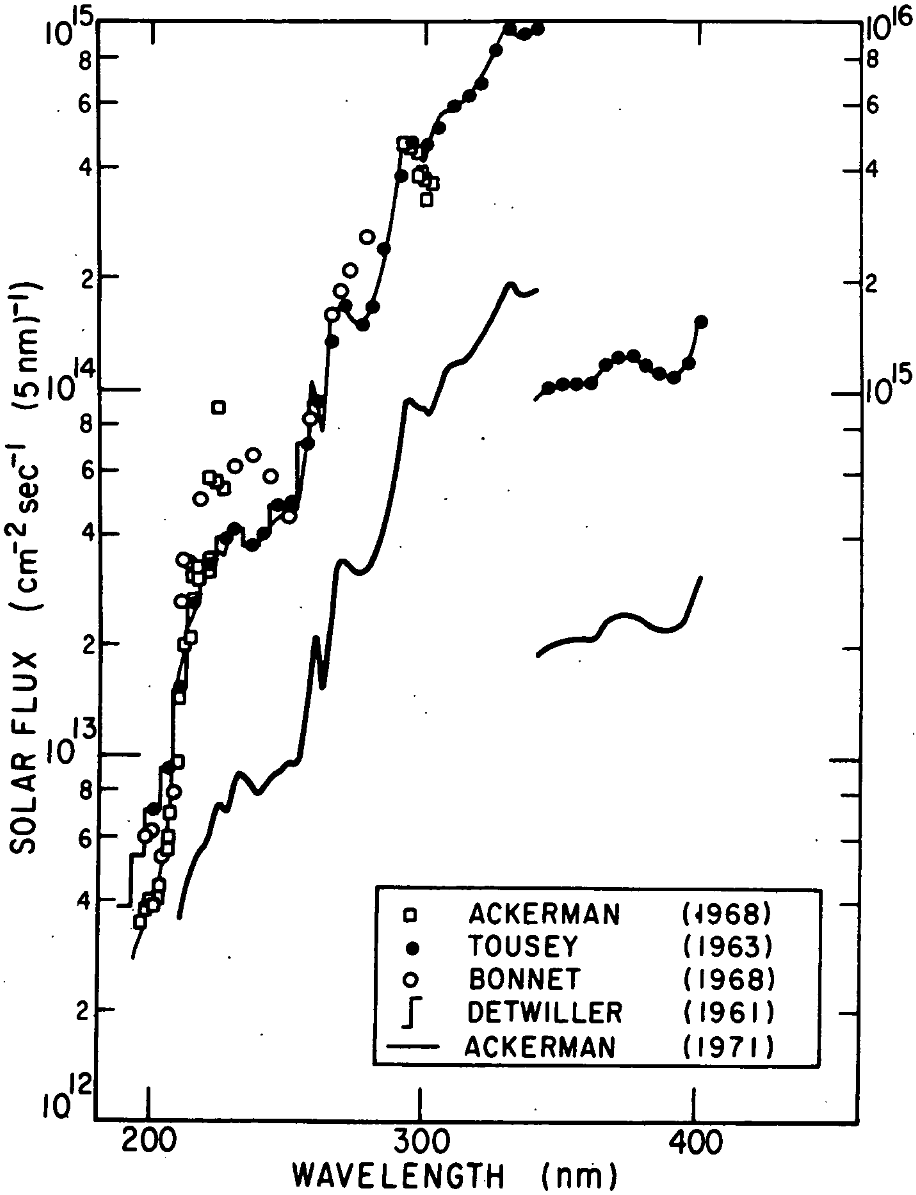
XBL 728-6736

FIGURE 9



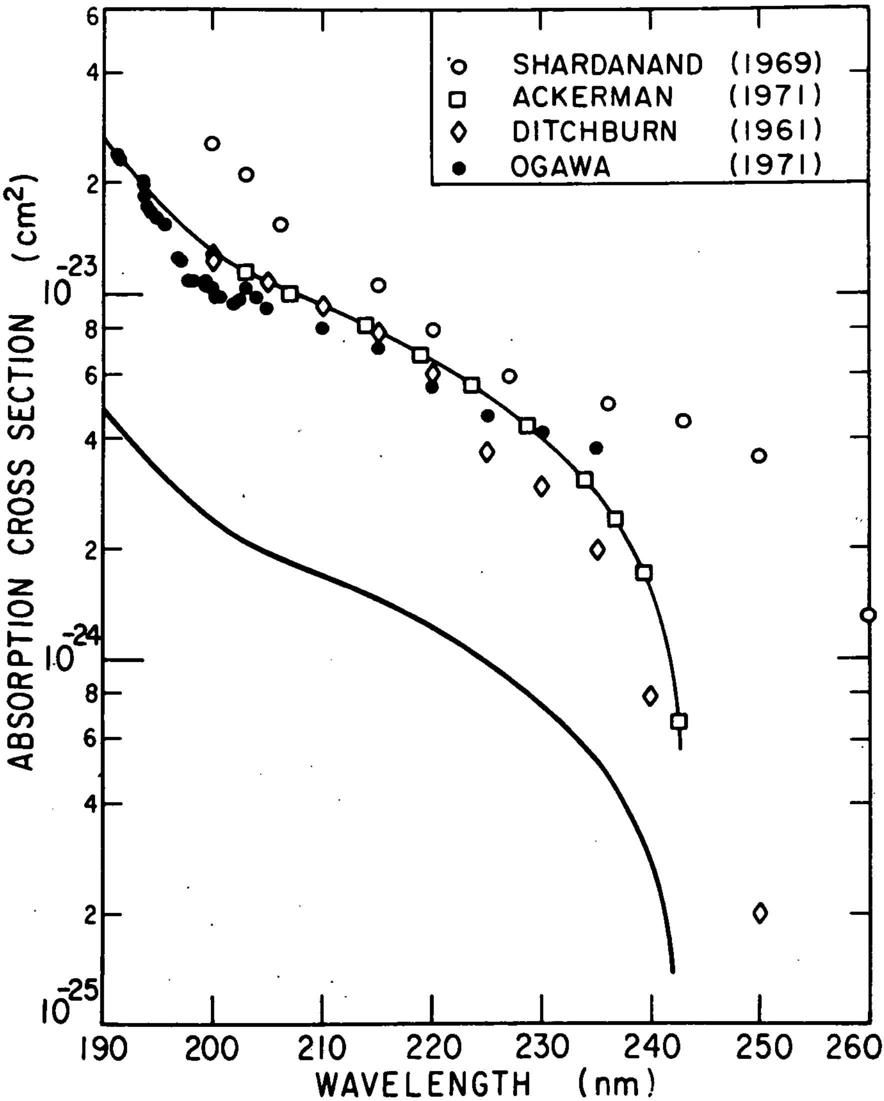
XBL 728-6735

FIGURE 10



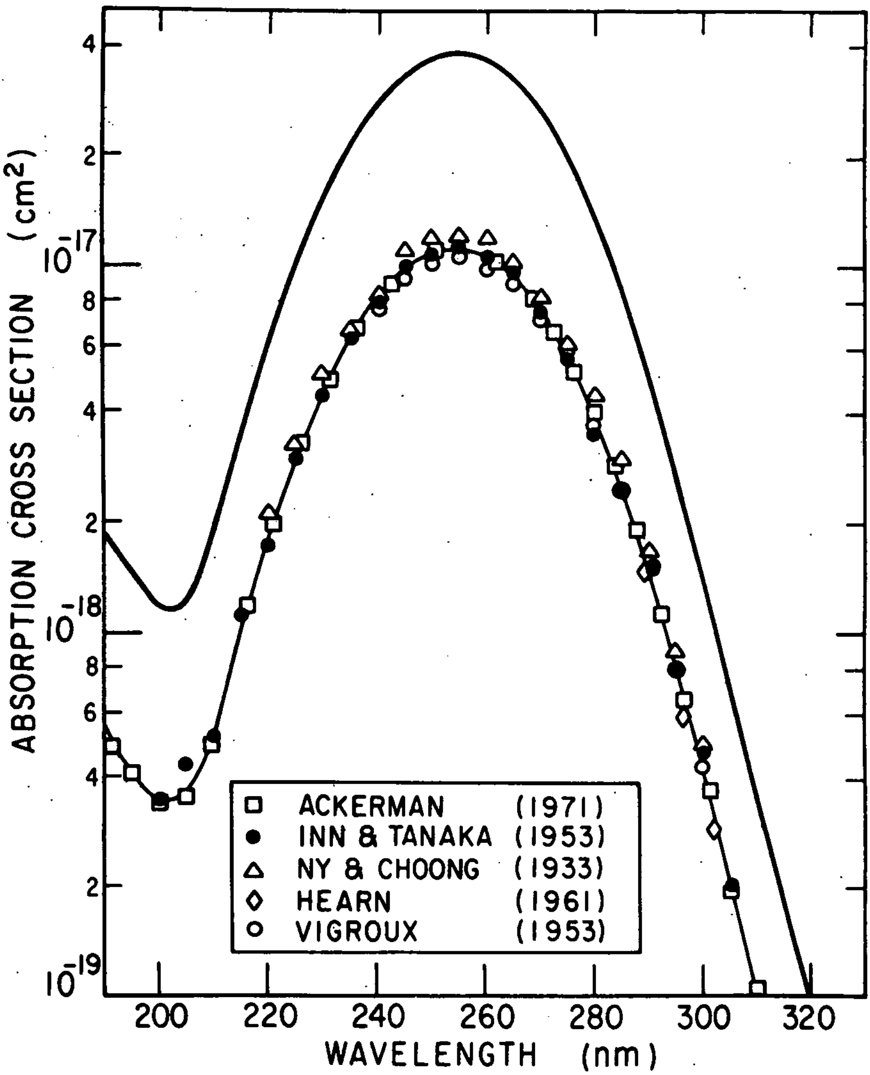
XBL 7211-7471

FIGURE 11



XBL 7211-7470

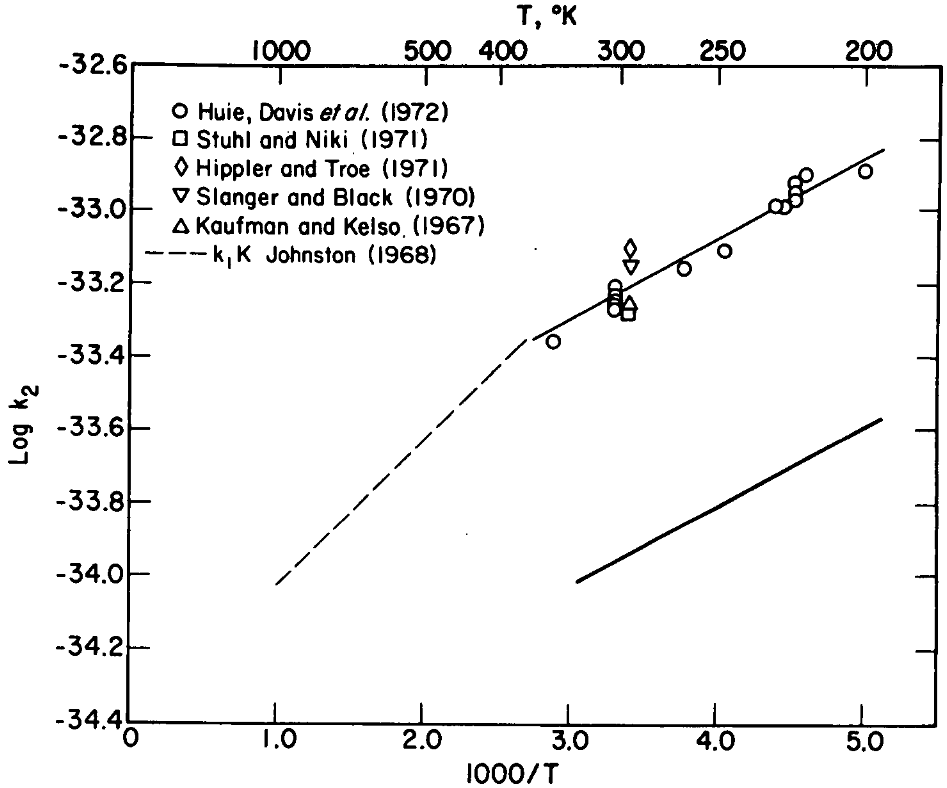
FIGURE 12



XBL 7211-7469

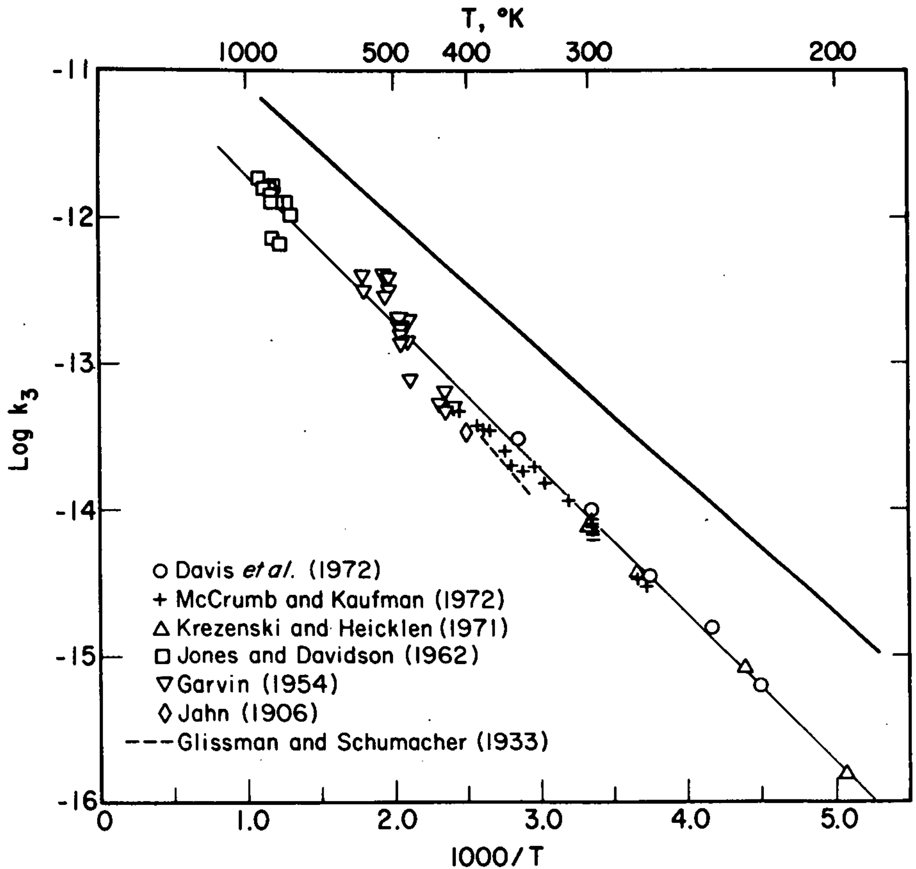
90-912 O - 73 - 9

FIGURE 13



XBL 7211-7316

FIGURE 14



XBL 7211-7311

Chairman PROXMIRE. Well, thank you, Professor Johnston, very much. This is most helpful. There have been fascinating developments. Here you bring us up to date on we did not know about, at least I was not familiar with it.

Let me clarify the import of your analysis. It was reported several weeks ago that an analysis of atmospheric data from the nuclear tests has shown no nitric oxide effect on the ozone shield, but you now reaffirm that there is such an effect. Would you repeat your basis for your assertion?

Mr. JOHNSTON. Yes, sir.

Well, in that particular report by Foley and Ruderman they looked at the same ozone data that we looked at, but they looked at a very small fraction of the data. They were looking for large, dramatic local effects whereas if they had been examining their quantities more carefully they should have been looking for relatively small long term effects.

We examined, as I said, all of the data. This had been going on for almost 9 months; we were examining these data before the Foley and Ruderman report came out.

On the basis of our examination of all the data if the data show anything, they show a decrease in ozone during the period of testing, 1960 to 1962, and an increase 1963 to 1970.

As I say, in terms of the quantities involved it was a mistake just to look for the sky falling in, a big local effect, but they should have looked for long term, somewhat smaller effects. I believe if the data show anything they show an effect of the bombs. If these are natural trends, we just do not understand them.

Chairman PROXMIRE. Is it correct to say that a fleet of 500 SST's which, I understand, would be the number necessary for an economic production run, clearly would result in a significant reduction in ozone, but that the intensity of the effect on life here on earth is still not certain?

Mr. JOHNSTON. In my articles in 1971 I estimated that the expected range of effects was reduction of ozone between 3 percent and 50 percent. That was just——

Chairman PROXMIRE. Three percent and 50 percent?

Mr. JOHNSTON. Between 3 and 50. That was my estimate then. That is a very wide range. We are still left with a very wide range every time we approach this problem.

Chairman PROXMIRE. Has it narrowed at all since then? Fifty would virtually wipe out life on earth.

Mr. JOHNSTON. Fifty would be very serious, indeed. Well, it has narrowed very much. The first line of evidence I gave——

Chairman PROXMIRE. Let me go back to that. What would a 25 or 50 percent do? As I understand it, if we had no ozone whatsoever, the ultraviolet radiation would make it impossible for any life to survive on earth except maybe in the oceans; is that right?

Mr. JOHNSTON. I am not a biologist and would not want to make so sweeping a statement. Fifty percent reduction, my biologist friends say, would be a very, very serious matter. I would not like to answer the question, there is too much involved.

Chairman PROXMIRE. Very serious matter, what does that mean? I know you are not a biologist, but do you have any opinion as a scientist as to what, when you say serious, what is going on in your mind?

Mr. JOHNSTON. Now, let me back up just a little bit. Taking the central figures presented by the Government panel in 1971, I got a 50 percent effect reduction. That is now regarded as the extreme, not the central figure, but an extreme figure, very extreme.

Chairman PROXMIRE. I understand that, I said that.

Mr. JOHNSTON. Understood.

The effects most serious to watch out for are probably plant damage in tropical regions, between 30 degrees north and 30 degrees south; the ozone shield is the thinnest there in the world. The sun is most nearly overhead. The natural variations are the least. So a large systematic reduction in ozone there, according to biologists, might cause serious damage to plants and to simple one-cell animals and things that have no natural protection procedures. I think that is one of the regions.

People who know about skin cancer continue to say there is a very serious problem here, that the kind of radiation that you let through if you reduce ozone is just that which causes skin cancer.

Chairman PROXMIRE. Well, they testified last year and it was from NIH Cancer Institutes, the outstanding people in the country——

Mr. JOHNSTON. Yes.

Chairman PROXMIRE (continuing). Came down, including the outstanding skin cancer specialist from Harvard and they testified, as I recall, that a 10 percent depletion of the ozone could have an increase in skin cancer ranging from about 10,000 new cases a year to about 50,000, is that right?

Mr. JOHNSTON. As I remember the testimony, it was 3 percent. I may be wrong here but as I remember the testimony, the testimony before your committee, was that a 3 percent reduction of ozone would increase the cases by 60,000 a year. That is my recollection of the record, I may be wrong.

Chairman PROXMIRE. At any rate—the effect then would be skin cancer, as was pointed out by the proponents of the SST, is not that fatal? That anything that has the word "cancer," we have visions of terminal illness within weeks but this is a disfiguring disease, occasionally it is fatal but it is not the terrible disease that bone cancer or stomach cancer or breast cancer would be.

But, at any rate, it is a very serious adverse effect on human life.

You talk about strong evidence that nitrogen oxides from SST exhausts could seriously reduce stratospheric ozone. If substantial amounts do take place what would this mean in terms of increassed ultraviolet radiation penetrating to the earth's surface?

Mr. JOHNSTON. Yes. You see, ozone is at present, so to speak, the space helmet for the earth that shields it against ultraviolet radiation.

Chairman PROXMIRE. It is our filter.

Mr. JOHNSTON. Our filter and, as you reduce ozone, you decrease the wavelengths of radiation that reach the surface of the earth.

Now, the effect is not as big as at first you might think. That is, if you reduced ozone by a factor of 2 the threshold is reduced from about 3,000 Angstroms to about 2,950 Angstroms, something like that, but this lets in a considerably increased biologically active component of radiation so it has the effect not of destroying the shield entirely, but it would shift it.

Chairman PROXMIRE. You say in your prepared statement that the climactic impact assessment program should be able to complete its upper atmospheric studies, and have a recommendation on the SST, by late 1974.

Last year though, Mr. Reginald Newell, I recall, when he testified before the Appropriations Committee, said it would take 8 to 10 years at a minimum to answer the ozone depletion question. What is your reaction to that?

Mr. JOHNSTON. Well, he certainly understands the atmospheric motions aspect of this problem totally better than I do.

I think there is some inclination of the atmospheric scientists to want to solve more of the problems than is absolutely necessary to get a grip on it.

Chairman PROXMIRE. I see. You think you can get a grip on it so you could have a reasonably prudent estimate by 1974, but the total comprehensive definitive finding might take a little longer?

Mr. JOHNSTON. That would be my present judgment, yes.

Chairman PROXMIRE. Now, assuming there is an ozone depletion problem with the present design of the SST, do you see any likelihood of designing an SST in the future that would overcome the ozone problem?

Mr. JOHNSTON. Well, Professor Antonio Ferri (New York University) has recently published a paper stating that the nitric oxide emissions from an SST engine could be reduced by a factor of a hundred to 400. Clearly, if you could reduce the nitric oxide emissions to zero you would eliminate the NO_x pollution problem. It would appear that a factor of a hundred to 400 is extreme, again, but there are, I believe, scientific and engineering grounds for believing that engines could be developed that could give substantially less oxides of nitrogen emissions.

Chairman PROXMIRE. Are there any indications of the economic viability of that kind of an engine? Would the fuel consumption be much greater or the other elements that might be counter-productive?

Mr. JOHNSTON. This, again, is not in my field but I can quote what I have heard other people say. As I understand it, there is room in terms of science and engineering substantially to reduce the oxides of nitrogen without substantially reducing performance, not by tinkering with present engines but by more or less starting over again.

Chairman PROXMIRE. Now you refer, I thought one of the most significant and startling elements of your presentation is in your prepared statement, the propensity of some participants in the scientific atmospheric effects to "hide the bad news."

Mr. JOHNSTON. Yes.

Chairman PROXMIRE. And you also mentioned that in your oral statement, to hide the bad news.

Mr. JOHNSTON. Yes.

Chairman PROXMIRE. Could you tally up the list of bad news that you feel is being suppressed?

Mr. JOHNSTON. In the cases I referred to, you are faced with a range, and I keep emphasizing there is a range. The effect could be as small as a few percent, it could be as large as 50 percent, and when people want to hide the bad news they only look at the low end of the range.

I would like now to say I think the press has just the opposite tendency and that is also a disservice to the total cause. They tend only to look at the upper range; they want to hang on the big numbers.

I think, to understand this thing, we really should keep before us that even now there is a range.

Chairman PROXMIRE. Depending on how the press expresses it, I think that is disservice if they simply say this is what is going to happen. But if they say this is the outside possibility, do they not perform a service in letting us know that? You gave us an outside range this morning of 50-percent depletion of the ozone, that was outside. There is nothing wrong with it as long as you say what it is.

Mr. JOHNSTON. Yes. If that is clearly stated as the extreme eventuality in terms of present knowledge and lack of knowledge, that is all right.

Chairman PROXMIRE. I think it might well be not the press but those of us who are advocates one way or the other and pick it up and say this is it—I have not read any press story that has overstated this element. Maybe there have been some. I would like to see this documented.

Mr. JOHNSTON. My impression is they continue to say that I say the SST is going to reduce ozone by a factor of 2, whereas really the statement is: Here is a range, one extreme of which is a factor of 2.

Chairman PROXMIRE. Yes.

Does that mean that is all you want to give us on the bad news being suppressed? Why do they suppress it? Because the Department of Transportation is funding it and they want an SST?

Mr. JOHNSTON. I do not say the Department of Transportation is suppressing any bad news. I think the intention there, as I say, is to come up with the scientific facts in this case. There is just—well, there is just a tremendous atmosphere of pressure on this issue.

Chairman PROXMIRE. Pressure not to disclose the bad news?

Mr. JOHNSTON. Pressure to give the desired answer; yes, not to give the bad news.

Chairman PROXMIRE. Where does that pressure come from?

Mr. JOHNSTON. Well, will you accept secondhand and thirdhand hearsay evidence?

Chairman PROXMIRE. Of course. [Laughter.] I will accept it as secondhand, thirdhand hearsay evidence, but I would like to know who the secondhand and thirdhand source is.

Mr. JOHNSTON. Yes. I have had secondhand and thirdhand hearsay evidence that, for example, the Office of Management and Budget tells agencies that their budget will suffer if they do not give the right answer on this SST problem.

Chairman PROXMIRE. You have heard that?

Mr. JOHNSTON. Twice.

Chairman PROXMIRE. Twice?

Mr. JOHNSTON. From two different sources.

Chairman PROXMIRE. What is the right answer, in favor of it?

Mr. JOHNSTON. Favor of SST, yes.

Chairman PROXMIRE. Have you heard that this year?

Mr. JOHNSTON. Yes, sir.

Chairman PROXMIRE. Since the SST was killed by the Congress?

Mr. JOHNSTON. Yes, all this in recent times, this year.

Chairman PROXMIRE. Their budget would suffer if they came up with answers that are adverse to the SST.

Mr. JOHNSTON. Yes.

Chairman PROXMIRE. Can you tell us a little more about this?

Mr. JOHNSTON. Well, how much would you like to know?

Chairman PROXMIRE. I would like to know who your source is, secondhand and thirdhand.

Mr. JOHNSTON. Well, it would be embarrassing to certain people, I guess, if I called them by name.

Chairman PROXMIRE. That is the mission of this committee.

Mr. JOHNSTON. I beg your pardon?

Chairman PROXMIRE. That is the mission of this committee, to be embarrassing to people. I do not mean that in a cruel way. I meant that to say our job is to get whatever the facts are and disclose them. We are a fact-finding committee.

Mr. JOHNSTON. At a meeting of the CODATA—I am not sure what all the letters stand for—panel last July a number of people were talking and they were joking, and it was a fairly grim joke. The people were from the National Bureau of Standards. I do not remember the names, but I could look up the record and trace it. They were saying that as they were presenting their budget proposals for next year they pointed out they were capable of developing information pertinent to the SST problem. The budget hearing officer said words to the effect: "If you want this to have a favorable impact on your budget, you see to it that the information is in favor of the SST."

These are surely not the direct words but the sense of the words.

Chairman PROXMIRE. Who said that?

Mr. JOHNSTON. The budget officer.

Chairman PROXMIRE. The budget officer?

Mr. JOHNSTON. Yes.

Chairman PROXMIRE. Can you identify him?

Mr. JOHNSTON. No, oh, no. I could not possibly.

Chairman PROXMIRE. You cannot?

Mr. JOHNSTON. I do not know who it was.

Chairman PROXMIRE. You do not know?

Mr. JOHNSTON. I never heard a name.

Chairman PROXMIRE. But you can identify the people who told you this?

Mr. JOHNSTON. I can identify the group of people, the attendees of the meeting.

Chairman PROXMIRE. Would you do that for us? I do not mean right now, I mean get it as soon as you can.

Mr. JOHNSTON. Yes.

Chairman PROXMIRE. We would like to follow up on that.

Mr. JOHNSTON. The statement he made, one statement the budget officer made, was, "We on this subject have the same policy as the ancient kings," I forget whether it was Persia or Greece or wherever, "as the ancient kings who killed the messenger who brought bad news." It was a figure of speech. They were joking about this; it was a very grim joke.

Chairman PROXMIRE. They did not mean they killed them, they killed the program, cutoff their funds which is the modern-day equivalent of cutting out your tongue if you bring bad news.

Mr. JOHNSTON. Yes.

Chairman PROXMIRE. Very, very interesting and very helpful to know that. What approximate time was that?

Mr. JOHNSTON. That was last July.

Chairman PROXMIRE. Last July.

Do you know, what is your knowledge, to the extent that you have any, of the attitude of the administration toward pushing the SST? You indicate there is a desirability of getting good information or favorable information, favorable to the SST development. Do you have any information on timing when they would like to proceed with it?

Mr. JOHNSTON. No.

Chairman PROXMIRE. Put funds into the budget, that kind of thing.

Mr. JOHNSTON. No; I know nothing except what I hear from the papers and questions I get—I had a long talk with the correspondent from the Wall Street Journal, who told me a number of things that Mr. Magruder said that were not in the first article—sort of background information. I think in the Government there are many different points of view.

Chairman PROXMIRE. May I say at this point, I am glad you referred to that Wall Street Journal article. Frankly, that is one of the major reasons why these hearings are being held, a responsible article and thoroughly reported and, without objection, that article will be put in full in the record.

(The article referred to follows:)

[From the Wall Street Journal, Nov. 1, 1972]

TRY, TRY AGAIN—DIE-HARD SUPPORTERS OF SUPERSONIC AIRLINER PLOT TO REVIVE PROJECT: OFFICIALS OF BOEING, FAA SAY THEY HAVE NIXON'S BACKING, FORESEE VICTORY THIS TIME; AIMING FOR NEXT GENERATION

(By Albert R. Karr, Staff Reporter)

WASHINGTON.—America's supersonic transport plane, shot down by Congress early last year, is a dead bird. Or is it?

Die-hard supporters of the project, still refusing to admit defeat, are beginning to try to resurrect the supposed corpse. They include not only such enthusiasts as Boeing Co. Chairman T. A. Wilson and Federal Aviation Administrator John Shaffer but also President Nixon's top domestic adviser, John Ehrlichman. They claim the backing of the President himself, they're talking of serious revival moves next year, and they seem confident of ultimate success.

These prophets say that current research is leading toward development of a new and better "second-generation" supersonic—one that would be quieter, carry bigger loads, fly longer distances and make better economic sense than the downed Boeing version. By the mid-1980's, the proponents say, such a plane may take to the air.

"The SST will come back," insists Boeing's Mr. Wilson; Mr. Nixon's expected reelection would assure a revival move, he feels. Aviation Administrator Shaffer has predicted such an effort "in the first year of President Nixon's second term," and Mr. Ehrlichman, who maintains "the SST isn't dead," recently told a group in his and Boeing's home town of Seattle that "planning or start-up" money might be included in next January's budget, "so we don't completely lose momentum."

FOES ARE READY AT BARRICADES

Any such proposal would seem to defy the expressed will of the current Congress, and the SST's foes are ready to man the barricades again if necessary. "We don't think it's any better an idea than it was before," says Robert Gallamore, policy development director for Common Cause, the public-interest group that helped knock down the project last year. "It isn't one of the better things we ought to be putting our money into."

With big budget deficits still looming ahead, Congress could well balk at the potentially higher price tag for a new SST. One proponent warns that the government might wind up having to underwrite much of a $5.5 billion program; its share of the defunct SST was reckoned at $1.2 billion.

But the backers contend they can overcome the opposition on the next go-round by meeting many of the original objections. Though little can be done about the familiar drawback of sonic boom, researchers are closing in on the problems of engine noise, pollution and shaky economic potential. In the fiscal year ending next June, the National Aeronautics and Space Administration is devoting $11 million to work on a new engine and redesigned structure, and to research on the effect of SST emissions on the upper atmosphere; last year's outlay was only $1.5 million.

In particular, NASA is trying to develop a lighter-weight, "variable-cycle" engine; it would operate quietly, though rather inefficiently, around airports, then switch over to efficient operation at altitudes where the noise wouldn't bother anyone. The dual-cycle engine could save 40,000 pounds, or 15%, of the fuel needed for an Atlantic crossing, by one estimate.

IS CONGRESS WILLING?

With such possibilities in sight, administration strategists maintain the next Congress will take a kindlier view of the SST than did its predecessor.

"Congress would very much like to get into an SST program if it can be shown that the airplane is economically viable and the ecological issues can be settled," one official contends. "The favorable impact of an SST on our balance of trade and on jobs here at home is recognized much more now."

Up to now, asking for new SST support from Congress would have prompted the Democrats to put it at "the top of the list for wasteful spending," says William Magruder, who headed the defunct SST project and now is a White House consultant on technology. But in the cooler post-election atmosphere, Congress may be more receptive to an administration request, he reasons.

The revivalists will point to the British-French supersonic Concorde, whose prototypes now are flying, as a threat to capture the world SST market. They admit the Concorde's first version has encountered plenty of problems but predict that an improved second version will be a much fiercer competitor for supremacy on the international airways. The Russian TU–144, though trailing the Concorde in the supersonic development race, could also capture the fancy of some airline buyers.

"I should imagine the U.S. wouldn't want to let other nations do this (sell an SST) alone," says Transportation Secretary John A. Volpe.

There's little doubt that President Nixon still feels the U.S. should have an entry in the race. Last year, after Congress had refused to vote funds to continue development of two SST prototypes, Mr. Nixon inspected a Concorde when on a visit to the Azores; he said he wished the U.S. had its own supersonic and predicted that some day it would.

ADDING TO THE "FAMILY"

SST revival could be part of a coming administration effort to assist the troubled aerospace industry by financing new aircraft construction. A broad program to help preserve the U.S. lead in world aircraft sales is being advocated by some administration men, including Mr. Magruder.

He says the administration now is unified on the need to do something more about the U.S. balance-of-trade deficit; in the first three quarters of 1972 it approached $4.9 billion, up from $2 billion in all of 1971. Aircraft exports have been the biggest plus on the trade ledger, and that must be preserved, Mr. Magruder contends. But to sell successfully, he concludes, the U.S. needs a whole "family of airplanes" including an SST.

To help hatch a new version, NASA's "advanced supersonic technology" work may well be expanded beyond the current $11 million rate. That figure was assigned by the White House without any NASA request; the agency itself is seeking a larger sum for next fiscal year. While insisting that no commitment to SST development has been made, George W. Cherry, a deputy associate administrator of NASA, says "this is a program that is a necessary prerequisite to development."

Much of the NASA work focuses on the SST engine, because the original power plant, built by General Electric Co. was noisy—and generated both environmental and economic problems. Boeing was forced to install noise suppressors to quiet the roar; that boosted the plane's weight, reduced its range and payload, and hurt its market potential, in the view of many airline executives. (One terms the Boeing SST "as economic abort.") Now the optimists see possible salvation in the dual-cycle engine.

NASA's work also is aimed at determining whether nitric oxide emissions from an SST fleet would damage the earth-protecting ozone shield in the upper atmosphere. Opponents of the plane have warned that such damage would lead to severe temperature changes on earth, plus eye injuries and increased skin-cancer hazard from overdoses of radiation. "To get a U.S. SST flying, you're going to have to settle this question once and for all," says Mr. Cherry.

Much money is being spent for such environmental studies. Mr. Magruder says, "to get from being 95% sure (as he says he is of the environmental safety of the SST) to as close to 100% as we can get."

The government has even handed part of the environmental assignment to a known critic of the project. A $400,000 contract has gone to Harold Johnston, a University of California chemistry professor who has written papers implying that an SST fleet would damage the ozone shield. "Johnston has been a critic, so we gave him the money, and he's going to find out what the answers are," Mr. Magruder says.

Meanwhile, the Transportation Department has kept Boeing working on seven different projects, including noise reduction, which grew out of the SST program; officials say the goal is merely to aid aviation in general. (Boeing has "dozens of workers" researching the possibility of an American SST, according to Chairman Wilson.) The department also delayed sale of Boeing's SST mockup for a year, partly for such work and partly, according to Federal Aviation Administration officials, because of prospects for reviving the SST sometime.

Administration planners stress there's no need to move quickly on new SST development, if and when it's decided to do so. The Concorde, the big competitive threat for the future, now has more severe problems than did the Boeing SST, according to these analysts. They say it's noisy, possibly polluting, lacks adequate range and carrying capacity, and altogether isn't too attractive to the airlines. Pan American Airways has been indicating it might not exercise its option to buy the Concorde, and United Air Lines has already dropped its option.

The Concorde's range now is such that there are doubts about its ability to cross the Atlantic with a decent complement of passengers. The FAA has even been toying with the idea of letting the Concorde have first priority to land at, say, New York's Kennedy airport, so it wouldn't run out of fuel while stacked up waiting to come down.

Sources add that Congress may well ban the first-generation Concorde from U.S. airports because of its noise, though a proposal to do so lost out in the closing days of the recently adjourned Congress. "The Concorde is going to be the biggest turkey ever to come along," declares a Senate Commerce Committee aide.

Nevertheless, administration officials warn that the Europeans are already at work on a much-improved second-generation Concorde. So, they say, there isn't much time for the U.S. to get going on a rival version.

Unless the schedule can somehow be accelerated by heavier spending on research, says NASA's Mr. Cherry, it would probably be 1975 before preliminary design by manufacturers could begin and 1985 before a commercial SST could actually rumble down the runway.

"This program can't be delayed too much," he says, "there's definitely an urgency if we're going to compete. The first generation SST is here today, and it's European. They have technology base, and they're going to be able to provide a better SST."

But the obstacles facing a revived American SST are more than technological. Administration men say a new kind of financing arrangement would be necessary; neither aircraft manufacturers nor airlines were happy with the old one. Mr. Magruder argues that it must be more difficult for the government to "default" on its commitment, as he says Congress did by killing the SST. He contends the government would have to help support at least prototype work, subsequent development, aircraft certification and initial production tooling—all of which produces the $5.5 billion cost estimate.

And that could be one of the points on which Congress might boggle, leaving the American SST still a dead bird.

Mr. Johnston. Well, as I said, there was a second case of pressure to hide the bad news. Another agency was having a discussion with the budget officer. They had made a detailed study of my reports, and they were asked, "What is your finding?" The Government worker said in effect: "We tend to agree, not in every detail but we tend to agree, with the basic case Johnston made," and the budget officer said in effect: "If you come out with that, that will be very hard on your budget next year."

Chairman PROXMIRE. What agency was that?

Mr. JOHNSTON. Here I know the name of the individual—which I could give that to you privately or do you want that now?

Chairman PROXMIRE. I would like that publicly.

Mr. JOHNSTON. All right, Mr. John Baldeschwieler. This is third-hand information, I did not hear him say this but I heard someone else say he said it.

Chairman PROXMIRE. I understand that this man in the agency agreed with your findings, he was told if he reported he agreed that the budget would be reduced?

Mr. JOHNSTON. That was my understanding, and that I heard only 2 or 3 weeks ago.

Chairman PROXMIRE. You do not know the name of the agency, you have given us the man.

Mr. JOHNSTON. I think it is the Office of Science and Technology.

Chairman PROXMIRE. All right, we will find out.

One of the reasons I am pursuing this is because we did invite the Department of Transportation to appear, we did invite the CAB and the FAA to appear, and they refused to do so and, as a matter of fact, the FAA and the Department of Transportation promised they would until 24 hours before they were to appear. Tuesday they told us they would not appear on Wednesday. So, apparently there is this great pressure within the administration not to take any chances on disclosing any information that might be damaging to the SST and if they had to appear and be cross-examined perhaps they feel they might disclose something damaging. And what you have told us this morning confirms that.

Do you think we should delay certification of the Concorde pending the outcome of the CIAP project, or does the small number of planes apparently involved make this unnecessary?

Mr. JOHNSTON. I think a small number, nine or so——

Chairman PROXMIRE. The reason I say "delay the certification of the Concorde" is once we take that step and certify any number of SST's we may be taking a step very hard to reverse but, at the same time, it may very well be that nine would not have any effect and also, as you point out, the Concorde is far less of a polluting plane than the larger SST—U.S. SST—version.

Mr. JOHNSTON. I am very much a specialist in this field and have no statement on policy matters. However, the nine Concordes would have very little effect on the earth's ozone shield, I am convinced of that.

Chairman PROXMIRE. I want to make sure I understand, when you said "bad news is being suppressed," does this tendency also affect the information available from the CIAP project?

Mr. JOHNSTON. It does not, I believe. That is wide open.

Chairman PROXMIRE. I am glad you made that clear.

Mr. JOHNSTON. No, I would like to emphasize that.

Chairman PROXMIRE. Does the CIAP project have any important applications other than to supersonic travel?

Mr. JOHNSTON. Well, historically—the stratosphere has been bypassed. People, of course, are very interested in the troposphere, that is where we are and where our weather is. They are interested in the ionosphere above the stratosphere because of communication. But, there is a very great gap in data on the stratosphere, so I think anything and everything obtained, information of the stratosphere, will be potentially useful.

Chairman PROXMIRE. Can you just quickly tell us in what other areas it will be useful besides the SST? Space?

Mr. JOHNSTON. Well, all forms of transportation up and through the stratosphere. Here you have a region of the earth neglected scientifically and it is really almost impossible to say what the practical applications might be of research in the area. I feel, we should have information, further information on it.

As we got into this problem, we found we just did not know the present amount of oxides of nitrogen in the stratosphere. There were more unknowns than knowns in the stratosphere. A great deal should be found out about this neglected area, whether you can say what the use will be or not.

Chairman PROXMIRE. What sort of follow-on research might be contemplated?

Mr. JOHNSTON. I would hope that after this 3-year crash program is mature and the end is in sight that some agency, perhaps the National Science Foundation, would support the long-range research, the sort of thing that really will take 8 or 10 years to get answers. This would be my general hope on the subject.

Chairman PROXMIRE. Very good. Thank you, your testimony has been important. Once again I understand you come not as an advocate or opponent of the SST but just accommodating the committee by appearing.

Now, I would like to ask our two next witnesses to appear as a panel. We are fortunate to have two important conservationists and environmentalists who are the leading movers and shakers in the drive to keep this planet as unpolluted as possible. Gary A. Soucie, president of the Environmental Policy Center, and David A. Brower, president of the Friends of the Earth.

We are delighted to have you gentlemen here this morning, and, as you know the committee rules, you each deliver your statement of 10 minutes and then we will proceed to questions.

STATEMENT OF GARY A. SOUCIE, PRESIDENT, ENVIRONMENTAL POLICY CENTER, WASHINGTON, D.C.

Mr. SOUCIE. As my voice is likely to fail first I will go first. I am suffering from a New England winter cold, Mr. Chairman.

My name is Gary A. Soucie, I am a free-lance writer on environmental affairs and president of the Environmental Policy Center.

During 1970–71 I served as chairman of the Coalition Against the SST. During the same time period I served as executive director of Friends of the Earth and as an adviser to the noise committee of the President's Aviation Advisory Commission. Because of my involvement in numerous environmental issues involving aviation, I have participated as panelist or speaker in many Federal Aviation, Department of Transportation, and aviation industry meetings, and was coordinator of one of the general sessions of the Conference on Aircraft and the Environment sponsored last year by DOT and the Society of Automotive Engineers. Prior to becoming a professional environmentalist in 1967 I was employed as a writer and public relations officer by an international airlines (Swissair).

I am pleased the subcommittee has given us this opportunity to reiterate the grave concern and adamant opposition of the environmental community regarding Government support, by any means and under any guise, of a supersonic transport plane. Candidly, I am shocked that the rumors emanating lately from the White House, DOT, CAB, and other sources have made this hearing necessary. One hopes that the rumors are unfounded and that the administration is not seriously considering flouting Congress, the public, and commonsense by reviving the SST. Especially after so indecently brief a time.

In the chorus of support for an American SST one hears two dominant themes: (1) that the U.S. needs to play catch-up ball to overcome the British, French, and Russian lead in SST development, otherwise our aviation industry will not be able to compete in the world market, and (2) that supersonic civil air transportation is inevitable. Both views are based on faulty premises and ignore a rather large number of variables and even imponderables. The first presupposes the commercial success and societal acceptability of the Concorde or the Tupolev 144, presuppositions that simply are not warranted by the evidence; the second fails to consider the new rules of the ball game imposed by the constraints of environmental considerations and social priorities. Supersonic air transport will come when, and if, the right answers to a great many questions are found.

Whether the Concorde or TU–144 are viable aircraft in any meaningful sense has not been demonstrated. So little information is available about the Russian plane that it is impossible for anyone to make any assessment with reasonable certainty. But the few rumors leaking out of the Soviet Union are mostly negative and the shreds of available circumstantial evidence seem to confirm the rumors. As for the Concorde, things do not look much rosier.

Deadlines have come and gone and the only orders in hand are from the captive customers at Air France and BOAC. Iran and China have signed letters of intent that commit them to nothing. At least four airlines with options on delivery positions—Air Canada, Qantas, Sabena, and United—have dropped them. Still other airlines have announced their decisions not to purchase the Concorde. Lufthansa's chief executive has branded the first-edition Concorde as "economically not worth discussing." Several nations, including some whose territory underlies crucial air transport routes, have legislated against supersonic overflight.

Last May, in a story filed from Toulouse, France, the San Francisco Chronicle described the Concorde as "the wrong plane, of the wrong size and performance, arriving at the wrong moment in history." This does not exactly sound like the kind of competition that is going to topple the U.S. aviation industry from its global preeminence.

The British and the French have beaten us to the punch before, and in neither case was the punch a haymaker, nor did our aviation industry turn out to have a glass jaw. The British DeHavilland Comet was the world's first commercial jet airliner and it was the same kind of premature turkey the Concorde is looking to be. The French Caravelle was a good airplane and the first short-range jet transport but the edge enjoyed by the French aviation industry was short-lived; Caravelles are rather scarce these days, but you see a lot of McDonnell-Douglas DC–9's and Boeing 737's at the world's airports.

The Concorde's noise alone is probably enough to keep it from ever being truly successful, and noise is not the Concorde's only problem by any means. Just how noisy Concorde is depends on which week's BAC or Aerospatiale press release one reads. The dean of the faculty of medicine at the University of Toulouse, Professor Calvet, has measured the Concorde's community noise at 135 decibels. That makes the Concorde about six times as noisy as a Boeing 747, an aircraft that can carry four to six times as many passengers. Another, unpopular, way to compare the Concorde and the 747 is to refer the subcommittee back to Mr. Richard Garwin's calculation that an SST would make as much noise as 50 subsonic jets operating at the same time.

Concorde's manufactures admit their prototype is noisy, but they assure us the production version wil be no noisier than the majority of the large jet transports currently in operation. That is no consolation at all. The majority of large jet transports in operation are the Boeing 707's and DC–8's whose JT3D engines are responsible for most of the airport racket that has the public up in arms and the future of commercial aviation in jeopardy. The whole noise abatement strategy of the aviation community hangs on phasing out these noisy 4-engine jets and replacing them with the quieter DC–10's, L–1011's, and late model 747's. If the production Concorde is only as noisy as the 707 (and that is a promise, not a reality) the situation will actually be worse than at present. Consider that the Concorde is smaller than either the 707 or DC–8, so to carry as many passengers it will have to make more flights, and that means more takeoffs and landings, and more noise.

Parenthetically, I would like to say I spent part of yesterday talking on the telephone with various people at DOT. Charles Foster, who is head of DOT's Noise Abatement Office, told me the FAA is now leaning toward the retrofit of silencers on the DC–8's, 707's, and 737's and if this retrofit program is carried out that means the Concorde, if it is introduced, would be that much noisier than the world's noisiest subsonic airplanes.

Airport and aircraft noise is a serious problem. We know that exposure to excessive noise can be annoying, sleep-disturbing, efficiency-robbing, and damaging to the hearing. A few years ago a British study showed that admissions to mental institutions were higher than average in areas near large airports. The November 29, 1971, issue of the Journal of the American Medical Association carried an article that said:

> In the London area mortality from multiple sclerosis was high in those western boroughs and adjacent counties, most exposed to the noise of aircraft using the airports of London. The geographical pattern in England suggests that noise and vibration of particular kinds may be a factor in causation along with a climatic factor.

Last year a report by three University of Georgia scientists in the Environmental Mutagen Society newsletter showed that exposure of plants and animals to noise can cause sterility and chromosomal aberrations and augment the effects of X-rays and radiomimetic chemical mutagens, with attendant increases in lesions, tumors, seizures, and other physiological and teratogenic consequences.

At the world environment conference in Stockholm last summer, a World Health Organization report called noise "the curse of modern times and a major environmental problem," and listed noise as the cause of one-third of all neurosis cases and one-fifth of all headaches.

Aircraft noise cannot be blamed for all those neuroses and headaches, of course, but millions of people around airports are exposed to excessive intolerable noise. Professor William C. Meacham of UCLA's School of Engineering has estimated that about one million Los Angeles area residents are exposed daily to jet aircraft noises five to ten times greater than normal background sound levels. As air traffic increases, the situation will worsen at Los Angeles and other noise-impacted areas, unless we can get quieter planes carrying more passengers per flight. Should Concorde surmount all of its other obstacles—and fortunately that is not likely—it will aggravate rather than alleviate this noise problem.

The Federal Aviation Administration has not yet issued its noise standards for supersonic aircraft—and again, parenthetically, I was told by FAA that they are iminent—and our environmental and public health needs require that these standards be at least as stringent as the relatively lenient subsonic standards. Environmentalists are not alone in this appeal.

The more thoughtful members of the aviation community see that some significant achievements in airport noise reduction are necessary in short order, unless commercial aviation in this country is to founder. Last July, speaking at a transportation engineering conference in Milwaukee, Neal Montanus, director of aviation for the Port Authority of New York and New Jersey, pointed out that:

> A critically important element in commitment to noise reduction is the requirement that Part 36 standards apply to all aircraft, including supersonics, lest the door be left open to further derogation of the noise environment.

Using existing technology, reducing jet engine noise extracts heavy penalties in the areas of range, payload, or fuel consumption. Concorde does not have any of these to spare, so it is unlikely the plane is going to be any quieter than FAA requires it to be. Supersonic flight requires a prodigious fuel consumption and if we are to believe the energy-crisis propagandists' threat of brownouts, blackouts, industry shut-downs, fuelless winters, and national insecurity, iti s a mystery how we can afford even to think about SST's. NASA has on the drawing boards a "quiet" SST engine that it claims will also reduce fuel consumption by 15 percent over earlier designs like the GE engine that was to have powered the aborted Boeing SST.

However, that still would leave an SST burning about one-third more fuel per passenger-mile than a 747. Last fall the Organization for Economic Cooperation and Development issued a transportation study that showed that rail transport needs to be given much more emphasis, if only to help push back the coming energy crunch. According to the OECD report, automobiles use three times as many British thermal units per passenger-mile as trains, and aircraft—today's subsonic aircraft—use six times as many Btu's.

Chairman PROXMIRE. That is per passenger-mile?

Mr. SOUCIE. Yes, per passenger-mile.

In any rational system of social priorities, a supersonic transport surely must rank lower than a great many other unfunded and underfunded programs. In the air transport field alone, the Office of Management and Budget has impounded most of the funds appropriated by Congress for relatively small programs to deal with airport congestion and aircraft noise. Our air traffic control system is in woeful need of modernization. Why introduce SST's with marginal fuel reserves into a traffic system that has not been revamped much since the days of the DC–3's and Connies? The July 17 issue of Aviation Dailv contained a succinct reminder of our needs in this area:

As an example of how far the FAA must go to catch up with modern technology, the agency is still the world's largest buyer of vacuum tubes, although almost all electronic equipment for the past ten years has been produced with solid-state power systems.

If the Government is so terribly anxious to spend a few billions of dollars on aviation, there are plenty of places to spend it—on air traffic control facilities, on enabling the airlines to phase out the 707's and DC–8's and replace them with cleaner, quieter, more efficient aircraft, on developing even cleaner and quieter engines, on means to effectively prevent hijackings, on decent ground transportation so the air traveler can get more quickly from city to city rather than just from airport to airport.

The SST is an idea whose time simply has not yet come.

Mr. Chairman, if you will permit, I would like to submit an article which I just discovered this morning from the September 29 issue of Science magazine. It is called Public Interest Science, and it is an article about misrepresentation of scientific and technical data in the political process. The SST controversy is one of the examples used by the authors and, I must say, the scientific evidence presented by our side comes out smelling much better than that presented by the other side, so I would like to submit it.

Chairman PROXMIRE. Fine. We would like to have it, and it is relatively brief apparently, so we will put it in the record. Thank you very much, Mr. Soucie.

(The article referred to follows:)

[From Science magazine, Sept. 29, 1972]

PUBLIC INTEREST SCIENCE—THE GOVERNMENTAL AND PUBLIC ADVISORY ACTIVITIES OF SCIENTISTS HAVE GREAT POLITICAL IMPACT

(By Frank von Hippel and Joel Primack[1])

Although scientists as technical experts make important contributions to the federal policy-making process for technology, that process remains basically political. At present, the primary recipient of technical advice on matters of public policy is the executive branch of the federal government. To the extent that this arrangement results in an informed executive branch dealing with a relatively uninformed Congress and public, a corresponding shift in power occurs. Indeed, *it is not unheard of for the executive branch to abuse its near monopoly of politically relevant technical information and expertise.* We cite below several case studies exemplifying the sorts of abuses that occur: *politicization of advisory committees; suppression and misrepresentation of information, and analyses.*

---

[1] Dr. von Hippel is an associate physicist at Argonne National Laboratory, Argonne, Illinois. Dr. Primack is a junior fellow of the Society of Fellows and a member of the physics department at Harvard University, Cambridge, Massachusetts. This article is adapted from an invited talk that was given by Dr. von Hippel at the annual meeting of the American Physical Society, January 1972.

This leads us to the question of whether individual scientists can contribute significantly to a restoration of a balance of power between the public, Congress, and the executive branch of the government. We find, again on the basis of case studies, that *a few scientists can be surprisingly effective in influencing federal policies for technology if they are sufficiently persistent and skillful and if various other circumstances are favorable.* These success stories and the present high level of concern about the adverse side effects of technology among both scientists and the public suggest that the time is propitious for a much more serious commitment within the scientific community to "public interest science."

This article is divided into two main sections. The first deals with devices by which the executive branch exploits its scientific advisers for political advantage while concealing much of the information they have provided; the second discusses ways in which scientists can help bring into being counterbalancing political forces by providing the public and Congress with the information they need.

For brevity we refer below to scientists advising officials in the executive branch of the government as insiders and scientists taking issues to the public and Congress as outsiders. Of course the same scientist can and sometimes does find himself in both these roles at different times.

ABUSES OF THE EXECUTIVE ADVISORY SYSTEM

Many thousands of scientists serve part-time on committees advising officials in the executive branch. It appears, however, that, if substantial political and bureaucratic interests are at stake, the dangers these insiders point out are often ignored. This is not surprising; it is one reason why our government was designed with checks and balances. These checks and balances are undermined, however, when executive spokesmen can use the authority of inside advisers to mislead the public and Congress about the technical facts or certainties that must be taken into account in the policy-making process.

Thus, for example, William Magruder, director of the supersonic transport (SST) development project, appeared before a congressional committee to allay fears about the SST sonic boom, airport noise, and stratospheric pollution. Magruder summarized the Administration's views on these issues as follows (1):

"According to existing data and available evidence there is no evidence of likelihood that SST operations will cause significant adverse effects on our atmosphere or our environment. That is the considered opinion of the scientific authorities who have counseled the government on these matters over the past five years."

Compare the above with the following quotations from the report of a panel of President Nixon's SST ad hoc review committee (2, 3) which included in its distinguished membership the President's science adviser. [The report was released 8 months after its completion, as a result of strenuous effort by Representative Henry Reuss (D-Wis.)]. Regarding the effect of the SST on the upper atmosphere, the panel noted that a fleet of SST's "will introduce large quantities of water vapor into the stratosphere," and concluded that much more research was needed before serious deleterious effects could be excluded. With regard to the impact of the SST sonic boom on the human environment, the panel concluded

". . . all available information indicates that the effects of the sonic boom are such as to be considered intolerable by a very high percentage of people affected."

Finally, as to the impact of the SST engine noise, they stated

". . . over large areas surrounding SST airports . . . a very high percentage of the exposed population would find the noise intolerable and the apparent cause of a wide variety of adverse effects."

In its adverse statements on the SST's environmental impact, the ad hoc committee report echoed many other reports available to the Nixon administration (4). Thus Magruder's statement is extremely misleading. Similar misrepresentations of scientific advice have been made by spokesmen for the federal executive branch in virtually all the other cases that we have studied (5).

Perhaps the most frequent means by which the public in misled in through the incomplete statement. Typically, an executive branch spokesman tells Congress that agency A, after consulting the greatest authorities, has decided to do X. The spokesman neglects to mention, however, that the experts have given mostly reasons why X might be a dangerous policy. The public cannot check what the experts actually said, because the reports are kept secret. Of course, Congress can ask several well-known scientists to appear before it and offer their views on the matters at issue in congressional hearings, but this is no substitute for requiring an executive branch agency to make available for public review and criticism the detailed technical basis for its decisions.

EXAMPLES OF ABUSES

There is a whole spectrum of devices by which the federal executive's advisory establishment has been used to mislead Congress and the public. Perhaps a few additional examples will indicate the possibilities:

(1) In the final throes of the SST debate, an advisory committee report was released which stated that, with noise suppressors, the SST airport noise could be reduced to tolerable levels (6, 7). No report was issued on what these changes would do to the SST performance, however. Every indication is that the noise suppressors, whose weight was of the same order of magnitude as the total payload of the aircraft, would seriously threaten the already questionable economic viability of the aircraft (7). Thus, government officials can selectively make public advisory committee reports that present only some of the positive terms in a cost-benefit calculation.

(2) A report on sonic boom effects by an advisory panel organized by the National Academy of Sciences-National Research Council (8), was so written that, when it was released, it stimulated a *New York Times* headline (9), "Sonic Boom Damage Called 'Very Small.'" In fact, simple calculations based on extensive government tests results lead to the estimate that, with 400 SST's flying supersonically over the United States, the sonic boom damage each year would be of the order of a billion dollars (10). What the advisory committee had meant to say was that the probability is small that a single sonic boom would damage a particular building, and therefore that experiments on sonic boom damage should be carried out in a laboratory with a sonic boom simulator. When a clarifying statement was eventually issued, after a petition from Academy members, it appeared only in the Academy newsletter and received no press coverage.

Thus advisory committee reports may be so written that they are seriously misleading, at least to the press. Political and institutional pressures may prevent the issuance of a proper clarification, or the press may ignore it.

(3) In 1966 a report by an independent laboratory under contract to the Department of Health, Education, and Welfare indicated that T,4,5-T (2,4,5-trichlorophenoxyacetic acid), a popular weed and brush killer, causes birth defects. This report was repeatedly sent back for "further study" for 3½ years (11) until it finally became public as an indirect result of a Nader investigation (12). In the meantime, enormous quantities of this chemical were used in the defoliation of about one-eighth of the area of South Vietnam (12, 13).

It may give an idea of the amount of bureaucratic foot-dragging involved in this case to note that, when one of the chemical manufacturers suggested that an impurity, not 2,4,5-T itself, might have caused the birth defects, the experiments that had taken 3½ years to complete were repeated in about 6 weeks. Both 2,4,5-T and the contaminant were found to produce birth defects (11). When these results became public, the use of 2,4,5-T in Vietnam was banned, its domestic use was partially restricted, and further restrictions are now being debated (11).

The studies relating to the question of whether pesticides cause birth defects were undertaken partly in response to the public furor caused by Carson's *Silent Spring* (14). Nevertheless, even while the public was being assured that the government had undertaken to protect it from such possible dangers, the government was concealing relevant new information. Thus, when the government has exclusive access to certain information about a public health hazard, it can simply ignore it.

(4) In October 1969, Secretary of Health, Education, and Welfare Finch was forced by law to ban foods containing cyclamates because cyclamates had been shown to cause cancer in animals. At the same time, he decided to overule protests from the Food and Drug Administration and allow manufacturers of these products to continue to sell them as nonprescription drugs for the treatment of diabetes and obesity (15, 16). After announcing his decision, he called together an advisory committee which reported back that, indeed, Secretary Finch was right in overruling the FDA medical people. The committee concluded (15):

". . . the medical benefits in these instances [treatment of diabetes and obesity] outweigh the possibility of harm."

After the publication of a Nader study report on the background of Finch's decision (17), its legality was examined in a rather devastating congressional investigation. The advisory committee was then called together again, and, although it had received essentially no new evidence, it issued a new report on the safety and effectiveness of cyclamates. This time the committee contradicted its earlier statement by saying (16):

"The literature provided to the group does *not* contain acceptable evidence that cyclamates have been demonstrated to be efficacious in the treatment and control of diabetes or obesity." [Italics ours]

Cyclamates were thereupon totally banned. In this example it appears that an advisory committee became so political that it adapted its advice to the political needs of the official whom it was advising.

CORRECTING THE RECORD

It is natural to ask whether insiders cannot do something to curb these abuses. In fact, advisers have tried to set the record straight in a number of recent cases:

Richard Garwin, a member of the President's Science Advisory Committee, was chairman of a committee of scientists reviewing the SST project for President Nixon at the beginning of his presidency. Although his committee's report was kept secret its existence was not, and Garwin was invited to testify at Congressional hearings (4). In his testimony he expressed his personal criticims of the SST, documenting them from publicly available sources.

Garwin explained his actions in the following words (18):

"I'm not a full-time member of the administration, and I feel like a lawyer who has many clients. The fact that he deals with one doesn't prevent him dealing with another so long as he doesn't use the information he obtains from the first in dealing with the second. Since there are so few people familiar with these programs, it is important for me to give to Congress, as well as the administration, the benefit of my experience."

Kenneth Pitzer was chairman of a President's Science Advisory Committee panel charged with looking into the safety of underground testing of large nuclear weapons in November 1968. The panel concluded that there was a significant danger of earthquakes and resulting tidal waves being triggered by bomb testing in the Aleutians. They also commented (19):

". . . the panel believes that the public should not be asked to accept risks resulting from purely internal government decisions if, without endangering national security, the information can be made public and decisions can be reached after public discussions."

The report expressing the panel's concerns was kept secret. Pitzer, however, helped make these concerns public (20).

Sidney Drell and Marvin Goldberger served on a committee advising John Foster, Director of Defense Research and Engineering, on the effectiveness of the Safeguard ABM system. When Foster misrepresented their committee's report as supporting the Administration position, they spoke up to set the record straight (21). Goldberger expressed their opinion of Safeguard rather pungently. He said

". . . I assert that the original Safeguard deployment and the proposed expanded deployment is spherically senseless. It makes no sense no matter how you look at it."

Unfortunately, these examples appear to be the exceptions. It seems that advisers usually watch in silence when they know that the public is being misled. The authors of the National Academy of Sciences sonic boom study mentioned above, and also academy officials, actually resisted the issuing of a clarifying statement.

Two main reasons are given for this silence: (i) Most advisers have very little faith in the effectiveness of speaking out, and they fear that by going public they would lose their inside influence. (ii) There is also the argument that, since the President is elected by all the people, he has the ultimate responsibility for making national policy. In its extreme form, this "elected dictatorship" theory of government leaves the adviser with only the responsibility to see that the President and the officials in his administration are well informed.

The loss of effectiveness argument emphasizes the serious dilemma in which a frustrated inside adviser may be placed as a result of the executive branch's insistence upon loyalty and confidentiality. However, insiders should beware of exaggerating their supposed effectiveness, and of confusing prestige with influence.

The elected dictatorship argument obviously denies the whole system of checks and balances by which our democracy has been safeguarded. It also ignores the fact that the ultimate responsibility in a democracy resides with the individual citizen, and that denying him the information he needs to defend his own health and welfare effectively deprives him of the rights of citizenship. The writers of our constitution understood this very well. James Madison said (22):

"Knowledge will forever govern ignorance. And a people who mean to be their own governors must arm themselves with the power knowledge gives. A popular government without popular information or the means of acquiring it is but the prologue to a farce or tragedy, or perhaps both."

It is obvious that the responsibilities of government science advisers should be discussed widely, both within the scientific community and in the larger political community. Lack of such discussion leaves scientists unprepared when they become advisers and find themselves confronted with difficult and unfamiliar decisions—often in an atmosphere of great pressure. Science, no less than scientific research, needs a code of ethics. And this code should take into account the fact that we live in a democracy in which the ultimate responsibility resides not with the President, or even with the government as a whole, but with the individual citizen.

Before going on, let us try to rectify the misunderstandings that may have resulted from the discussion so far. We do not wish by our criticisms of the abuses of the executive science advisory system to diminish or obscure the many important and legitimate functions inside advisers perform (23). Their roles as independent critics and connoisseurs of technical policies and people are essential throughout the executive branch. The executive advising system also provides a tremendously important part by which information and ideas can flow rapidly through the government, and between governmental and independent scientists, outside the slow bureaucratic filter. Indeed, in our opinion it has been a serious weakness of the most recent administrations that they have failed to exploit adequately these potential strengths of the advisory system.

PUBLIC INTEREST SCIENCE

The executive branch of our government has not been acting in an unbiased manner in making available to the citizen the technical information he needs. Scientists must therefore make their expertise directly available to the public and Congress.

The idea that the public, as well as the government and industry, should have scientific advisers is an old one—as is the idea that the interests of the public should have lawyers to defend them. It was not until the 1960's, however, that public understanding of the insensitivity of governmental and industrial bureaucracies led to a substantial commitment in the legal profession to public interest law. It appears to us that the scientific community may now have reached a similar point. The growing public awareness of the dangerous consequencies of leaving the exploitation of technology under the effective control of special industrial and governmental interests has led to a readiness within the scientific community to undertake a serious commitment to what we have termed "public interest science."

There is an important difference between the practice of public interest law and public interest science, however. In a legal dispute, once both parties have obtained a lawyer, they can hope to obtain a fair and equal hearing in front of a trained judge who gives their arguments his undivided attention, whereas in a public debate over an application of technology tremendous inequalities exist, The contending sides must speak to a distracted public through news media to which executive officials have comparatively easy and routine access. Moreover, an executive official speaks with the authority of his office, while an independent scientist is usually an unknown quantity to the public.

In view of these inequalities, it is interesting to find out whether the public interest activities of independent scientists can activate political and legal restraints on irresponsible actions of the executive branch. In working on this question, we have thus far examined the effectiveness of outsiders in informing the public about the negative aspects of the SST, the decision to deploy the Sentinal and Safeguard antiballistic missile systems, the program of crop destruction and defoliation in South Vietnam, and the regulation of pesticides. We have also studied the effectiveness of a local group of scientists, the Colorado Committee for Environmental Information, in bringing to public attention in 1968 through 1970 the dangerous practices of two federal agencies in Colorado.

EXAMPLES

In all these instances, the outsiders have had a surprisingly large effect, considering their small numbers, in bringing to public attention an aspect of the issue that concerned them. Consider a few examples:

(1) Serious public opposition to the SST developed only after a few scientists notably Shurcliff, made dramatically clear in press releases and advertisements that the sonic booms created by a fleet of SST's flying supersonically overland would be intolerable (4).

(2) The residents of the Denver area did not realize that they might have a problem until scientists of the Colorado Committee for Environmental Information (CCEI) issued a public statement describing the possible consequences of an airplane crashing into the huge stockpiles of nerve gas stored near the end of Denver's busy airport. After trying in vain to reassure the public, and then to transport the nerve gas across the country to dump it in the ocean, the Army finally agreed to destroy it (24).

(3) The U.S. program of defoliation and crop destruction in South Vietnam came to an end when a group of scientists sponsored by the AAAS brought back photographs and a detailed report of the devastation that resulted (25).

(4) The deployment of an ABM system to defend the major cities of the United States became a public issue only after scientists in the Chicago area and elsewhere raised what most experts considered a minor issue—the possibility of the accidental detonation of an ABM (antiballistic missile) warhead in the metropolitan area it was supposed to be defending (26).

Of course, we could equally easily compile a list of cases in which public protests by scientists have had little effect on federal policy. Most technical issues cannot be taken directly to the public because there is little public resonance with the ideas involved. That does not decrease the importance of the issues that can be taken to the public, however.

The effectiveness of outsiders in influencing government policy seems to depend on many factors. For one, where outsiders have been influential, the dangers they pointed out usually threatened huge numbers of people personally. Their effectiveness seems also to have depended upon how important the policy being criticized was to the government. Consider the obsolete nerve gas, for example; leaving it at such a dangerous location was simple negligence that could be rectified by spending a little money when it became clear that reassuring statements would no longer suffice. On the ABM, SST, and pesticide regulation issues, however, the critics were attacking policies that governed the allocation of billions of dollars. Over these issues the battles have been rough and prolonged and have required the active involvement of large numbers of citizens in addition to scientists.

The effectiveness of the outsiders also often depends upon the timeliness of an issue. Thus, after Shurcliff and a few others had been denouncing the SST for years, the new environmental movement came to see it as a symbol of all that is destructive to the environment. Similarly, the ABM became a popular issue in part because the public had become concerned about the insatiable appetites of the military-industrial complex. And, after a few biologists and ecologists had been protesting for years about defoliation and crop destruction in South Vietnam, they were finally heard when the public had become disgusted with the United States entire Indochina policy.

Our case studies give substantial encouragement that some issues can be taken to the public by scientists with partial success at least. It is not easy, however. Enormous persistence and skill are required, as well as a good and timely case, to be heard above the din that accompanies everyday living in this country.

CREDIBILITY

It is also necessary for the scientist to establish credibility—that is, that he is not a "crackpot." Credibility has sometimes come from the quotation of governmene reports that contradict the official line. It has come from preparing a compelling and well-documented case from the open literature, as Carson did in her criticism of pesticide regulation (14). It has come from a study sponsored by a scientific organization: an example is the AAAS study of the effects of defoliation in Vietnam (25).

Yet another technique for handling the credibility problem was applied quite effectively by CCEI (24). In two of the debates in which it became involved the CCEI publicly challenged the responsible government agency to establish the basis for its assertions. The Colorado group accompanied the challenge with a specific list of technical questions, the answers to which would make possible an independent determination of public safety. Finally, credibility—and also publicity—can be obtained if one can persuade Ralph Nader to take up the issue. The extent to which we all depend on Nader in these matters is a testimonial to the timidity of the professional societies, universities, and national laboratories.

The scientist's public credibility must, of course, be earned. A specialist who uses his authority as a recognized scientist to lend support to a political position without presenting the technical arguments casts doubt both on his political position and on his scientific authority. The standards of accuracy to which a scientist adheres in public statements should be no lower than those he strives to attain in his scientific work. It is also necessary for the scientist to maintain a sense of perspective; it is all too easy to exaggerate the significance of a subject on which a critic happens to be an expert. The danger of crying wolf is not merely that the next time a justified alarm may be ignored; it may also happen that the false alarm will be heeded and the nation stampeded toward a foolish or unnecessarily hasty action. Obviously, the proper ethics for outsider science deserves discussion within the scientific community no less than the ethics of insiders.

During and after each of the major technological debates of recent years there have been charges that scientists who participated as outsiders were politically biased and scientifically irresponsible (27). While there have certainly been a few instances that substantiate such charges, the vast majority of independent scientists who have argued technological issues before the public have been honest and accurate. A scientist's reputation is his most precious possession, and the scientist who misrepresents the truth or makes unsound technical judgments calls down upon himself the censure of his colleagues. In any event, technical arguments presented in public can be rebutted in public, in the usual self-correcting manner of scientific discourse. Indeed, it is unfortunate that the statements of the executive branch officials are not subject to similar constraints. Apparently, the standing of these officials depends more on their loyalty than on the accuracy of their public statements.

As we have mentioned, the route of taking issues to the public is very important but also quite limited; many issues cannot be so treated. Other routes are available, however. Sometimes recourse to the courts is possible. Recent developments in the law, particularly the National Environmental Policy Act of 1969, make this approach increasingly effective. Taking advantage of the protection offered by the law requires more than public interest lawyers, however. It requires public interest scientists as well. The collaboration of scientists and lawyers in the Environmental Defense Fund is one notable example; another is the current collaboration between the M.I.T.-based Union of Concerned Scientists and a number of the leading environmental organizations in a legal challenge to the Atomic Energy Commission to establish an adequate basis for evaluating the safety systems of nuclear reactors (28).

ORGANIZATION AND FUNDING

Thus far there has been little funding for public interest science. Almost all who are involved do it as an unremunerative sideline. Perhaps this is good. Only recently the scientific community delegated its public responsibilities mostly to the insiders. As governmental regulatory agencies have repeatedly demonstrated, responsibility cannot be successfully delegated—it can only be shared. Large numbers of part-time outsiders are required to keep the system honest.

More than part-time people are required, however. The coordination of the efforts of part-time people and the lobbying to see that the issues they raise get a fair hearing rapidly become a full-time job. This is the function, for example, of Jeremy Stone, executive director of the Federation of American Scientists (29). Under Stone's leadership the FAS has been instrumental in establishing a new tradition of open adversary hearings before the House and Senate Armed Services Committees and in providing technically competent witnesses before many other congressional committees.

Examples of full-time public interest scientists are few and far between. Ralph Lapp could be identified as such a person. Like Ralph Nader, he supports his activities by writing and lecturing on the issues with which he is currently concerned. A number of academics seem also to have become nearly full-time public interest scientists. Universities have the advantage of having undergraduate and graduate students who are willing to commit great amounts of energy and idealism to a project (30), although, as Ralph Nader has shown, such students will go where the action is even if it is not at a university.

Foundations are beginning to show an interest in funding public interest science projects, and the federal and state governments may begin funding them in earnest if the field becomes more respectable—like public interest law. Nevertheless, it is doubtful that direct government funding will provide the kind of political insulation appropriate to some public interest science. Responsibility for some funding should be closer to the scientific community itself. Scientific societies could do some of it. Another possibility would be for universities and other research contractors to devote part of their overhead on research contracts to a fund for public interest science controlled by the scientists at the institution. This is in effect how law firms and medical doctors support their pro bono activities.

One need only look at the student-funded Public Interest Research Groups in Minnesota and Oregon (31) to see how varied the possible sources of support for public interest science are. The more diverse the sources of support, the more securely established public interest science will become as one of the responsibilities of the scientific community.

SUMMARY

We have described some of the abuses that develop when policy for technology is made behind closed doors in the executive branch of the federal government. And we have tried to demonstrate that public interest science is no more quixotic than public interest law.

REFERENCES AND NOTES

1. Testimony before the Senate Appropriations Subcommittee on Transportation (27 August 1970), p. 1336.
2. Report by the Panel on Environmental and Sociological Impact of the President's SST ad hoc review committee, March 1969. The report and other material generated by panels and members of the review committee were introduced by Representative Sidney Yates into the *Congressional Record* (31 October 1969), pp. H10432–46. Some of this material is also reproduced as an appendix to Shurcliff's book (*3*). Congressman Reuss tells how he used the Freedom of Information Act to force the release of the reports in the *Congressional Record* (18 November 1969), p. E9733.
3. W. A. Shurcliff, *SST and Sonic Boom Handbook* (Ballantine, New York, 1970).
4. We have presented a case study of the involvement of scientists as insiders and outsiders in the SST debate (*Bull. At. Sci.* 28 (4), 24 (1972)).
5. We discuss further examples in *Appl. Spectrosc.* 25, 403 (1971), and in *The Politics of Technology: Activities and Responsibilities of Scientists in the Direction of Technology* (Standard Workshops on Political and Social Issues, 590A Old Union, Stanford University, Stanford, California, 1970). The SWOPSI publication grew out of a student-faculty workshop at Stanford in 1969–1970 led by J. Primack, F. von Hippel, M. Perl. See also M. Perl. *Science* 173, 1211 (1971) ; C. Schwartz *The Nation* 210, 747 (1970).
6. Report of L. L. Beranek, chairman, SST Community Noise Advisory Committee to W. M. Magruder, director of SST Development, Department of Transportation, 5 February 1971.
7. C. Lydon, *New York Times*, 1 March 1971, p. 15.
8. Subcommittee on Physical Effects of the Committee on SST–Sonic Boom, *Report on Physical Effects of the Sonic Boom* (National Academy of Sciences-National Research Council, Washington, D.C., 1968).
9. *New York Times*, 5 March 1968.
10. Results of government tests over a number of cities with military jets, compiled by Shurcliff (*3*), give an average of about $600 damage awards per million "man-booms" even for booms considerably less intense than those that would have accompanied the SST. If we then assume that each of 400 SST's flies 10,000 miles (1 mile = 1.6 kilometers) daily at supersonic speeds, creating a boom path 50 miles wide, populated with an average density in the United States of about 60 people per square mile, we obtain a rough estimate of $2.5 billion annual damage. Although this estimate could doubtless be made more exact, it certainly indicates that sonic boom damage is not a negligible problem.

11. *Effects of 2,4,5-T on Man and the Environment*, Hearings before the Subcommittee on Energy, Natural Resources, and the Environment of the Committee on Commerce, United States Senate, 91st Congress, 2nd Session, 7 and 15 April 1970. This history is summarized in the testimony of Surgeon General Jesse Steinfeld on pp. 178–180.
12. T. Whiteside, *Defoliation* (Ballantine, New York, 1970), p. 21.
13. A. Galston, in *Patient Earth*, J. Harte and R. Socolow, Eds. (Holt, Rinehart & Winston, New York, 1971).
14. R. Carson, *Silent Spring* (Houghton Mifflin, Boston, 1962).
15. This example is documented in *Cyclamate Sweeteners*, and *The Safety and Effectiveness of New Drugs (Market Withdrawal of Drugs Containing Cyclamates)*. Hearing before a Subcommittee of the Committee on Government Operations, House of Representatives, 10 June 1970 and 6 May 1971, respectively.
16. *Regulation of Cyclamate Sweeteners*, Thirty-Sixth Report by the House Committee on Government Operations, 8 October 1970.
17. J. S. Turner, *The Chemical Feast* (Grossman, New York, 1970), chap. 1.
18. H. Sutton, *Saturday Review* interview, 15 August 1970.
19. The summary of the panel report is reproduced in *Underground Weapons Testing*. Hearing before the Senate Committee on Foreign Relations, 91st Congress, 1st Session, 29 September 1969. The panel report was released that same morning: *Underground Nuclear Testing*, AEC Report TID 25810, September 1969, pp. 51 *ff*.
20. Pitzer's address, "Affecting National Priorities for Science," before the American Chemical Society, 14 April 1969 [*Chem. Eng. News*, 21 April 1969, pp. 72–74] was partly devoted to the underground testing issue. Pitzer had just received permission from the President's science adviser to make public his personal views on the issue. For his congressional testimony, see (*19*, p. 33).
21. *ABM, MIRV, SALT, and the Nuclear Arms Race*, Hearings before the Subcommittee on Arms Control, International Law, and Organization of the Senate Committee on Foreign Relations, 91st Congress, 2nd Session, March–June, 1970. Foster's citation of the committee report appears on pp. 442–444; rebuttals by Drell and Goldberger appear on pp. 525–580. Senator Fulbright was finally able to obtain a declassified version of the report and inserted it in the *Congressional Record* along with his comments on pp. S12901 ff., 6 August 1970.
22. James Madison, letter to W. T. Barry, 4 August 1822. We thank Paul Fisher, director of the Freedom of Information Center, University of Missouri, for providing us with this reference.
23. The functions of the advisory system have been widely discussed; see, for example, T. E. Cronin and S. D. Greenberg, Eds., *The Presidential Advisory System* (Harper & Row, New York, 1969). The essay by H. Brooks, reprinted in this volume, is especially useful.
24. A short case study of the effectiveness of the Colorado Committee in this and two other cases may be found in (5).
25. P. Boffey, *Science* 171, 43 (1971).
26. A. H. Cahn, *Eggheads and Warheads: Scientists and the ABM*, thesis, Massachusetts Institute of Technology (1971).
27. A recent, well-publicized example of such an attack is the Operations Research Society of America report criticizing congressional testimony of several scientists against the Safeguard ABM system. [ORSA Ad Hoc Committee on Professional Standards, *Operations Res.* 19 (5), 1123 ff. (1971)]. The first part of the ORSA report purports to be a statement of ethics for operations analysts, but it provides little ethical guidance beyond urging loyalty to one's employer under almost all circumstances. The report's attack on the anti-ABM scientists focuses upon a very narrow technical issue, from the analysis of which the report then draws a broad and unjustifiable condemnation of the ABM critics. (For detailed criticism of the ORSA report, see statements of numerous technical experts collected and reprinted in the *Congressional Record*, pp. S1921–51, S2612–13, S3521–23 (17 and 29 February; 7 March 1972); and P. Doty, *Minerva*, in press.
28. R. Gillette, *Science* 176, 492 (1972).

29. The Federation of American Scientists, 203 C Street, NE, Washington, D.C., is the only registered lobby of scientists. FAS has been traditionally interested in issues associated with nuclear weapons, but recently it has provided testimony before Congress on many other technological issues.
30. A good example of such a university-based program is the Stanford Workshops on Political and Social Issues. More than a hundred "workshop" courses for academic credit at Stanford University have been sponsored by SWOPSI during its 3 years of existence, and these have produced more than a dozen comprehensive and authoritative reports on subjects like "Air pollution in the San Francisco Bay area," "Balanced transportation planning for suburban and academic communities," "Logging in urban counties," and "DOD-sponsored research at Stanford." Several of these reports have had considerable political impact [for SWOPSI's address see (5)].
31. For a discussion of the manner in which such groups can be organized, see R. Nader and D. Ross, *Action for a Change—A Student's Manual for Public Interest Organizing* (Grossman, New York, 1971).

Chairman PROXMIRE. Please proceed, Mr. Brower.

STATEMENT OF DAVID R. BROWER, PRESIDENT, FRIENDS OF THE EARTH

Mr. BROWER. Mr. Chairman, thank you very much for the opportunity to appear here and for the very fact of your holding these hearings. I am David Brower of Berkeley, Calif., president of Friends of the Earth, an organization founded in New York in 1969 and now numbering 29,700 members. We have close association with independent sister organizations of the same name or translation of it in eight countries and three coming up.

We do not believe development and operation of supersonic transports, whether by this country or any other, is consistent with the rational use of the earth for reasons I shall try to develop. We believe that Congress acted wisely in voting against this development, and that this action by Congress signaled an important turnaround in the what had theretofore been a mesmerization with technology for technology's sake. In view of the environmental predicament of mankind, it would be immorally wasteful of vanishing resources, and of the opportunity of developing countries to share in these resources with reasonable equity, for the U.S. Government now to attempt to reverse the turnaround this Congress achieved in spite of the entreaties to the contrary by the administration.

We deplore the indications that the administration now wishes to try mouth-to-mouth resuscitation of an albatross that should be given a decent burial and be forgotten. Organizations devoted to the protection of the environment here and abroad have a heavy enough burden without having to refight battles, properly won at substantial cost, with such frequency.

As we have tried to make clear before, the supersonic transport is economically unsound. It produces an intolerable level of noise, whether flying supersonically or subsonically. It adds to atmospheric pollution, unacceptably at lower elevations and possibly catastrophically at its higher altitudes—and I would add that, if we reduced the density of the earth's atmosphere to that of water for direct comparison, we would be living in a lake only 34 feet deep and we had better be careful what we do about it. It threatens an unconscionable drain on the world's vanishing stores of fossil fuels, oil in particular.

It is likely to expose its passengers to excessive radiation, dangerously excessive now that we have seen radiation limits lowered once again. It is likely to intensify the problems, already serious, caused by zone fatigue—and I think we have all been witnessing the impairment of judgment this causes. Of no less importance, the SST adds one more technical device to the long list that widens the gap between developing countries and the overdeveloped countries, to use Sir Frank Fraser Darling's term.

We find further that the SST promoters become so enamored of their project as to suffer severe impairment of their candor. I do not need to remind this committee of the difficulty the Congress experienced in getting timely facts from the administration in the recent battle. We see that there is similar trouble in the United Kingdom, as witnessed in the article by David Harris in the Daily Telegraph, London, December 22, 1972, headlined "Concorde Sales Details Secret 'In Public Interest.'" We got the same thing, as you must know, from our administration now. The full account, and a further note on "Anglo-U.S. Talks in Concorde" are submitted as part of this oral statement.

Chairman PROXMIRE. We will place those articles in the record at this point.

(The articles referred to follow:)

[From the Daily Telegraph, London, Dec. 22, 1972]

CONCORDE SALES DETAILS SECRET "IN PUBLIC INTEREST"

(By David Harris, political staff)

The Government refused yesterday a request from an official committee of MPs to make public how much of Concorde's £970 million research and development costs would be recovered through sales.

In its observations on a report by the all-party Commons Expenditure Committee, the Government says that it is "not persuaded" by the committee's arguments that the information should be published.

Instead, it believes that "the public interest in this case is best served by not releasing the information."

In May, BOAC placed orders for the first five Concordes to be delivered in 1975. Each plane will cost £13 million.

25-MILLION-POUND LOAN

A Bill now before the Commons provides another £225 million loan to the British Aircraft Corporation, the British builders, for production costs on top of the £125 million provided earlier.

MPs carrying out the detailed examination of the Bill in committee will probably press the Government to say how much of the research and development costs will be recovered.

The expenditure committee, which looked into public money in the private sector, suggested that the Government should publish an annual White Paper on Concorde and on other major projects which were receiving State aid.

In its observations, the Government says it is considering what would be the most suitable arrangements for keeping Parliament as fully informed as possible.

The Government rejects the committee's conclusion that State help to the shipbuilding industry has not been "thoroughly thought out."

It comments: "The fact is rather that the criteria have inevitably been changed from time to time to meet changing consequences."

Government assistance was needed because of the rise in the general level of unemployment during 1971, and the increasing difficulties which the industry was facing.

(Public Money in the Private Sector: Government Observations on the Sixth Report of the Expenditure Committee: HMSO 8p.)

[From the Daily Telegraph, London, Dec. 22, 1972]

ANGLO-U.S. TALKS IN CONCORDE

(By Our Washington Staff)

A team of British officials from the Department of Trade and Industry and from the French Aviation Ministry, discussed aerospace matters yesterday with experts at the American Federal Aviation Administration. It was believed that the Anglo-French Concorde was uppermost in the discussions, including its ability to meet noise and pollution limits at American airports.

Official sources said, however, that the talks were of an explanatory character. Nevertheless, a crucial moment in Concorde's history is rapidly approaching. Soon the two big American international airlines—Pan American and Trans World Airlines—will have to decide whether to take up their options for purchasing the costly Concorde airliner, allow them to lapse or ask for more time.

Mr. BROWER. In short, for the presumed convenience of a favored few, the populations of the earth are being expected to make an untenable environmental contribution.

Accordingly, we urge the Congress, which also received a mandate in November 1972, to play its historic role to the full as a vital part of the Government of the United States. We suggest that it would be profitable for this committee, and for other investigative arms of the Congress, to inquire in detail into the possibility of making major savings in the use of what has been called the swing fuel oil. Economies in the use of oil could quite likely come from slower jet speeds than those now used, from development of means other than air transport for short hauls, and from setting as a national goal the achievement, in a rapid transition from the Nation's present prodigality with energy, of at least twice as many passenger-miles per gallon of fuel as we now attain. I would like to submit for the committee's record an article from the current issue of Your Environment, a British publication, on steam as one of the alternate sources. It is a very good piece and not very long.

Chairman PROXMIRE. We are happy to have it and will place it in the record at this point.

(The article follows:)

[From Your Environment, vol. III, No. 3, autumn, 1972]

WATT'S NEW IN MOTIVE POWER

(By Nicholas Pole *)

The steam engine will almost certainly be one of the major power sources for vehicles of the future. It simply has too many advantages to be ignored for very much longer. As pollution from exhaust emissions grows with the number of cars on the road, as city-dwellers are gradually throttled by the filth, and as world supplies of crude oil dwindle against demand, alternatives to what Ralph Nader called the Eternal, Infernal, Internal Combustion Engine will have to be found; and the steam engine recommends itself extremely strongly.

It must be said first, of course, that infinitely preferable to having even steam cars purring up and down the roads would be having no cars at all. But every country which has accepted the motor car on a large scale is going to be stuck with it for some time yet. And even if great advances are made within the next ten years, even if every major city in Britain closes its centre to all but pedestrians, bikes and buses, even if inter-city rail travel is revamped on a massive scale, the private car is not going to fade conveniently away. The need for small

*Nicholas Pole is directing the Cambridge University Conservation Society's Transport Research Project, 6 Cavendish Avenue, Cambridge, CB1 4US. The Project welcomes inquiries and information from any one interested in transport research and reform.

independently-powered vehicles (service vans and lorries, mini-buses, ambulances, police cars et cetera) will still exist: and it makes good sense to ensure that these vehicles run with clean exhausts. To the vast majority of drivers, who like the great convenience which cars can sometimes afford, but dislike the pollution which they cause, a non-polluting engine would be an obvious good. Facing the economic facts, we know that in both Britain and the US about one-sixth of the entire economy is accounted for by the manufacture, sale, maintenance or use of automobiles, and that in the US 82% of families own at least one car. There are more than 180 million cars on the earth today, and the number is increasing all the time. As we cannot make them disappear just yet, as we cannot even expect their number to stabilize for many years, it makes sense to consider the advantages of steam power for auto engines of the future.

Ever since 1769, when a French army engineer, Nicholas Cugnot, chugging along in his newly-designed steam artillery wagon, drove into a wall on a test run, the development of steam-powered road vehicles has been plagued by lack of luck, lack of money and lack of professionalism. In many people's minds the plain fact that the internal combustion engine—I.C.E.—is the car engine universally *used* is proof enough of its superiority over steam. With images in the back of their minds of 18th-century gentlemen riding unsteerable, explosion-prone, contraptions through panic-stricken throngs, they bemusedly consign steam to its 'proper' place in history. In fact, steam coaches in England were quite popular in the 1820's and 30's; they were unfairly legislated off the road by parliament—because of competition with other forms of transport, not because they were dangerous or inefficient. In 1906, while Henry Ford was just setting himself up in business, a steam racer built by the Stanley brothers in the US set five world speed records at Ormond Beach in Florida, reaching a top speed of 127 mph.

There were others like the Stanleys who built and sold steam cars, but none of them had the business genius or vision of Henry Ford; most were far more interested in the mechanics of their subject and, making a comfortable profit, carefully hand-crafted their automobiles, handling as many orders as they could manage. None used Ford's techniques of mass production; and this leisurely attitude to business was the major cause of the steam engine's failure to compete with the I.C.E. in the early days of the automobile. One firm, Doble Detroit Steam Motors, after showing a new model at the 1917 New York Auto Show, received $27 million worth of orders: but had built only a few cars before the US Government commandeered car manufacturers' materials for war purposes. Production at Doble resumed in 1921 but proceeded at a painstaking pace, each car a luxury item. When Doble closed down in 1930, the I.C.E. was already firmly established as the engine of the future. Andrew Jamison in his excellent book *The Steam Powered Automobile* concludes that 'Steam has never been an inferior power source. It seems to have been afflicted with an historical curse—not enough money at the proper time, freak accidents at crucial moments, no mass-production—plus aggressive competition from the automobile manufacturers who have never ceased to claim that the gas [petrol] driven car is 'the only kind to have.'

It was nearly 40 years after Doble closed down, when Henry Ford's dream of a car in every garage had been realised with a vengeance, and American city-dwellers were being introduced to the 'smog alert', that interest in the steam engine was renewed. In 1967 the US Senate set up a joint committee and held hearings to find out if steam was really a possible alternative to the I.C.E.[1] It was at these hearings that the advantages of the steam engine (technically known as the Rankine Cycle Engine) were finally spelled out to the public. Witnesses were invited from the numerous scattered organisations and firms which were either doing research on or actually building steam engines. Witnesses were also invited from the established auto industry, representatives from Ford and General Motors, who did their best to discount steam as a possible power source. But although these representatives went about their job in a not always unsubtle manner they stood little chance of success, as testimony after testimony added to the list of the steam engine's advantages.

The steam engine is an *external* combustion engine. Instead of burning its fuel by explosion in a confined space (and therefore incompletely) it burns it steadily at normal air pressure and so produces virtually no pollutants. In the cylinders of an I.C.E. a mixture of fuel and air is compressed and ignited, causing an

---

[1] *Automobile Steam Engine and Other External Combustion Engines:* joint hearings before the Committee on Commerce and the Subcommittee on Air and Water Pollution of the Committee of Public Works of the US Senate, 90th Congress, 2nd Sess., 1968.

explosion which forces the piston downward and drives the crankshaft. The exhaust from this explosion contains unburned hydrocarbons (HxCx), carbon monoxide (CO), nitrogen oxides (NOx) and lead in varying degrees. These are the components of the toxic and obnoxious fumes that build up in our city streets and, in the hot and windless weather frequent in California, turn into lethal layers of smog. The steam engine, with its external combustion, produces these pollutants in negligible quantities, all except for lead, which it does not produce at all. Basically the steam engine works like this: the burning fuel heats the working fluid (usually water) as it passes through a narrow tube, turning the fluid into vapour. The vapour passes through the throttle and the motor, where its energy is transferred through the pistons to the axle. It is then condensed back into fluid and pumped around to be heated and vapourised again. The whole system is hermetically sealed so that no vapour is lost and no water need ever be taken on.

Because combustion takes place at normal air pressure a much wider range of hydrocarbon fuels is available to the Rankine engine than the I.C.E.; often normal kerosene is used. This also means that 'octane' ratings can be abandoned and tetraethyl lead is not necessary in the petrol to protect the engine from 'knock'. Refining oil for external combustion is far simpler than making gasoline and would result in a greater return of fuel per barrel of crude oil, thus easing the pressures on our dwindling oil reserves. According to at least one witness at the 1968 hearings in Washington, fuel consumption can be up to 20% better than that of the I.C.E.

The steam engine also has the advantage of delivering high torque (turning force) at low or zero speeds. This means that there is no need for a clutch or a transmission; the engine is consequently simpler and needs less maintenance. Mechanical brakes are unnecessary, since braking can be done by instant reverse acceleration. No starter motor is needed, no carburetor or fuel-injection unit, no engine-block cooling system, no distributor and no muffler. Only one spark plug is required. It is estimated that the I.C.E. loses 40% of its power in transmitting the energy from the motor to the axle; the steam engine, because it needs no transmission, loses only 10%, with consequent savings on fuel. Another fuel-saving advantage is that in stop-go city traffic the steam engine does not need to be kept ticking over. When the car stops, the engine stops too and no fuel is burned. When starting again there is no spluttering cloud of exhaust.

It is also likely that the steam engine would be quieter than the I.C.E. Even the Ford witness at the Washington hearings admitted that one of steam's advantages was its 'ultra-quiet operation'. The fuel is burned non-explosively so no muffler is needed, the high torque at low speed means no noisy revving up, and as there is no need for a transmission the grinding, whining and shuddering of gear changes would be eliminated—a special advantage for buses and lorries. Maintenance is another plus. Because of its simpler design, one witness at the hearings said 'In my opinion, any modern steam car put into production should not require a major overhaul more frequently than once in 200,000 miles'.

Finally, because it is an inherently non-polluting engine, there is no need for the expensive and elaborate emission-control devices which the US auto industry is going to have to install on every vehicle it makes after 1975. These could increase the price of cars in the US by hundreds of dollars, reduce engine efficiency and increase fuel consumption. In the words of one outspoken advocate of the Rankine engine, Wallace Minto, president of an engineering company in Florida, 'an internal combustion engine for 1976 would be bulky, sluggish, complicated, expensive, difficult to maintain and a gluttonous consumer of irreplaceable resources which are even now in short supply. It could not compete in the open market with a properly-developed Rankine powered automobile.'[2]

Mr. Minto, however, was well aware that the US auto industry is anything but an 'open market'. It really consists of just three gigantic companies, General Motors (the largest corporation in the world), Ford and Chrysler, which have always maintained a solid front against any threatening initiative from consumer or government organisations. And for them the question of the steam engine was no exception. The two representatives at the hearings from Ford and GM both gave an impressive list of the number of alternative forms of engine they were looking into. Both said that they had done a considerable amount of research on steam power. But, alas, in spite of their prodigious efforts, both had found that the steam engine was beset by too many problems. 'Too bulky' they

[2] Public relations/information material from Kinetics Inc., 1121 Lewis Ave., Sarasota, Florida 33577. US.

said, 'too complicated', 'too expensive to produce'. GM even went as far as to build two prototype steam cars to prove its good faith, the S.E. 101 and the S.E. 124; but strangely enough both of the designs were far below the standard of independently produced steam engines. A British expert on steam, Mr. Thomas Hindle, said of the S.E. 101, 'The design does not impress me in the least. It gives me the impression of deliberately making the worst possible case for steam power applied to a car.'

The evidence against the auto industry was damning enough, and when the report of the hearings was published[3] it accused the industry of 'dragging their feet in the development of a Rankine propulsion system' and came out strongly in favour of steam power. 'Opponents of change may dispute our conclusion', the Report said, 'but their previous attacks on the feasibility of the Rankine cycle engine are no longer viable; they will have to find new criticisms. For example, the Ford Motor Company, in the face of the evidence, can no longer argue that complexity is a disadvantage for the Rankine vehicle.' Concluding, the Report passed judgment as follows: 'Without the myopic persistence of the automobile industry in devoting most of its research funds to the I.C.E., a reliable, low-polluting Rankine cycle engine could probably have been developed 20 years ago.'

This overwhelming official endorsement of the steam engine as a satisfactory pollution-free power source had no effect on policy among the 'big three' auto manufacturers. To this date, GM in its public relations releases has the audacity to state 'in our experience, we have not found the steam engine to be a low-emission power plant'.[4] This is either a blatant piece of misinformation or a damning indictment of GM itself. Surely they cannot mean that GM, the largest auto builders in the world, with all their engineering expertise, could not manage to make a low-emission steam engine? The steam engine is, *by its very nature,* a low emission engine. It is a little like saying 'We've put a lot of work into what we think might be an alternative to the automobile; the only thing we can't get it to do is move'.

Ford's publicity material on alternative power sources is even more unbelievable. 'We at Ford believe the Rankine cycle engine is still far from being a practical reality,' they blandly state. 'The basic principle on which the Rankine cycle engine works is the same as that used by the locomotives of bygone days in which water was heated to steam and allowed to expand against pistons of the engine. Locomotives consumed large quantities of water and fuel in comparison with the engines that replaced them'.[5] As a valid comment on the disadvantages of modern steam power this is of course sheer nonsense. The problems which it tries to associate with steam engines of the 1970s disappeared long ago. It is almost as absurd as using the myth of Icarus to discredit modern air transport.

One fear which the uninitiated often have about steam engines is their liability to explosion; this fear has also been played upon by the steam engine's detractors. At the time of the 1968 hearings an exchange took place on this subject which is worth quoting in detail. Hartley W. Barclay, the editor of *Automotive Industries*, attacked steam power in a fanatical tirade which included the following: 'Even granted that the hypothetical steam engine could be manufactured, how would Senators Kennedy, Ribicoff and Magnuson et al. [the Senators involved in the hearings] like to be driving down the street behind a steam engine which operates at 3000 psi and 700 degrees F total temperature, and have the engine or the boiler leak this superheated steam which could cause such complete physical damage to a human body that even instant death would be more likely than effective first aid? The high pressure, furthermore, could result in steam explosions with a tremendous potential for great damage to the car, car occupants or nearby pedestrians.'

An amusing answer to this soon came from a company called Gibbs-Hosick Steam Motor Systems: 'To paraphrase your quality of reasoning, how would Senators Magnuson, Kennedy and Ribicoff et al like to be driving down the street behind an I.C. explosion engine (conventional gasoline engine) which operates on a highly poisonous mixture of obnoxious, toxic gases at 5000 psi of pressure and 4000 degrees F of searing temperature, while burning a highly volatile and flammable mixture of lead-containing hydrocarbons, stored in a tank in twenty-gallon quantities having the explosive potential of 600 pounds of pure nitroglycerine, enough to blow up an entire city block? Neither man nor animal

---

[3] *The Search for a Low Emission Vehicle,* US Senate Committee on Commerce, US Government Printing Office, 1969.
[4] *General Motors Policies and Progress,* 1972, p. 14.
[5] "Ford Has A Better Idea", *Alternative Power Sources,* 1972, p. 11.

would be safe within quarter of a mile of such a machine.' The truth is that the modern steam engines present no danger whatsoever of any exploding boiler, for the good reason hat it has no boiler. The working fluid is hermetically sealed in a thin tube and only a small amount is necessary as it is continuously vapourised, condensed and recycled within the tube.

It would, however, be misleading to suggest that the steam auto engine has no problems at all at this stage in its development, especially considering that it has missed out on the decades of research and development invested in the I.C.E. The greatest problem is that if water is used as a working fluid it is liable to freeze in very cold weather. No anti-freeze additive has yet been found which does not decompose when repeatedly vapourised and condensed. The most promising working fluids besides water, the fluorocarbons, will not freeze nearly so easily but do have other disadvantages, one of them being that they can give off toxic products if directly exposed to flame, something which admittedly could only happen in a severe crash. Another problem is that in most steam engines so far designed the condenser unit is rather bulky; but the work on this has already succeeded in producing experimental engines of the same size as or smaller than an equivalent I.C.E. Although no perfect steam auto engine has yet been built, answers to all of its problems have been found.

The truth is that the only thing preventing a large-scale adoption of steam power for cars, at least in the U.S. is the deliberate opposition of the auto industry. Without the industry's huge resources, without its enormous dealer network and advertising expenditure, there are not many people around willing to put up the estimated $400 million or so necessary to start a nationwide steam engine production, sales and distribution company. On both sides of the Atlantic there are but few signs of hope. Kinetics Inc., a Florida steam car company, has signed an agreement with the Japanese Nissan Motor Corporation (makers of the Datsun) which may possibly bring forth a cheap Japanese steam-powered import later in the decade. In the U.K. British Leyland have been working in a steam-powered Mini for some time, but they say now that there is no prospect of production in the foreseeable future, and have published no information on it whatsoever. In general, the attitude of British automobile and mechanical engineering interests towards steam is just as conservative as that of their counterparts in the U.S. In a research paper published by the Institute of Mechanical Engineers in 1970[6] the author concluded that "the problems attendant on the use of a steam power plant for a motor car are such that it could not compete on technical or operational grounds with a conventional engine. If, however, exhaust emissions are an over-riding consideration, a practical steam car, with its good potential in this respect, does seem to be a possibility in the future." The general gloomy tone of this conclusion sounds strange when contrasted with that of the U.S. Senate Commerce Committee Report of 1969, which said "The Rankine cycle propulsion system is a satisfactory alternative to the present internal combustion engine in terms of performance, and a far superior engine in terms of emissions." But it is not so strange, perhaps: when it is realised that the British research paper was the result of a study done especially for General Motors and that GM's permission was necessary for its publication. The British firm (Ricardo & Co) which did the paper is now working on an actual steam engine under a sub-contract for the U.S. Government, a customer who, unlike GM, actually wants to see steam cars put into operation. If Ricardo do build an efficient steam engine, (and they are a highly respected engineering firm with a long history of achievement, so it would be surprising if they did not), it would be only too likely that the results of their expertise would be used by the U.S. Government and completely ignored by our own.

It is a sad and disgraceful fact that the government of this country, a country with the highest vehicle density in the world, has done virtually nothing to control levels of exhaust emissions. While the U.S. legislation to control exhaust pollution has encouraged an enormous amount of research into cleaner fuels, pollution control devices and alternatives to the I.C.E., the British government's attitude on the subject is frighteningly complacent. In cavalier fashion they conclude that while inhaling car exhaust probably doesn't do you any good, no one has yet proved that it does you serious harm over short periods. As Alastair Aird says in his excellent book *The Automotive Nightmare*, this attitude is a little like saying "Well, we know that large doses of this poison are harmful, but nobody's man-

---

[6] *An Exercise in Steam Car Design*, R. M. Palmer, Institute of Mechanical Engineers, Auto Division, Inst. Mech. Eng. Proceedings, Vol. 184, pt. 2A, 1969–70.

aged to prove conclusively that small doses are harmful in the same way. So we'll make small doses of it a part of everybody's daily diet, whether they like it or not." Perhaps the most dangerous of all the poisons in our daily diet—lead—has recently been the subject of Mr. Peter Walker's attentions. But the limits he set on the maximum permitted level of lead in petrol are so feeble that they are less stringent than those of any of the other five countries which have introducd controls on lead. According to the Public Interest Research Centre, the limit will do nothing to reduce the *total* amount of lead emitted from car exhausts, because "the limit set for 1976 corresponds almost exactly with the *average* quantity of lead in all grades of petrol sold today . . . and the advantage to be gained from reducing the average amount of lead in petrol will be totally outweighed by the estimated increase in road traffic over the next few years". Steam engines, it should be remembered emit no lead pollution at all.

In spite of its many environmental advantages, the outlook for the External Combustion Engine at the moment does not seem very promising. The auto industry the U.S. and Britain has little intention of even considering it as an alternative to the I.C.E. in the near future. The ultimate irony is that the steam engine is probably still 20 years ahead of its time.

Mr. BROWER. We also urge the Congress in view of the threat to the world's ozone barrier, to eliminate all SST takeoffs and landings in the United States and its possessions. And in view of the threat to so-called primitive peoples, and to wildlife and wilderness, on land, at sea, or in the air, we urge the Congress to seek global support for prohibition of sonic booms for profit.

PERSONAL OBSERVATIONS

If my own experience is to be of value to the committee, it is probably that which relates to the opinions I have sampled in my travels, for the most part by air, as a working conservationist, here and abroad. One of my own relevant experiences was when I arrived from Nairobi from which I just returned last week. Recent action of the United Nations means that Nairobi is about to become the environmental capital of the earth. I was fortunate to meet Mr. Maurice Strong there as he arrived to prepare the way for the U.N. Environmental Secretariat. Before his arrival I spoke with several Kenyan conservationists, African, and other. I found no enthusiasm for supersonic transport, and it is easy to see why. The uninhabited areas over which it is proposed that the supersonic transports bang their way are, of course, not uninhabited. They are thronged by creatures who have no vote yet in SST circles. Some of those creatures are people, and some of these are what we call civilized. Others are closer than that to living in some kind of balance with their earth.

If we believe we have an energy crisis because we foresee difficulty in doubling our attack on energy resources every decade, consider how they, the people in developing countries who would like to begin to catch up, look upon the SST extravagance. A Washington engineer of great competence assured me that the fleet of 500 Boeing SST's that Mr. Magruder wanted so badly to see built would have been criminally wasteful of fuel. Just for extra speed, those 500 Boeings—compared to the 747 in passenger miles—would use up what happens to equal the predicted drain on North Slope oil that the proposed trans-Alaska pipeline would carry. Moreover, only about one-seventh of that kind of oil is presently refined into jet fuel. It is not likely to be economical to more than double that fraction. But if it were all pure jet fuel, then the convenience of the jet set would cost the world the entire Prudhoe Bay discovery, one of the largest, in less than 2 decades. I would add further, considering the refining ratio mentioned above, we would need to discover five Prudhoe Bays between now and the year 2000 to feed Mr. Magruder's fleet.

To use that kind of energy for that kind of convenience and triviality could not be expected to sit well with people who with a fraction of that resource could bring major advances to their own countries.

A good deal of my jet travel, always subsonic, has come about because of speaking tours, on which I have been able to sample opinions of widely diverse audiences. Quizzes of various kinds, at which audiences vote by a show of hands, have been producing interesting results—particularly in showing the audiences themselves how effective their participation in government can be. It is predominantly against the SST.

To sum up this point, we believe the American public does not want the SST, in spite of all the expensive promotion of it. We believe the public has expressed itself to this effect admirably and expects the Nation's technological skill to be addresed to projects the world needs, not jet-set toys the world already deplores, or soon will if they are not halted in time. We believe that the public still knows that, to be safe, we must resist the beginnings and not wait until so heavy an investment has been made in a mistake that leaders would rather make the public suffer the mistake than admit it.

Since for the past 2 years I have spent almost two-thirds of my time in travel, much of it abroad, I am all too aware of the problems engendered by zone fatigue, or jet lag. They are serious problems, and do not need to be aggravated. I have heard Arthur Godfrey ask: "What good does it do you to get to Paris at 3 o'clock in the morning instead of 6 o'clock in the morning?" No one has better epitomized the misdirection of national talent and energy than the Stanford professor——

Chairman Proxmire. If you mentioned any other city than Paris I believe I would agree with you, Philadelphia, for example. The more I hear of Paris it might make a difference.

Mr. Brower. Or Los Angeles. No one has better epitomized the misdirection of national talent and energy than the Stanford professor who noted how much faster the SST would let one travel from Harlem to Watts. My own feeling is that, no matter how fast a supersonic transport might move me from New York to London, I am almost sure that my baggage would take much longer, and know beyond doubt that my judgment would arrive at the speed of a Cessna.

In conclusion, the world does not need more noise, it needs more serenity.

It does not need to hasten its vanishing oil resources into pollutants at any level, and it dare not endanger the ozone barrier.

The ways of exceeding the radiation to which we dare expose our genes are legion, and we do not need the further exposure likely at SST heights.

Whoever travels fast needs more judgment, not less, upon arrival.

Other nations, particularly developing ones, are not likely to appreciate our joining the less-than-rational SST race, and would surely appreciate our trying to apply our talents to the lessening of the world's inequities.

90-912 O - 73 - 11

Neither we, who are rapidly becoming more and more dependent upon distant sources of oil, nor any other nation can afford to deplete an irreplaceable resource at an immoral rate for a dilettante, status-seeking SST speed game. Oil will have too many far more important uses throughout all the future we can envisage. This generation does not have the moral right, and should not have the gall, to waste this oil on SST's whoever builds them.

Sonic booms are unsound, and in the last analysis, the SST is a loser. Let us keep it lost, and get on with important work.

Friends of the Earth will try to give this committee abundant help in discouraging the administration from reopening a battle that is much too costly in time, in natural resources, and in patience—if that is what the committee decides to do, which we hope it will.

Please put the SST back in Pandora's box and nail the lid shut.

Nearly 15 years ago, before a field hearing conducted by the U.S. Senate in Oregon. I tried to explain what I thought was a goal of the Sierra Club, of which I was then executive director, and I still think it is a goal of that organization, as well as our own, and your own, too:

> We seek a renewed stirring of love for the earth; we urge that what man is capable of doing to the earth is not always what he ought to do; and we plead that all people determine that a wide, spacious untrammeled freedom shall remain as living testimony that this generation, our own, had love for the next.

With no time to spare, we are becoming cognizant of the earth's limits. Mindful of these limits, we may see that progress is not the speed with which technology expands its controls or the rising number of things a man possesses, but a process that lets man find serenity and grow more content at less cost to the earth.

Now, Mr. Chairman, George Alderson, who is the coordinator of the Coalition Against the SST, is present in the hearing room this morning. It is his responsibility to coordinate the effort of citizen groups all over the country which oppose the SST and are dedicated to fighting any revival of the project.

Mr. Alderson has told us that the coalition is prepared to oppose the Aerospace Reconstruction Finance Corporation, proposed by Secor Browne, chairman of the Civil Aeronautics Board. Recent news reports suggest that the aerospace industry sees this finance corporation as a way of reviving the SST.

Secor Browne summed up his proposal in a speech last year—"What I want to see done is get the Government to alleviate that enormous obstacle—negative cash flow."

Chairman Proxmire. It will be helpful to have Browne's statement. He had a statement for this committee, we asked him to testify but he submitted a statement, which is in the record and it is entirely explaining that proposal.

Mr. Brower. So I would like to submit for the hearing record Mr. Alderson's critical summary of the finance corporation proposal, and the Washington Post news story of December 21, "Aerospace Industry To Lobby for Aid Bill."

I would also like to submit a letter from Richard Wiggs, of the British Anti-Concorde project, summarizing current knowledge of the Concorde's noise impact. These documents are here.

Chairman Proxmire. We will be happy to have them for the record.

(The documents referred to follow:)

SUMMARY OF PROPOSED AEROSPACE RECONSTRUCTION FINANCE CORPORATION

(From Coalition Against the SST)

What I want to see done is to get the government to alleviate that enormous obstacle—negative cash flow . . .

SECOR D. BROWNE,
Chairman, CAB.[1]

One possible method of reviving the SST is the proposed Aerospace Reconstruction Finance Corporation, a braindchild of Secor D. Browne, Chairman of the Civil Aeronautics Board. (The CAB is the government agency responsible for regulation of the routes and rates of commercial airlines.) Browne bases the proposal on the same argument we heard often during the 1970–71 SST fight—that the U.S. Government should underwrite the development of commercial aircraft, to prevent other countries from capturing the aircraft-building industry.

Browne explains the role of ARFC as follows:[2]

I would like this aerospace Reconstruction Finance Corporation to undergird the historic process. In that process airlines decide they need an airplane, the manufacturers put forth proposals, the airlines contract for the aircraft, and make down payments, progress payments and final payment. What does the Aerospace Reconstruction Finance Corporation do? It simply guarantees the loans, guarantees the risks of those portions of that process which are beyond the resources of prudent management either of airline or manufacturers.

In another speech, Browne elaborated on this:[3]

Probably appropriations would not be necessary. I am sure that the private sector can put up the money, but the private sector cannot pay for the risk because of the magnitude involved in such programs. I think the Aerospace Reconstruction Finance Corporation by guaranteed loans and by policy of accelerated depreciation can encourage replacement of aircraft, and by help in the support of interest rates could make programs come to life which otherwise would not exist.

Browne also urges that the ARFC not get involved in the technical decisions—they would be left up to the manufacturers.

The proposal boils down to this: The government takes on the risk, without any supervision over the technical aspects of the project. The aircraft company builds the plane, without the constraint of having to pay the tab if some of its technical decisions come out wrong. When a new plane doesn't sell, the government appropriates the money to pay off the banks that financed the project. In such a case, it's like the original SST setup, except that the government pays at the end, instead of throughout the development process.

Browne says, "Senator Magnuson wrote me a letter asking me to keep talking the subject up, keep trying to create interest. I have heard from both sides of the aisle."

No legislation has been introduced on this subject, to our knowledge, but it could be written to go to a favorable committee, such as Magnuson's Senate Commerce Committee.

[From the Washington Post, Dec. 21, 1972]

AEROSPACE INDUSTRY TO LOBBY FOR AID BILL

The Aerospace Industries Association—the trade group for the major commercial and military aircraft manufacturers—will push legislation in the next session of Congress to provide up to $3 billion worth of government support for new commercial aircraft, such as a supersonic transport or STOL (short takeoff and landing) aircraft.

Under the legislation, the government would provide either direct loans or guarantee private loans to aerospace firms preparing new aircraft. The money could be used for design development and production.

Karl G. Harr Jr., president of AIA, said that the government funds could only be used to finance "totally unborn projects"—not derivatives of current planes. He didn't disclose details, but presumably, "stretched" versions of current aircraft wouldn't qualify.

Harr indicated that the legislation—he said that no potential Congressional sponsors had yet been contacted—would face strong opposition in Congress. Aero-

[1] Browne's speech of November 22, 1971, before the Dallas Chamber of Commerce, Dallas, Tex.
[2] Browne's speech of January 17, 1972, before the Economic Club of Detroit.
[3] Browne's speech of December 16, 1971, before the Downtown Rotary Club of Houston.

space firms have argued that the huge amounts needed for new commercial planes, totaling hundreds of millions, can't be raised privately, and that U.S. companies need government support to compete with firms and their new aircraft.

Frequently mentioned European planes are the Concorde (a supersonic aircraft) : the A–300 B (a two-engine, jumbo "air bus") ; and the Mercure (a larger aircraft similar to the DC–9 and Boeing 737).

In a speech to the Aviation Writers Association, Harr also said the money could not be used to support the development of planes that would compete with existing models built by other U.S. firms. Nor, he said, would the legislation allow the funds to aid "weak sister" firms in financial trouble.

In his speech, Harr also disclosed that total sales of aerospace firms rose 5.9 per cent in 1972 to $23.5 million, the first increase since 1968; he predicted, however, that sales next year would decline slightly to $22.5 million. Employment dropped from 924,000 to 917,000 in 1972; he said it would slip to 913,000 in 1973.

THE ANTI-CONCORDE PROJECT,
October 14, 1972.

Senator ALAN CRANSTON,
Senate Office Building,
Washington, D.C., U.S.A.

DEAR SENATOR CRANSTON: Your amendment to the Environmental Control Act, requiring SSTs to conform to airport noise levels prescribed for subsonic aircraft, has made front-page news in the London *Times* and *Daily Telegraph* today.

The *Telegraph* quotes the comments of Mr. Pat Burgess (sales director of the Concorde project) that:

"Concorde already met current international standards for subsonic jet planes, but it did not meet American legislation. It was, however, within three decibels of meeting their requirements on noise from the side of the plane and within five decibels on noise from underneath on take-off and landing approach."

I assume that Mr. Burgess was referring to the noise levels of the production Concordes (not the portotypes) ; and I am now able to give you further information from an official source on the predicted noise levels of the production Concordes, which is very much at variance with Mr. Burgess's claims.

Recently Mr. Cranley Onslow, M.P., Parliamentary Under-Secretary of State for Aerospace at the Department of Trade & Industry, invited me and other representatives of associations concerned with aircraft noise to visit the National Gas Turbine Establishment, Pyestock, Farnborough "to see some of the work . . . and to discuss the national noise research programmes which are monitored by NGTE on behalf of DTI". This visit occupied a whole day. The latter part of it was a discussion between the visitors and several members of the staff of the NGTE, notably the Director (Mr. Ivor Davidson) and the Head of the Acoustic Aerodynamics Department (Mr. F. W. Armstrong) ; two representatives of the Department of Trade & Industry were also present. During the discussion, in reply to questions from Mr. Armstrong stated that the "commitments" written into the Concorde sales contracts are that commercial Concordes will comply with these noise levels:

Take-off 113 EPNdB Approach 117 EPNdB

When asked for the PNdB equivalents of these figures, Mr. Armstrong stated that they are:

Take-off 114 PNdB Approach 125 PNdB [1]

The international standards for new *subsonic* aircraft of Concorde's weight are:

Take-off 105 EPNdB Approach 107 EPNdB [2]

Thus the contract "commitment" levels for commercial Concordes exceed the international Certification Standards for new subsonic aircraft of equivalent weight by 8 dB (take-off) and by 10 dB (approach). This signifies a *noise energy output* from Concorde almost 10 times as great as that of an aircraft conforming

---

[1] I expressed surprise at the large difference of 8 dB between the PNdB and the EPNdB figures for the approach noise. Mr. Armstrong confirmed that there is an "allowance" of 8 dB on Concorde's approach noise; he added that the justification for this is that "the peak noise is of very short duration".

[2] The international standards for the *largest* new subsonic aircraft are 108 EPNdB on both take-off and approach.

to the standards (which means that one Concorde taking-off or landing would make as much noise as the simultaneous take-off or landing of about 8 or 10 aircraft conforming to the standards). (The noise level of the Lockheed Tristar on the approach is 102 EPNdB. Concorde at 117 EPNdB would produce as much noise as the simultaneous landing of 30 Tristars).

The main noise problem with Concorde is the noise during the approach to land. The noise levels of the prototype Concordes are, as you know, substantially higher than the "commitment" levels for the commercial models.

Mr. Geoffrey Holmes (Technical Director of The Noise Abatement Society, London) has twice measured the approach noise of Concorde prototype 002 at its base at Fairford. The readings were 131 and 135/137 PNdB. In Australia a research team directed by Mr. Louis Challis measured Concorde 002 on the approach, at 132 PNdB. (All these measurements were taken at the standard measuring point, one nautical mile before touchdown). Mr. Armstrong, at the NGTE, produced a chart showing noise levels as Concorde 002 approached Heathrow airport (London) on its return from Australia. At the standard measuring point the level was 129/130 PNdB.

The Concorde's poor aerodynamic performance at low speeds has important consequences. Concorde has to approach to land in a nose-up, tail-down posture, under high engine power. Its condition in this phase is unstable, and in order to maintain control, constant adjustments of engine power are required: the engines (under automatic control) produce a series of "surges" alternating with throttlings-back. The chart seen at the NGTE showed that on July 1, when the reading of 129/130 PNdB was obtained at the standard measuring point, the Concorde was not at that moment at the peak of a "surge".

The staff at the NGTE (which establishment, as Mr. Cranley Onslow wrote, monitors the U.K. national noise research programmes on behalf of the government) said that the design of the commercial Concorde engine is "now virtually frozen"; and that they consider that the noise-attenuation mechanisms which will be fitted to the commercial Concordes may give a reduction (below the prototype noise levels) of 7 dB.

The very important question arises whether the "commitment" level of 117 EPNdB (125 PNdB) is a top limit or some sort of average? If it is a top limit then there seems to be some doubt whether a reduction of 7 dB below the prototype noise levels will be sufficient. If it is an average, then by definition it will frequently and routinely be exceeded. On 4 September (4 days after the visit to NGTE on August 31) I wrote to Mr. Armstrong asking this and other questions. I have received an acknowledgement but, as yet, no reply.

The Advisory Committee of The Anti-Concorde Project and our supporters will join me in congratulating you upon your Amendment and upon the very substantial vote in its favour in the Senate. Both the Amendment and the vote are clear expressions of informed public opinion in the U.S. We are confident that U.S. citizens will not tolerate either the noise of Concorde at airports, or its sonic bang.

U.K. citizens living near Heathrow airport will be especially grateful to you for your efforts, since if the result is to keep Concorde off the North Atlantic routes, the people beneath the Heathrow flight paths will be spared an enormous amount of noise (and the fact may be noted that Concorde operation on the North Atlantic must entail night landings or take-offs at one end or other of the route).

I will send copies of this letter to Representatives Sidney R. Yates and Henry S. Reuss (both of whom I met in Washington in March 1971 when I submitted statements to the subcommittee hearings on the SST of both the Senate and the House) in the hope that some of this information may be useful when your Amendment is considered by the joint Senate/House conference.

Yours sincerely,

RICHARD WIGGS, *Secretary.*

Chairman PROXMIRE. Your timing is perfect. Incidentally, I want to say that George Alderson—legislative director of Friends of the Earth—certainly was a major factor, and I mean a major factor, in stopping the SST. I led the fight against it on the floor of the Senate and we relied very heavily on Mr. Alderson, and he was absolutely invaluable, not only to us in the Senate but to those in the House where we were also successful.

Mr. BROWER. Thank you very much. I would also like to submit—I do not know whether it has come to you—a full page Anti-Concorde ad in the Times December 4.

Chairman PROXMIRE. We would like to have it very much.

(The Times article follows. See fold-in facing this page.)

Mr. BROWER. It seems to me it would be nice to have the record left open so that somehow a group of us can get together to add to this record the highlights of what has gone before.

Chairman PROXMIRE. Yes; there is another purpose, too, in all fairness. This is a record that will be loaded, at least as far as oral appearance is concerned, on the part of opponents of the SST. We would like to incorporate not only Mr. Secor Browne's statement but any statement we can get from proponents of the SST so the record will remain balanced. It will remain open for you.

Mr. BROWER. We might come up with recommendations that we have not yet thought of. One that occurs to me is the new stance we must take that you must read things with one eye closed so you can discern the hidden information and close one ear so you can understand half truths. We need some way to assist the legislative arm of the Government in getting the information. The present adminstration apparently does not wish to give it. The press itself is already having a rough time in getting information out. I believe it is now being bullied, and now when I find the administration will not come on invitation and talk to a committee of the Congress, I get rather alarmed. It seems to me that maybe the citizen organizations will have a new and different role. They can play it quite well if some means can be found to get them a little bit of financial support—they are all very poor—to enable them to do the job that the executive branch seems not to want to do in the public interest.

Chairman PROXMIRE. Well, we welcome this. It is a good suggestion, and we will keep the record open until January 15. We would keep it open longer except we do want to have a report and we do want to print our hearings so they will be available to Members of Congress as they return.

I am especially impressed by the emphasis you gentlemen gave the relatively new argument that the advent of a large fleet of SST's would seriously aggravate the oil shortage. You point out the fuel consumption of air travel even at subsonic speeds is greater than the passenger miles traveled by train or automobile, and the SST would be far worse. Can you give us any qualification of this so we can assess how serious an argument this would be if we proceed with the SST? They tell us that it will be at least 25 years, if not more, before we have a substitute for oil that is workable. Most of our energy needs cannot be supplied by the oil we have or will have. We know we are very dependent already on overseas shipment of oil. How would a development of the SST, say, beginning next year or the year after that, with SST's flying in substantial numbers, say, 8 or 10 years from now—how would that affect the oil shortage?

Mr. BROWER. Well, in one round number we just worked out yesterday, when Larry Moss, an engineer, and I were playing with numbers: The SST eats up its own weight in fuel on every trip, and they make many trips.

ADVERTISEMENT

The Anti-Concorde Project

CONCORDE—1962-1972

IS IT ALREADY OBSOLETE?

Concorde's development bill, if the project continues, will be £1,000,000,000—irrecoverably spent on an aircraft

- **which makes an intolerable, damaging sonic bang;**
- **which makes unacceptable noise at airports;**
- **which would be unprofitable to operate;**
- **which would produce only slight benefits;**
- **which in terms of both aircraft capacity and environmen:al acceptability, is already out of date;**
- **which, in any normal commercial sense, is unsaleable.**

After years of effort by the Concorde sales teams and after two international Concorde sales tours, the only orders for Concorde are those of the " captive " national airlines of Britain and France—and these orders are backed by government guarantees and government (i.e. taxpayers') money.

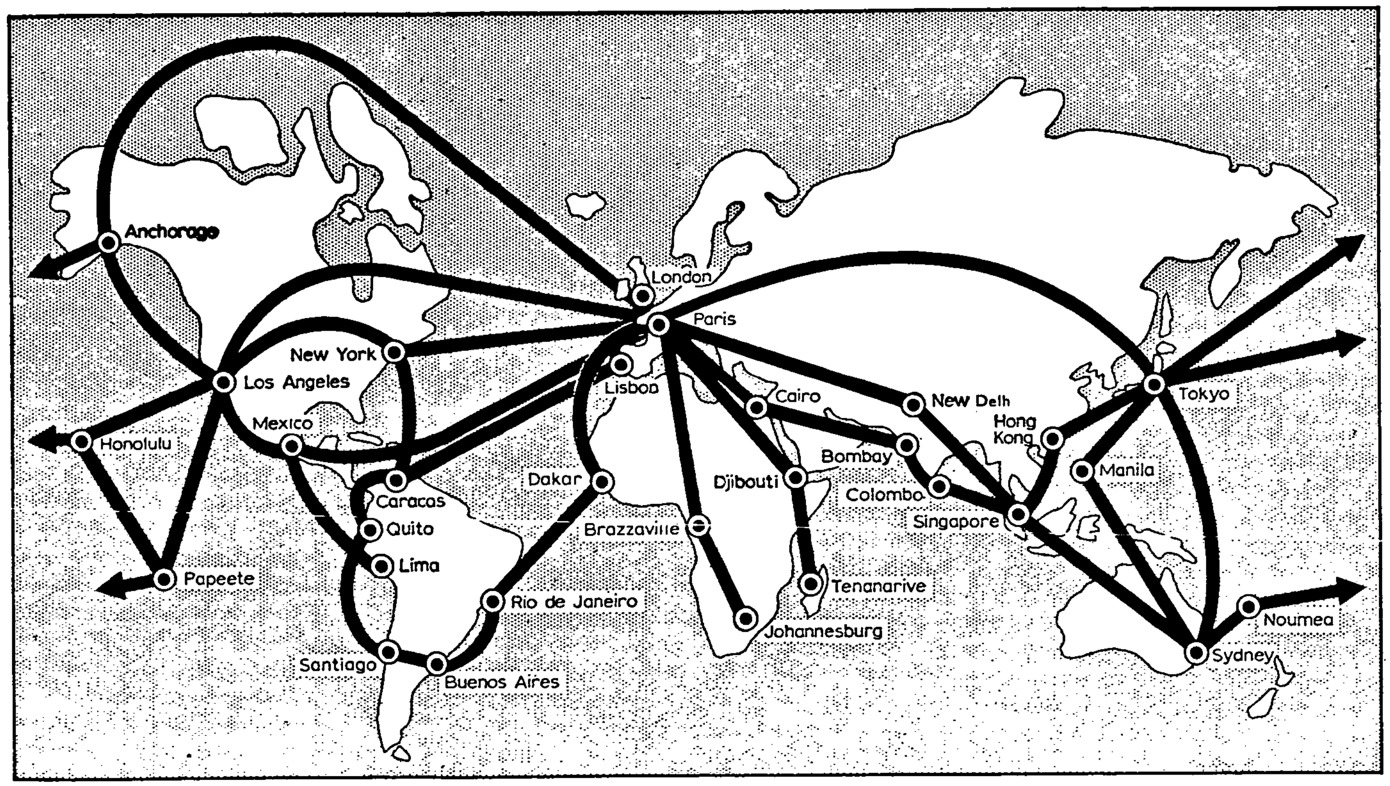
The much-publicised Concorde " orders " of Iran and China are apparently no more than letters of intent.

Recently Air Canada has cancelled its 4 Concorde options and United Air Lines has cancelled its 6 options. The President of Sabena has said that his airline " has given up all thoughts of buying Concorde " (*Financial Times* 25 Sept. 1972). Lufthansa " has no intention of exercising its three options " (*The Times* 8 Aug. 1972). Swissair " has no intention of buying the Concorde " (*The Times* Aug. 4 1972). The president of the French airline UTA has said that his company " had decided against buying the Concorde " (*The Times* Sept. 14 1972). Japan Air Lines and Qantas have requested postponement of the date for deciding whether to confirm their options. 32 of the surviving Concorde options are with 6 U.S. airlines—most of which have very negative attitudes towards Concorde. Spokesmen for Pan Am and TWA have expressed serious doubts about Concorde's profitability and its environmental acceptability (1).

" Mr Knut Hammarskjold, the director-general of IATA, has said that he doubts if the . . . Concorde aircraft is really what the airlines need " (*The Times* Aug. 1 1972)

The orders from BOAC and Air France are less representative of world airline attitudes to Concorde than are the cancellations—for hard commercial reasons—by Air Canada and United Air Lines.

There are no willing purchasers of Concorde, but development and production continue. On November 24 1972 the British Government announced that " loans " possibly amounting to £700m. will be required for the production programme. This is in addition to the £1,000m. development costs (which are irrecoverable). There is no evidence that sufficient Concordes can be sold to enable repayment of the production " loans ". There is abundant evidence that the commercial operation of Concordes would be both unprofitable to the airlines and environmentally unacceptable. (2, 3)



Supersonic routes proposed by the makers of Concorde (redrawn from maps in BAC/Aerospatiale publicity material, 1972).

SST development was started on the assumption that the sonic bang would be " accepted ". What this really meant was that people on the ground would have no option. Since it became clear that this assumption was ill-founded, the advocates of SST have produced statements along two completely different lines. One set of statements is intended to reassure the public and the politicians. The other set is intended to sell Concordes. The total contradiction between them in our view deprives Concorde's makers of all claim to credibility.

On the one hand Concorde's makers, assert that it will not be flown supersonically over inhabited land.

In the summer of 1971 the Committee on Economic Affairs and Development of The Council of Europe organised a Round Table to discuss Concorde. This included " representatives of the Aerospatiale/British Aircraft Corporation Consortium responsible for its development led by General André Ziegler, Chairman and Managing Director of the Aerospatiale ". The Committee reported: " it was made absolutely clear at the Round Table that nobody (including the Consortium constructing Concorde) envisaged the operation of the aircraft at supersonic speeds over inhabited land areas ". (4)

And on BBC2's television " Controversy ", 19 September 1972, Dr Stanley Hooker, Technical Director of Rolls Royce (makers of Concorde's engines) said: " Concordes are being sold on the predication that they will not be flown overland at supersonic speed ".

On the other hand the maker's sales efforts are based upon the assumption that Concordes will extensively fly supersonically over land.

This is shown by the map above. That Concorde's makers are indeed trying to promote *supersonic* operations even on the *overland* routes is proved by the flight times and " time-savings " quoted in their recent publicity material:

	Flight time in hours	
	Subsonic	Concorde
London-Johannesburg	12.10	7.30
London-Sydney	26.30	15.00
London-Singapore	17.45	10.00
London-Tokyo (via Moscow)	14.4	6.45

The ANTI-CONCORDE PROJECT is part of a world movement opposing all supersonic airliners.

Advisory Committee :

Dr. John G. U. Adams, M.A., Ph.D.
Professor G. V. R. Born, F.R.S.
Dr. N. F. Coghill, M.A., F.R.C.P.
Dr. A. W. F. Edwards, Sc.D.
Mr. C. B. Edwards, B.A., A.C.W.A.
Mr. Arthur Koestler.
Professor Sir Nevill Mott, F.R.S.
Dr. R. M. S. Perrin, M.A., Ph.D.
Mrs. Wendy Perrin
Dr. J. R. Ravetz, Ph.D.
Professor H. E. Rose, D.Sc.(Eng.).
Dr. William A. Shurcliff, Ph.D.
Professor C. A. B. Smith, M.A., Ph.D.
Dr. Peter J. Smith, B.Sc., Ph.D.
Baroness Stocks, LL.D., Litt.D.
Professor W. H. Thorpe, F.R.S.
Professor N. Tinbergen, F.R.S.
Mr. John Vinelott, Q.C.

International Associate

Dr. Bo Lundberg, Fellow of the Royal Aeronautical Society, Hon. Fellow of the American Institute for Aeronautics & Astronautics, former Director-General of the Aeronautical Research Institute of Sweden.

Secretary : Richard Wiggs, 70 Lytton Avenue, Letchworth, Hertfordshire. Telephone : 046 26 2081.

Assistant Secretary : Nigel Haigh, M.A.

Bankers : Lloyds Bank, Letchworth.

Accountants : Bradshaw Johnson & Co., Hitchin.

Affiliated to :

Association Nationale contre les Bangs Supersoniques (Paris).
Citizens' League against the Sonic Boom (U.S.A.)
The Conservation Society.
Coalition against the SST (U.S.A.).
European Union against Aircraft Nuisance.
Federation against Aircraft Nuisance.
The Noise Abatement Society.
Project to Stop the Concorde (Australia).
Town-Village Aircraft Satety and Noise Abatement Committee (U.S.A.).

WHY THE AIRLINES DO NOT WANT CONCORDE

Economic reasons

Concorde was designed to compete with the subsonic jets of the early 1960s—the 707, DC8, VC10. Even this hope was ill-founded. But while the Concorde remains a design of the early 1960s or even the 1950s, subsonic air transport is now dominated by a new generation of aircraft with which, in impor-tant respects, it is grossly uncompetitive. For example, compared to the new sub-sonics Concorde's *purchase* price per seat is about 10 times as high; its *operating costs per seat-mile* are twice as high; its *fuel consumption* per seat-mile is 3 times as high; its *range* is not much more than half; while its *payload* is only a quarter. The selling price per Concorde was esti-mated in the early 1960s (when the airlines took their options) at £3m. to £4m. This has risen to £23m. Meanwhile the payload of Concorde has dropped from 136-146 (Jane's Aircraft, 1966) to 100-108.

Environmental unacceptability

The SST (supersonic transport) projects were started upon the assumption that the environmental ill-effects of SST operation would be "accepted". Even at the time this view was authoritatively challenged; and in the 1970s these ill-effects will not be tolerated.

To the problems of sonic bang and high airport noise has now been added the further problem: would pollution of the stratosphere by SSTs have harmful results?

More cancellations?

The poor economics and the environmental ill-effects of Concorde (and of any similar aircraft) are great obstacles to their com-mercial operation. Advocates of supersonic transport claim that these obstacles will be overcome, but the environmental problems are inherent in the operation of such air-craft and are insoluble, and the economic problems can be overcome only by subsidy.

The environmental ill-effects have serious economic consequences. The most obvious is the fact that the SSTs will be almost entirely forbidden to fly over land at the speeds for which they were designed.

The New York Times (27 October 1972), re-porting the cancellation by United Air Lines of its six Concorde options, stated:

"There has been some doubt about United's going-ahead with plans to buy the Concorde since environmentalists' protests over sonic booms began to win political support in recent years", and that on United's only overseas routes (California-Hawaii) "com-pany analyses indicated that there was no hope of operating the Concorde in an economically viable service".

Le Monde (28 October 1972), reporting the United Air Lines cancellation, commented: "Concorde becomes each day more of an encumbrance and more difficult to sell", and predicted that other airlines will adopt the attitude of United and will cancel at least some of their options.

Basic problems

The main reason for the poor economics and the environmental ill-effects of Con-corde and any similar aircraft is the *wave drag* that is encountered by any object forced through the air at supersonic speed. An SST requires far more power than a subsonic aircraft of similar size; this results in the poor payload and range and high fuel consumption referred to above. The SST, forcing through the air against the wave drag, generates throughout the entire length of supersonic flight a shock-wave: the now-notorious sonic bang.

The sonic bang results in restriction of over-land supersonic flight; which greatly restricts SST operations and reduces their competitiveness with subsonic aircraft.

The need to reduce wave drag produces the characteristic design shape of the SST; but this shape results in poor aerodynamic performance at low speeds. Therefore the SST approaches to land in a nose-up, tail-down posture, under high engine power. This results in high noise levels under the approach paths to airports. High power is also required for take-off: Concorde uses its "afterburners", which results in high "sideline" and take-off noise levels. To minimise drag the SST must operate at much higher altitudes than subsonic aircraft. This produces the risks consequent upon stratospheric pollution.

Most or all of these facts (with the possible exception of the risks consequent upon stratospheric pollution) were—or should have been—known to the designers of Concorde. Why were the facts disregarded? Further important consequences follow from the facts stated above. For example:

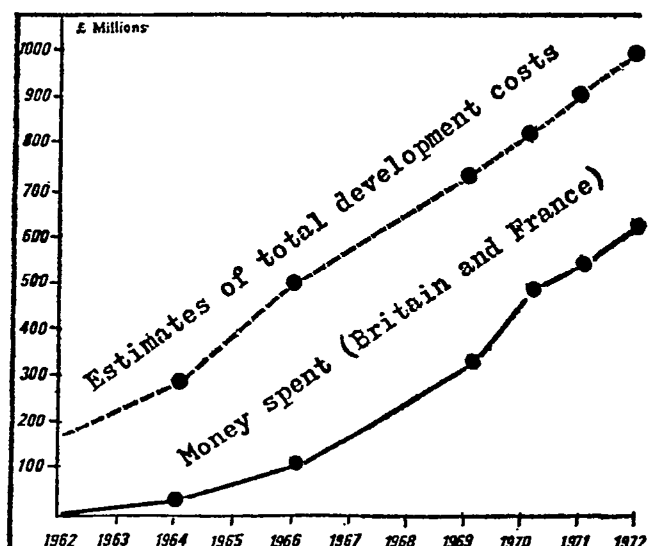
The high purchase price, small payload and high operating costs of the SST must result in a loss to the operator, compared to the return on equal capital invested in subsonic aircraft (and most airlines have been losing money on their subsonic opera-tions). The same factors must also result either in SST fares much higher than sub-sonic fares, or, for SST fares to be kept down, in subsidies—either from subsonic fares or, via government intervention, from taxpayers.

The very high purchase price of the SST makes the obtaining of maximum produc-tivity an extreme necessity. The SST must make more trips per day than a subsonic aircraft. But any attempt to schedule SST operations produces impractical or impos-sible results. For example, as Capt. G. C. McGilvray (chairman of the Technical Com-mittee of IATA) pointed out during IATA's recent London conference (reported in *Flight*, 5 Oct. 1972): with Concorde the night flight from New York to London must either start very late (say 2300 hrs) or arrive very early (say 0400 hrs). Both alternatives infringe curfew hours. Both are unattractive to passengers (how many people would pay premium fares to arrive in London at 0400 hours after little or no opportunity for sleep?).

Capt. McGilvray also pointed out that on the trans-Pacific route, assuming curfews in force at all points (Sydney, Fiji, Honolulu and Los Angeles), no departure time from Sydney could be selected which would allow Concorde to make the flight without infring-ing a curfew. The same applies to the route London to Sydney.

On long routes (with refuelling stops) that are partly subject to overland supersonic flight restrictions, the flight time by Con-corde would be little or no less than the flight time by long-range subsonic aircraft. An example is London-Sydney: assuming that this route was not made impossible for Concorde by night curfews at airports but that some overland sectors were subject to "sonic bang bans" the flight time by Concorde would be about the same as that of a subsonic aircraft making one inter-mediate stop—about 20 hours.

All these facts are known to the airlines. They explain the lack of orders for Con-corde. They also explain why the U.S. SST project was cancelled last year.



THE COST OF CONCORDE

Since 1964 the estimated total costs of development *have been consistently* £300,000,000 *to* £400,000,000 *more than the amount already spent at the date of estimating.*

At the time of the most recent estimate, May 1972, £630m. had been spent. Future spending on development was then estimated at £340m.—twice the original (1962) estimate of total development costs. (5)

The estimated total *development* cost of Concorde is now £970m. None of this can be recovered.

On 23 November 1972 the British Govern-ment published a Bill to authorise loans of up to £350m. to finance the *production* stage. A similar amount from the French Government will bring the total to £700m. This is additional to the development costs.

On 27 May 1972 the British Minister for Aerospace announced the provision of £115m. of "public dividend capital" to BOAC to finance its purchase of 5 Con-cordes. Air France's purchase of 4 Concordes is being financed by the French Government.

The total investment of British and French taxpayers' money in Concorde—develop-ment, production, and purchase by the national airlines—could thus even on present estimates eventually be almost £2,000m.

In October 1972 Mr John Davies, then Secre-tary of State for Trade & Industry, announ-ced that "the government intended to take powers to intercept those who sought by abusive practices to gain unjustified profit from the public" (*The Times* 14 October 1972). Mr Davies' successor, Mr Peter Walker —who, as former Secretary of State for the Environment, should be aware of the dis-advantages of SSTs—should inaugurate this new policy in his new department by stop-ping the payment of £5,000,000 per month to a project which has already taken more than £300,000,000 of British taxpayers' money—and which if it is not prevented, may take twice as much again.

WHY SUPERSONIC AIRLINE OPERATIONS ARE ENVIRONMENTALLY UNACCEPTABLE

Sonic Bang

Compensation payments for sonic bang damage in areas beneath the Concorde's Irish Sea test route now exceeds £35,000. There have been 8 flights along the whole route and 12 more on parts of it. Nine of the flights have crossed Cornwall, *where compensation payments exceed £9,000—an average of more than £50 per mile per flight.* In the U.K. the insurance industry has intro-duced "sonic bang exclusion clauses" into various classes of policy to remove the com-panies' liability. Presumably liability to pay compensation for sonic bang damage would devolve upon the airline whose SST had caused the damage. The advocates of super-sonic transport have refused to face the problems both of identifying the aircraft and airlines responsible and of processing the large numbers of claims that would result from supersonic operations overland.

Damage is not the only effect of the sonic bang. The intensity of the bang varies greatly over short distances on the ground; many people who have heard Concorde's bang at its more intense levels have said that it is by far the loudest noise they have ever heard.

Any government considering allowing super-sonic flight corridors over its territory should not underestimate the disturbance and damage that would result. Any airline considering supersonic operations overland should note the fact that the compensation of £50 per flight-mile paid in Cornwall exceeds the fare revenue of Concorde (assuming fares double the standard sub-sonic rates, and every seat sold) by a factor of 10.

Throughout the early years of Concorde's development its makers and sponsors assumed that the sonic bang would be "accepted". What they were really assum-ing was that people on the ground would have to accept the bang because they would have no option.

It is now certain that in countries where there is effective expression of public opinion the SST sonic bang will not be tolerated. A complete ban on overland supersonic operation would immediately be fatal to the commercial pretensions of the SSTs, so Britain, France and Russia are aiming to establish supersonic routes over various parts of the world (sometimes described as "sparsely populated") whose inhabitants, it is assumed, would have no option but to "accept" the bangs. Over-land supersonic operations must mean sonic bangs by night as well as by day—an in-supportable imposition upon any people, however "sparsely" distributed. The advocates of supersonic transport have pro-duced no adequate reply to questions about the effects of sonic bangs—including the "superbangs" generated during supersonic acceleration—upon people on ships.

Airport noise

Concorde's makers and their supporters have made many statements about the air-port noise levels of commercial Concordes that are far from correct. For example: "Mr Pat Burgess, sales director for the Anglo-French project, said last night that Concorde already met current international standards for subsonic jet planes. . . ." (*Daily Telegraph*, 14 Oct. 1972).

But the manufacturers' "target" landing noise level for the production Concordes is 115 EPNdB, while the international approach noise certification standards for new sub-sonic aircraft of Concorde's weight is 107 EPNdB (for the largest new subsonics, 108 EPNdB). Concorde at 115 EPNdB would produce as much noise as 6 aircraft con-forming to the limit. (The Tristar on the approach to land produces 102 EPNdB. Concorde at 115 EPNdB would make as much noise as about 20 Tristars landing simultaneously).

The President of the Airport Operators Council International wrote to the U.S. Secretary of State for Transportation on 6 July 1972: "A major concern of airport operators is that there are *no* noise stand-ards for supersonic aircraft at this time. . . . We urge that noise standards for supersonic airplanes be issued now and that these standards be identical to the standards which are in effect for subsonic airplanes in the same weight category. We believe that the issuance of these standards, at this time, is imperative."

On 13 October 1972 the U.S. Senate voted 61 to 17 in favour of SSTs having to comply with the same noise standards as subsonic aircraft. On this occasion the House adjournment occurred before action could be taken, but no doubt the proposal will be made again.

Exclusion of Concorde from U.S. airports would deny to Concorde the field of opera-tion—the north Atlantic—which is most vital to its commercial pretensions, and for which it was designed.

Upper Atmosphere Pollution

There is substantial scientific support for the hypothesis that destruction of strato-spheric ozone by SST exhausts would result in harmful ultra-violet solar radiation pene-trating to ground level. If this hypothesis is confirmed this will override all the other arguments surrounding the SSTs. In the context of such serious risks the operation of fleets of SSTs could not be permitted.

Concorde's makers claim that "there is little evidence to support the forecasts that SSTs will disturb the stratospheric balance" ("*Concorde. First airline orders*" BAC/ Aerospatiale. Sept. 1972). They appear to be unaware that in a case so serious, even a little evidence must be taken very seriously.

This matter was proposed by the Council of Europe and by the Scandinavian countries for discussion at the U.N. Conference on the Human Environment at Stockholm, June 1972, but this discussion was prevented by Britain and France.

The National Academy of Sciences of the U.S.A. appointed an Ad Hoc Panel on Nitrogen Oxides and the Ozone Layer. The Panel's Summary Report (1972) states: "There was general agreement with the conclusions of Johnston and of Crutzen that the introduction of nitrogen oxides from SST exhausts can have important effects on the ozone concentration." In August 1972 the U.S. Department of Transportation awarded $400,000 in research contracts to Professor Harold Johnston for investigation of the effects of aircraft operation in the stratosphere.

(1) *Airlines' Attitudes to Concorde.* The Anti-Concorde Project. (revised edition, in preparation).
(2) Lundberg, Dr B.K.O. *Economic and social aspects of commercial aviation at supersonic speeds.* International Council of the Aeronautical Sciences, Paper no. 72-51. Sept. 1972. (From The Anti-Concorde Project, 20p + 4p postage.)
(3) Lundberg, Dr B. K. O. *Concorde Economics* BL memo 26. November, 1972 (reprinted by The Anti-Concorde Project.
(4) Council of Europe. *Report on the economic implications of the introduction of civil supersonic aircraft* (Rapporteur: M. de Grauw). 11 January 1972. Doc. 3072.
(5) Edwards, Chris and Liz. *Concorde—ten years and a billion pounds later.* The Pluto Press, Nov. 1972. (From The Anti-Concorde Project, 30p + 4p postage.)

WHY HAS THE CONCORDE PROJECT NOT BEEN CANCELLED

Both the economic and the environmental cases against Concorde are so strong that either provides more than sufficient reasons for cancellation.

Against cancellation are opposed these arguments:

1 We've spent so much, we can't stop now.
2 We'll overcome the difficulties.
3 Nations need prestige projects.
4 Cancellation would put people out of work.

(1) is clearly nonsensical. We have already dealt with (2)—many of the difficulties are simply insoluble. (3) It appears that the pro-duction at an immense financial loss of a number of anti-social and unsaleable aero-planes is not likely to produce much prestige. As to (4) the fact that 50,000 people are em-ployed in two countries in making unwanted Concordes is the responsibility of the spon-sors of the project and of the successive governments which have continued to sup-port it. This employment cannot reputably be advanced as a reason for continuing to make Concordes and forcing them upon un-willing airlines.

Transfer of the money allocated for future spending on Concorde to more useful pur-poses would create other, more socially desirable, employment.

If only a small number of Concordes can be sold (for example, 30, as suggested by the former Minister for Aerospace, Sir Frederick Corfield, on BBC radio, May 5, 1972) then the work will soon be tailing off and the redundancy of the Concorde workers will not long have been delayed.

WHAT HAS THE OPPOSITION TO THE SSTs ACHIEVED?

Opposition to supersonic transport developed from the work of Dr Bo Lundberg, the former Director of the Swedish Institute for Aviation research. The Anti-Concorde Project was founded in 1966; the Citizens' League against the Sonic Boom in the U.S.A. in 1967. They have worked in close co-operation with each other and with Dr Lundberg. They have supporters in more than 30 countries, in some of which new, affiliated, anti-SST groups have been formed. There is in effect a world cam-paign against the SSTs.

As a result of the publicity given to the effects of SST sonic bangs, several countries have prohibited SST overflying or have stated that they will do so if SSTs enter commercial operation. These countries in-clude Canada, Denmark, West Germany, Eire, Japan, The Netherlands, Norway, Sweden and Switzerland. There can be no doubt that the U.S.A. will prohibit super-sonic overflying. These actual and poten-tial prohibitions have had drastic effects upon potential supersonic commercial opera-tions, and therefore upon the SSTs' sales prospects.

As a result of the publicity given to the high airport noise of the SSTs, the makers of Concorde belatedly (in 1969) began trying to find ways of reducing its noise. This has resulted in delay to the development pro-gramme, in cost rises, in increased aircraft weight and therefore in reduced payload/ range, and in diminished sales prospects.

The anti-SST campaign has revealed the SSTs as examples of runaway technology, of misplaced national priorities, of ill-con-ceived status-seeking, of gross and purpose-less extravagance, of political subservience to commercial pressure-groups. Indeed the SSTs have come to symbolise these things.

Concorde and the Russian SST attended the Hanover Air Show in April 1972. In response to public protests they were banned from making demonstration flights. International anti-SST action helped to turn Concorde's June 1972 trip to Australia and Japan into a fiasco.

The decisions of Air Canada and United Air Lines to cancel their Concorde options were to a large extent consequences of the developing understanding of the problems and ill-effects of SST operation. This under-standing has resulted from the anti-SST campaign. More cancellations are expected. **Most spectacular of all: in 1971, after a tremendous campaign, the U.S. SST project was scrapped.**

WHAT NEEDS TO BE DONE

Although the commercial prospects for supersonic transport are dwindling nearly to vanishing point, its advocates are not admitting defeat.

Britain and France have already embroiled their national airlines with Concorde. Britain, France and the U.S.S.R. are plan-ning to involve other countries in various deals involving supersonic flight "corri-dors" overland. They have the support of the U.S. SST lobby, which uses the "chal-lenge" of "foreign SSTs" as the main justification for demanding a new U.S. SST project.

Most of the airlines which are potential purchasers of Concorde are well aware of its poor economic performance. Some of the airlines are well-informed about its environmental ill-effects but much more work in this field is necessary.

The British Airways Board has had "in-tensive discussions with Russian representa-tives" concerning "a pooled supersonic airline service spanning two-thirds of the globe and jointly involving Britain, France, the Soviet Union and possibly Japan, (which) could force United States carriers to enter the supersonic race, Mr David L. Nicholson, chairman of the British Airways Board, has predicted" (*The Times Business News*, 7 October 1972). Mr Nicholson said he expected the talks to lead to agreements to operate Concorde and the Russian SST between London-Moscow-Tokyo and Paris-Moscow-Tokyo. It is clear that the spon-sors of both SSTs are intent upon super-sonic operation overland.

The British Government has persistently refused to give any undertaking that com-mercial supersonic flights will not be per-mitted over the U.K. The Government must again be warned that such flights will not be tolerated. It must be warned not to enter into reciprocal arrangements whereby super-sonic operating rights over other countries are traded against similar rights over the U.K.

The idea that the "supersonic age" is inevitable—even that it is desirable—per-sists. There are those who believe that the present Concorde is only moderately (and not grossly) uneconomic, and that the pro-blems of commercial supersonic transport would be overcome by the development of a larger Mark II Concorde, or by the re-vival of the larger U.S. SST. These ideas ignore the facts that the environmental ill-effects of a larger SST would be worse than those of Concorde, and that the eco-nomic disabilities of Concorde and similar aircraft are fundamental. These facts must be widely publicised in order to stop plans for a Mark II Concorde or for the revival of the U.S. SST.

In many countries continuing efforts are needed towards the prohibition of supersonic overflying, and towards ensuring that SSTs will not be excused from having to comply with existing airport noise regulations. Every success further reduces the operability and the saleability of the SSTs.

The cancellation of the surviving SST pro-jects will be a great practical and symbolic victory. It will show that runaway technology can be checked.

On BBC radio recently Andrew Wilson—aviation correspondent of *The Observer*—gave his opinion that when at the end of this century people look back at the Concorde they will find that "one of the most im-portant products of this whole programme was not technological but social—namely that it generated a highly-developed movement among people who became vitally concerned about what they felt was a threat to the quality of life".

We invite concerned people throughout the world to add their support to our efforts. Unlike the SST-builders, we rely upon volun-tary contributions to support our work.

Index slip for new supporters—below.

Surname ....

First name or initial ....

Address ....

....

★ Contribution £..........................

Profession, occupation, qualifications, if any (for statistical purposes only).

....

I support the Anti-Concorde Project

(Signed) ....

* *Cheques, etc., should be made payable to "The Anti-Concorde Project" and may be crossed "Lloyds Bank Ltd., Letchworth". Receipts will be sent only if requested.*

To: Richard Wiggs,

Chairman PROXMIRE. We can only compare it on a passenger-mile basis. Obviously it goes faster and we cannot say it eats up its weight. If people traveled by SST instead of by subsonic jet what would be the difference?

Mr. BROWER. Well, the factor I used on that Prudhoe Bay analogy is a factor of two, that the SST requires twice as much fuel, extra fuel. I have got to make sure. I can come up with the right number at the end, but I am not sure at the moment.

Chairman PROXMIRE. When you say twice as much fuel by the SST you are talking about the Concorde or the American?

Mr. BROWER. This is the American Boeing SST.

Chairman PROXMIRE. Which is more economical than the Concorde, I take it.

Mr. BROWER. Yes; and compared to the 747 Mr. Moss gave me a factor of two and we multiplied that out——

Chairman PROXMIRE. For the record, will you submit your calculations so we can in turn ask the Department of Transportation for them.

Mr. BROWER. Yes; I can. Mr. Moss was a White House Fellow with DOT in the previous administration. The figure there is that it would use 2 million barrels a day extra fuel just for the extra speed.

Chairman PROXMIRE. It would use 2 million barrels, what are you talking about?

Mr. BROWER. That is a fleet of 500; Mr. Magruder's predicted fleet of 500.

Chairman PROXMIRE. It would use 2 million barrels per day, that is in addition to consumption without the SST?

Mr. BROWER. Yes; so this 2 million barrels of jet fuel and, of course, the Prudhoe Bay pipeline carries only 2 million barrels per day altogether, only one-seventh of which is refined to jet fuel.

Chairman PROXMIRE. So the advent of the SST would wipe out all the oil from the Prudhoe Bay find of 2 million barrels a day on the assumption that we could develop refinery capacity?

Mr. BROWER. Yes; and the other figure I have is that, because only a fraction of the crude oil extracted can be refined into jet fuel, we would have to discover five Prudhoe Bays between now and the year 2000 if we had Mr. Magruder's fleet running now, and I think that is no way to spend a vanishing resource.

If we are worried about our balance of payments and work ourselves into a deficit oil situation with the SST fleet, then what we have done for our balance of payments except to put ourselves completely at the mercy of someone else? The solution they seem to be coming up with in this administration is that the way to solve the oil shortage is to hurry and use the oil up. I quite fail to see the logic.

(The information requested above was subsequently supplied for the record:)

If we assume that the proposed fleet of 500 Boeing SSTs would use 1300 barrels of jet fuel per trans-Atlantic flight or equivalent, would average five flights per day, and would carry one-third a 747's ton-mile payload per unit of fuel, an additional two million barrels of jet fuel would be consumed daily for the extra speed of supersonic flight. The fuel requirement includes the extra heavy demand of climbing to cruising altitude, but does not include the extra heavy demand that would be caused in adjustments in cruising altitude required by intense solar flares and excessive radiation.

The number of Prudhoe Bay discoveries that would be required between 1973 and 2000 may be conservative as stated. If we assume that the discovery totals 12 billion barrels and that it is withdrawn at the proposed trans-Alaska pipeline design flow of 2 million barrels per day, depletion will occur in 17 years. If the amount of jet fuel (8 gallons) now produced from a barrel of crude (55 gallons) were doubled, and if all the crude were to be shipped to the United States instead of a sizable part's going to Japan, and if, further, the pipeline were now flowing at capacity and the fleet of 500 Boeing SSTs were now flying, then the extra SST speed would deplete six Prudhoe Bay findings by the year 2000.

At 10¢ per gallon, the extra speed would cost $4 billion extra per year from now until the turn of the century. At 20¢, the more likely average price of jet fuel between now and then, with diminishing discoveries, the extra speed would average $8 billion per year—$216 billion by 2000.

The interest and amortization cost of the 500 SST's, valued at $80 million each and amortized over 12 years at 8 percent interest, would be $5 billion per year. If the planes were replaced without inflation or price increases due to scarcity of materials, the total cost from 1973 to the year 2000 would be $135 billion in all, encompassing resources, including energy, that are becoming increasingly hard to get. The capital cost for serving the same traffic with 747s would be at least two-thirds less.

It would seem to impose no great hardship on the minority of air travelers who may relish supersonic speed to expect them to spend a few hours extra aloft per year, and thus save twice as much as our annual foreign-aid generosity has amounted to recently. The energy saved could be applied to necessities instead of luxuries.

Chairman PROXMIRE. What is your viewpoint, Mr. Soucie, on U.S. certification of the Concorde to operate from American airports in view of its presently foreseeable characteristics? Do you think there may be a case for certifying the present version, despite its defects, in view of the small number likely to fly and of the desirability of maintaining good trading relations—in return for a commitment not to ask us to accept a follow-on version that does not meet strict noise and emission standards?

Mr. SOUCIE. Well, Senator, I think it would be difficult without knowing how many Concordes will ultimately fly to certify it with any degree of confidence that we are not opening Pandora's box. Certainly nine airplanes are not too likely to do any damage to the upper atmosphere and we can tolerate that. Whether nine airplanes making the predicted three or four trips a day between New York and London or Paris would set very well with the people of Hempstead, Long Island, I am not sure.

Chairman PROXMIRE. How about the noise element?

Mr. SOUCIE. That is what I mean about the noise around JFK Airport, because that is the airport that would be used. But I think that by saying we are only certifying nine airplanes it is fairly risky because suppose that we gloomy pessimists are wrong and they sell a lot of Concordes. It would be very difficult to say we are certifying numbers 1 through 9 now but from 10 forward we want to open up the certification procedure again. I think that would be unprecedented in aviation. I think once you certify a type of plane you certify the type and then however many of that type are sold are automatically certified for operation in the United States. I do not think you can certify individual aircraft, say Concorde 001 is certified, 001 through 009, but beginning with 010 they are not yet certified.

Chairman PROXMIRE. Under the circumstances, knowing what we do about the Concorde, would you place the top priority on noise so far as certification at our airports are concerned?

Mr. SOUCIE. Yes; I believe I would, because I do not think that the numbers of Concorde are going to be great enough from the emission standpoint to really make that much difference. Whereas from noise we simply have got to start showing our willingness to do something about the noise problem.

Chairman PROXMIRE. What is your interpretation of the FAA's delay in setting noise and sonic boom requirements?

Mr. SOUCIE. Well, they have issued, not too widely, their proposed sonic boom rule. I was able to get a copy of it from the city of Boston and, as I understand yesterday from FAA, the noise rule is imminent, it will be released at any point. Apparently it is drafted and is ready for release and is being reviewed.

The delay, I think, was caused 2 years ago when they announced their intention, published in the Federal Register, I think in June or July of 1970, to set a noise rule and they asked for comments and then they let out certain contracts to do studies and I think that is what they have been waiting for. Also they have been waiting for the Concorde manufacturers to assure them the levels which they can reach, and I have the hunch that FAA will set whatever BOAC and Aerospatiale will have reached, because the same thing was done with the subsonic set of standards. The manufacturers more or less told the FAA what they could reach, FAA lopped a couple of decibels off that and then exempted the first edition 747, which was the only new plane going to be introduced.

Chairman PROXMIRE. So you feel that it might be desirable to concentrate on the State legislatures?

Mr. SOUCIE. I think it would be an excellent thing.

Chairman PROXMIRE. The State legislatures would have, could have, a jurisdiction that might supercede the FAA with respect to the noise requirements at airports. If, for example, the Massachusetts Legislature should provide a certain decibel level as the limitation on airplane noise and airplanes that have higher decibel levels simply would not be allowed to land.

Mr. SOUCIE. Well, as the Senator knows, a number of States have considered legislation in the past.

Chairman PROXMIRE. Yes, indeed.

Mr. SOUCIE. And each time the aviation community has gone around lobbying on the grounds that if this passes then airplanes simply would be——

Chairman PROXMIRE. Say they skip New York and land at Philadelphia or Newark or some place.

Mr. SOUCIE. Yes; I think now that the FAA has indicated they may be looking toward actually going into a retrofit program which the airports have been advocating for years and the airlines have been saying is too expensive, we may see the States actually setting levels lower than the 108 set by the FAA. But even if the States would simply get in there and say, "Look, the FAA has not acted about the application of 108 to supersonics, the Concorde is going to be certified and, therefore, I do not want anything noisier than 108 operating in my airports," well, I think that would effectively foreclose the use of our airports to the Concorde. I do not think there is any way the Concorde is going to get down below 108 decibels.

Chairman PROXMIRE. The point you made, and maybe Mr. Alderson in the back of the room would like to comment on it, with the experience you gentlemen and Mr. Brower have had, do you think there is any likelihood we could persuade a sufficient number of States to enact legislation to fix a State limitation?

Mr. SOUCIE. I think there is some likelihood. In fact, several States including California have the means to set their standard airport by airport.

Chairman PROXMIRE. It would be hard to say you could land in Seattle and Los Angeles instead of——

Mr. SOUCIE. I think what we are talking about are actually California, New York, and New Jersey, and Massachusetts, and then, if those States went along then the only State that really has much tourist attractiveness would be Florida, and Florida has shown some willingness to set supersonic noise standards.

Chairman PROXMIRE. Do not forget Chicago.

Mr. SOUCIE. Oh, yes, of course, Chicago. But you see, flying to Chicago from Europe means that if you cannot fly supersonic speeds over Canada you are flying at an even more uneconomic mode.

Chairman PROXMIRE. Well, the last 600, 700 miles you have to slow down to subsonic.

Mr. SOUCIE. That is right. What it does is change an untenable situation into an unbearable one, I guess.

Chairman PROXMIRE. Mr. Brower, it has been stated that the SST will fly some day because, if it is possible to fly faster, we will, and I have been frankly somewhat skeptical of the notion that progress is going to stop. I have taken the position, which you may or may not share, that if we can solve the environmental problem, the noise problem, the emission problem, other problems that are less immediate now that relate to the environment, and if the private industry will develop the plane without a subsidy, it would be fine. I have no objection. There is no reason, if people want to fly faster, why they should not do it, provided they did not hurt anybody.

At the same time, some argue that there is a limit, that beyond a certain point it just is not economic—even if it may be technologically feasible to travel that way. What is your view about that?

Mr. BROWER. Well, my view is that we have passed that limit; that I like a statement from a certain Welshman, Mr. Olwyn Rees: "When you are at the edge of an abyss the only progressive more you can make is to step backward." And that is exactly where we are. That is what I think "The Limits to Growth," the Club of Home Studies, whatever the interpretation you may have, are saying. We have gone too far. We have exploded through our environment in this blip of time that man has occupied in the earth's perspective—even in the brief era of industrial man in man's own perspective. We cannot keep it up. We have to slow down to live. As one of the ways, I am myself ready to fly slower in the present subsonic jets.

Chairman PROXMIRE. Where would you put the limit at, Mach I or II?

Mr. BROWER. I would put it at what we are now.

Chairman PROXMIRE. Below Mach I?

Mr. BROWER. Yes, because we are right now using fuel much too profligately.

Chairman PROXMIRE. I think you said in your statement, as I recall, that we should require slower speeds, but you put it entirely in the context of conserving oil.

Mr. BROWER. That is one of the main points, that is, I think we have got to conserve——

Chairman PROXMIRE. If we required our present jets to travel more slowly we would conserve our limited supply of oil?

Mr. BROWER. I think we would, and certainly I would find myself more reading time. I would not need to hurry quite so fast between airports, as Mr. Soucie has pointed out, if there were less trouble getting to city centers from airports.

Chairman PROXMIRE. You are from California so you have more problems with distance.

Mr. BROWER. I think that the environmental aspect of the fuel problem is really the dominant one. We know now what we are having to do to get energy. We are having to rip up the West. We are having to rip up the East. We are threatening the last great wilderness in Alaska. As Thor Heyerdahl has shown, now we are threatening the oceans with offshore drilling and spilling. Now we are going farther into nuclear effort and risking our own genes without finding out how much, because here again the Government is not telling us. We are rather on a suicidal course and we have to slow up, to slow down to live. Certainly the least need we must have is to fly any faster. We have the kicks now of going up to 600; we cannot speed on much longer. I agree with Mr. Soucie.

Chairman PROXMIRE. I think psychologically you have a good ploy. I do not think there is any likelihood we could slow down, that we could reduce the legal speed of planes.

Mr. BROWER. I think we will slow down when we run out of oil. We will slow down very fast. I think it is our obligation now, looking at the needs of the developing countries, really to curtail our own using up of everything. We are using, at this point, just about half the world's resources for our population, and it is not sitting well elsewhere in the world.

Chairman PROXMIRE. Do you share that view, Mr. Soucie?

Mr. SOUCIE. Yes and no, Dave and I often agree and disagree at the same time.

I would like to point out there is a great misunderstanding about the advantage of the jets over the piston planes. Most people have been led to believe that the great advantage is speed. That is not the advantage at all. In fact, one of the world's most successful jet airliners, Russia's Yak–44 flies a maximum speed of something like 344 miles per hour. But the real advantage of the jets over the piston planes is that they are more efficient. They can fly more hours per day, they require less maintenance, they are simply more dependable and that is the real advantage of jet travel over piston travel. The fact that it is faster is an added benefit for those who want to get from place to place in a hurry.

But to address oneself to speed with respect to the fuels, fossil fuels, it is possible, and I believe there is a B–57 flying around somewhere that is fueled by hydrogen, it is possible, to power planes by other than fossil fuels, and in fact, NASA is working on a pie in the sky project of a Mach 6 to Mach 12 hypersonic jet powered by hydrogen, powered by a SCRAM jet engine——

Chairman PROXMIRE. You mean six to 12 times the speed of sound?

Mr. SOUCIE. That is right.

Chairman PROXMIRE. That would mean even 4,000 and 8,000 miles an hour.

Mr. SOUCIE. Exactly, at those speeds at 100,000 to 150,000 feet.

Chairman PROXMIRE. Who is working on that?

Mr. SOUCIE. NASA, National Aeronautics and Space Administration.

Chairman PROXMIRE. And how much money, how much of the taxpayer's money, are they devoting to that?

Mr. SOUCIE. I am not sure, I think this is just a little technical exercise, this is a spinoff of the SCRAM jet program, I think this is going to be a spinoff of the space shuttle or something. But, at any rate, burning hydrogen fuel, of course, you do not have particulate emissions and oxides of nitrogen, you do not pollute, but you do produce three to six times as much water vapor as a turbojet burning kerosene. And since you are putting out much more water vapor at higher and, therefore, drier altitudes we simply do not know what that would do. But at least NASA admits it is something that has to be looked into, although I do not think they view it with the seriousness environmentalists do.

Chairman PROXMIRE. What can you suggest we do pursuant to the very startling testimony we have just had from Mr. Johnston, that the Budget Bureau is asking for only good news and that there is a terrific pressure to suppress the bad news as far as the SST is concerned, what can we do to get the facts, the truth? Do you have any suggestions as to how we can be more effective in finding out what is being considered?

Mr. SOUCIE. Well, Congress has the subpena power which the environmentalists do not have. We have been trying to find out since we read the same newspapers about the rumors, and the answers we get from the administration are, "We read the same newspaper accounts you have," and some say there is nothing to it. Others say. "If you find out anything let us know." Mrs. Magruder was in the room yesterday, and I hoped to have a chance to talk to her after the hearing, but she darted away from me. I wanted to find out why Mrs. Magruder was present yesterday. We really do not know, Senator.

I have a feeling there are enough SST enthusiasts in the administration. It is always going to be a back burner project for them and if they keep it on the back burner and spend just a few pennies a year it is OK with me if it is going to keep six or seven people happy. But if they are going to try to ram it down our throats again, either directly as they tried in the past, or indirectly through an aerospace finance corporation——

Chairman PROXMIRE. The President himself has indicated he favored the SST, you remember, when he met with Mr. Pompidou in the Azores and indicsated he wished we had one——

Mr. SOUCIE. Exactly.

Chairman PROXMIRE (continuing). Referring to the Concorde.

Mr. Soucie, you state in your testimony that now is not the time for the SST. You put it in a matter of time.

Mr. SOUCIE. Right.

Chairman PROXMIRE. Unlike Mr. Brower, I think, who gave me the impression that perhaps there never was a time.

Mr. BROWER. The time is past so far as I am concerned.

Chairman PROXMIRE. There is one and that is it. You say now is not the time.

Mr. SOUCIE. The reason I say now is not the time——

Chairman PROXMIRE. In this because of budgetary constraints? The reluctance of private capital? Or because environmental problems have not been solved and, if so, do you see any problem of solving these problems?

Mr. SOUCIE. One is a matter of problems. There are a great many unanswered questions about ozone shield, about noise, and about the availability of fuel oil. All of these questions must be answered if there is going to be a time for SST.

Chairman PROXMIRE. Mr. Johnston told us this morning that he thought those answers would be forthcoming with sufficient precision by 1974. Mr. Newell indicated 8 to 10 years.

Mr. SOUCIE. Well, that is an answer to one question. I think there are a great many more questions.

Then, I think even once we get all these problems solved, if you look at this, the technology that is being proposed in this first go-around of SST's, I think that it is, even if there were no problems, it is just a bit early. The advantages simply are not great enough to merit the expenditures. And then even if we come up wtih a second- or third-generation proposal, and it looks like a great airplane and all the questions are answered, it is going to cost a great deal of money and, at that time, we have to say, I think, "Well, is that the best place for us to put the money at this time?" and perhaps the time for an SST never will come; I just would leave it an open-ended question.

Mr. BROWER. Mr. Chairman, on one point there——

Chairman PROXMIRE. Yes.

Mr. BROWER. On what can we do, I passed over that very briefly in my statement. It seems to me that the opportunity now, and the hopes of the people, are going to lie in Congress as they never have before. This kind of hearing, and others like this, are going to be extremely important in digging out information which we are otherwise just not going to get.

The attack on the press, and on the first amendment rights, and now the absences in this meeting room, just underline to me, as I have never had it underlined to me before, that the Congress really has to come to work full time, that this is the branch of the Government that now has to do a lot of second guessing of the executive branch, and it has got to help the fourth estate. The hopes right now lie right here.

Chairman PROXMIRE. Even more important than the suppression of the press or the failures to appear before this committee, is what Mr. Johnston told us this morning about intimidation, suppressing of facts without which Congress cannot possibly make a judgment.

Mr. BROWER. Yes; we have gone into this, as you may know, a great deal in the atomic energy safety hearings in Bethesda, in what has happened on radiation standards, in what has been happening on the safety of atomic reactors. And the difficulty of getting the facts out underlines what I have already said: "The Congress has really got to do more digging than it has done for a long time. I wish you well in the digging."

Chairman PROXMIRE. Thank you very much. I want to thank both of you gentleman.

Before we adjourn, I want to read a letter that I just received, just handed to me a few minutes ago from the Boeing Corp., Mr. T. A. Wilson, chairman of the board, who writes me as follows—it is a short letter so I will read it:

> We respectfully decline your invitation to The Boeing Company to appear before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee on December 27 and 28, 1972. Since the main purpose of your hearings is to assess Federal support for the development of a supersonic transport, I believe there is nothing we could add to the views of the Department of Transportation and NASA.

Which are not appearing also, incidentally.

> As you stated in your letter, Congress terminated the United States supersonic transport program in the spring of 1971. This, as you recall, caused Boeing and its subcontractors to terminate all contracts and to disband a professional team of approximately 14,000 employees. We were obviously disappointed with the decision of Congress. We still believe strongly in the economic and social merits of supersonic transportation. We were pleased, however, that the Department of Transportation, with congressional approval, decided to fund completion of certain highly important supersonic transport technology tasks in order to salvage important technical data from the billion dollar Government investment in the overall program—data required to determine the technical and economic feasibility of future advanced flight systems, as well as to fund the Climatic Impact Assessment Program to determine the true nature and magnitude of the environmental effects of supersonic aircraft.
>
> With respect to our status and performance on the programs for which we are responsible in this area, the Department of Transportation has all the data necessary for your Committee.

Of course, those departments neglected to appear and inform our committee.

> In September of 1972, NASA awarded contracts to McDonnell-Douglas, Lockheed, and Boeing to study other aspects of advanced supersonic technology. I believe NASA also can give you a status and performance report of our progress in this area.
>
> The Concorde, as we understand it, supports the position that commercial supersonic transportation is technically feasible. We believe this nation and its aeronautical industries can develop a commercial supersonic transport that will meet the environmental, technical, and economic criteria necessary for a successful program using as a baseline the terminated U.S. SST program and studies currently under contract. And, we believe further with the first generation supersonic airplanes flying, timing for an American SST program should be given careful consideration.

We have copies of this letter for the press.

Now, before we adjourn I wanted to say that this hearing has been an unfortunate experience because the administration has refused to appear. There is a long, sorry record on the SST. As you recall, when President Nixon took office he wisely appointed an ad hoc committee to study the supersonic transport and he appointed his own people, the Chairman of the Council of Economic Advisers, the Secretary of Labor, the Secretary of Commerce, I believe, all—the Under Secretaries, all the people in his administration appointed by him, obligated to him, but capable of eliciting from their departments the information they needed to make a judgment.

This ad hoc committee recommended against the SST, not for it but against it. The administration went ahead in spite of that.

Now, we are informed this morning by a distinguished scientist, who is not an advocate or an opponent of the SST, that he has reason to understand that the Bureau of the Budget has told various agency officials that, if they disclose information that would inhibit development of the SST, they might very well have their funds reduced or eliminated—cut. This, I think, is a most serious development. And then, of course, finally, we have the fact that this committee has been treated with considerable contempt. That we not only had a refusal of Mr. Secor Browne, the head of the CAB, to appear after he said he would—I could understand that; he had a family engagement that he said he could not get out of, and he explained that 3 or 4 days in advance—but 24 hours ahead of time, the Department of Transportation's designate who was to appear, and the FAA's designate who was to was to appear, informed us with no justification, simply saying they had a transition in the agency—all agencies have that now, I am sure—that they would not appear. As a result, this committee and the public are kept in the dark as to the plans of the administration on the supersonic transport in spite of very substantial evidence that there are significant plans ahead, possibly for the 1974 budget—and very likely in subsequent years, if not in the 1974 budget—plans that could involve billions of dollars, enormous resource commitments, and serious impacts on our environment. Under these circumstances, I do hope that the administration will reconsider and disclose information about the supersonic transport, and about their plans more clearly.

It is difficult to know what Congress can do in this instance. Fortunately, from my standpoint, I am chairman of a subcommittee of the Appropriations Committee that has a voice on the amount of money that the National Aeronautics and Space agency can spend. NASA funds much of the SST programs that Mr. Wilson, of Boeing, indicated, and I will certainly go into considerable detail when NASA comes before the subcommittee of which I am chairman, asking for money for these programs.

In addition, we would hope that the head of the Bureau of the Budget, the distinguished Mr. Ash, will enlighten us, or his predecessor will enlighten us, on the information that we received this morning of intimidation.

Gentlemen, thank you very, very much. We deeply appreciate your appearance. Your request for having this information submitted for the record will certainly be honored.

The subcommittee will adjourn, and the record will be kept open until the 15th of January.

(Whereupon, at 12:30 p.m., the subcommittee adjourned, subject to the call of the Chair.)

APPENDIX

LONDON, JANUARY 8, 1973.

Senator WILLIAM PROXMIRE,
Senate Building,
Washington, D.C., U.S.A.

DEAR SENATOR PROXMIRE: The London Observer yesterday published an abridged extract from the Congressional Record containing evidence submitted to the Joint Economic Committee of Congress, of which you are Chairman, by Mr. Andrew Wilson, the Air Correspondent of that newspaper, and the answers he gave to some questions put by you.

As the Cabinet Minister responsible for the Concorde project from February 1967 to June 1970, when the Labour Government was in power, and as the "Shadow" Secretary of State for Trade and Industry with Opposition responsibilities for Aviation since that date, I am writing to tell you that Mr. Andrew Wilson's evidence contains serious inaccuracies that, if not corrected, may mislead you and your Committee. I am therefore writing to correct the record, and I should be grateful if you would submit this letter and the text of my recent speech on Concorde in the House of Commons—a copy of which I enclose—to your Committee.

Mr. Andrew Wilson is reported as saying, "I myself am certain from conversations with those concerned that if the Labour Government had stayed in office, it would have cancelled Concorde in 1971 when decisions had to be taken on production to which the legal tie with France no longer applied." This is completely inaccurate.

First: After its preliminary review of the project in 1964 the Labour Cabinet supported the Concorde throughout the whole of its period of office.

Second: The Labour Government in 1968 passed legislation through Parliament to provide funds for the productions of Concorde.

Third: The legal tie with France was modified by negotiation in 1968 and the Labour Government had restored its own freedom of action while still in office. It cannot therefore be said that it only continued the aircraft because of the terms of the treaty signed by the Conservative Government in 1962.

Later, Mr. Andrew Wilson, in answer to a question put by you is reported as saying "But if you take those responsible in a Shadow capacity for thinking about the economic problems of Britain in the Labor Party leadership, I think, I am certain, that you will find a consensus that Concorde is a waste which must be terminated."

This is also quite untrue.

Last month the Labour Shadow Cabinet agreed to give full support to the present legislation promoted by the Conservative Government to increase the funds for production, that that view was expressed by me, speaking for the Opposition in the debate in the House of Commons on December 11, 1972, in the speech which I am enclosing.

I am very surprised indeed that an important Congressional Committee, under your distinguished Chairmanship, should allow such evidence to be submitted without the closest interrogation of the witness on the authority of what he says.

It is one thing for an independent journalist to come and give his views to your Committee, speaking for himself. But it is quite another thing to purport—by vague references to private conversations to be speaking for a former government and the major Opposition party in Britain.

Mr. Andrew Wilson has no authority whatsoever for the statements that he has made. He has cited no names in support of his assertions. His reported conversations with Labour Ministers include none with me that could lead to any such conclusion.

The only authoritative expression of governmental views could have come from Ministers or ex-Ministers directly responsible for this project in Britain or France during the year since its inception.

90-912 O - 73 - 12

I fully understand that you yourself have long campaigned against the United States SST project. That is entirely an American affair and the decision has to be made in Washington.

But Concorde is an Anglo-French project and if you wish to consider it one would expect that you would seek authoritative witnesses.

The finest skills in the British and French aircraft industries and many hundreds of millions of pounds of money have been put into the Concorde which is now on order and will enter airline service within the next few years. The American people are entitled to know that if an attempt is made to prevent these airline operations as a byproduct of a campaign against the U.S. SST this could become a major political issue that could have serious consequences in the relations between our countries.

Most people in Britain and France are very proud of Concorde and they have no intention of accepting any ban imposed on it to protect the U.S. aircraft industry from the competition that it will offer when it is in service.

Yours sincerely,

Hon. ANTHONY WEDGWOOD BENN, *M.P.*

FEBRUARY 1, 1973.

Hon. ANTHONY WEDGWOOD BENN,
The House of Commons
Westminster, London, England.

DEAR MR. BENN: I appreciate your letter and I am indeed happy to make it a part of our Record and available to those who wish to see it.

However, I must take strong exception to at least two of your assumptions.

First of all, our hearings were on the SST and its potential revival, which now seems more than potential from the details of the new budget. Far from being an unbalanced or an unfair group of witnesses, we invited an overbalance of witnesses, especially administration witnesses, who were friendly to the SST. As the issue of the Concorde was only a relatively minor point in the entire question of whether the SST is to be revived, I make no apologies whatsoever for having only one witness on that issue. If the subject had been the Concorde, I assure you that several witnesses and a balanced group of witnesses would have been requested to testify. But the hearing was on the SST, not the Concorde.

Consequently I must reject out of hand your inference that because of my opposition to the American SST I held what others might term a rigged hearing.

My second point is that I do not have the slightest intention of telling any witness before my Committee what he must say. We do not censor witnesses. Mr. Wilson is a responsible journalist. While we routinely question witnesses very severely I have no basis seriously to question his responsibility.

With best personal wishes.

Sincerely,

WILLIAM PROXMIRE, *U.S. Senate.*

NOTE

It should be noted that, in order to obtain a balance among viewpoints, persons from widely varying backgrounds, including some from the United Kingdom, were invited to appear as witnesses at the hearings, but that some either declined to appear or failed to respond.

Among these were the following Members of Parliament from the United Kingdom: Lord John Diamond, Member of the House of Lords and former Chief Secretary of the Treasury, 1964–70; Hon. William T. Rodgers, Member of Parliament and Chairman of the Subcommittee on Trade and Industry, Committee on Expenditures; and Hon. Joel Barnett, Member of Parliament and member of the Subcommittee on Trade and Industry, Committee on Expenditures.

The following spokesmen for the concerned United States Departments and regulatory commissions also were invited but declined: Hon. John Volpe, Secretary of Transportation; Hon. John Shaffer, Administrator, Federal Aviation Administration; and Hon. Secor Browne, Chairman, Civil Aeronautics Board.

Witnesses from the U.S. aircraft manufacturing and airline companies also were invited but declined.

THE OBSERVER,
London, January 12, 1973.

Senator WILLIAM PROXMIRE,
Chairman, Joint Economic Committee,
New Senate Building, Washington, D.C.

DEAR SENATOR PROXMIRE: Thank you for your letter of 1 January. I am glad my testimony was of some service to the Joint Economic Committee. It was most kind of you to hear me.

I see from a letter which arrived here yesterday that Mr. Anthony Wedgwood Benn has written to you contesting part of my evidence. As you know, Mr. Wedgwood Benn is Member of Parliament for Bristol South-East, a constituency with immediate interest in work at the factory making Concorde at Filton.

As shadow Minister for Trade and Industry he is not spokesman on overall economic policy within the shadow Cabinet, a responsibility that belongs to the shadow Chancellor of the Exchequer, Mr. Healey.

In answer to the points made in Mr. Wedgwood Benn's letter I should like to direct your attention to the extract of an article by him in the Bristol Evening Post of 23 September, 1970. I enclose this extract on a separate sheet.

In it Mr. Wedgwood Benn acknowledges that Concorde was started without any research into boom and noise problems, launched by the Conservatives on grossly wrong estimates, and pursued without any proper public discussion.

I should also like to call your attention to Mr. Harold Wilson's book, the Labour Government 1964–70, in which the former Prime Minister makes it clear that Labour was obliged to continue with Concorde for legal reasons.

You will not want me to expand on the reasons why a party may adopt a certain line of policy in opposition while having quite different ideas about what will be necessary when it regains office.

I will merely restate my sure conviction, based on reasons I explained in my evidence, that a Labour government, returned to office, would terminate Concorde.

Yours sincerely,

ANDREW WILSON.

Enclosure.

EXTRACT FROM ARTICLE BY ANTHONY WEDGWOOD BENN FOR THE BRISTOL EVENING POST, SEPTEMBER 23, 1970

"* * * it is commonly believed that the weight of official opinion was against Concorde and that the Macmillan Government decided on it for political reasons, as part of their application to join the Common Market.

If that is so, it was a very bad reason for reaching such an important industrial decision.

The Conservative Government was also clearly wrong in four other important respects:

First—they failed to undertake noise tests, particularly supersonic bang tests, using military aircraft to gauge public opinion before they reached a decision.

Noise is still Concorde's most serious problem, and it should have been faced at the start.

Second—the estimates of development cost on which the project was approved were wildly inaccurate. There was enough experience, even at that time, to have allowed for some of the escalation which subsequently occurred to be anticipated.

There is much misunderstanding about escalation. It is, of course, not due to extravagance or bad estimating in the ordinary sense, but is a product of technical complexity.

Very complicated aircraft which involve pioneering new technology inevitably throw up extremely difficult problems which take time to solve, and time is money—big money.

Once the team has been assembled, the costs start running at a very high annual rate. If redesign is necessary, the delay it causes is the main factor in the escalation.

Had all this been anticipated at the outset the aircraft would probably not have been started.

Third—the Conservative Government's decision to sign a treaty with no break clause in it was an act of supreme folly.

It is generally believed that this was insisted on by the Conservative Government, against the French preference for proper break points which would have allowed either side to suggest discontinuance at clearly defined stages.

Fourth—there was no real public discussion in Parliament or outside, as to whether it was sensible to commit such enormous resources of money, skilled manpower and industrial capacity to a project so incredibly complex and aimed at a supersonic market instead of, for example, going for the mass market which the Boeing 747 has now been able to enter, virtually without any competition.

Had there been a Parliamentary Science and Technology Select Committee in operation at that time to cross-examine Ministers and officials, or had the basic information necessary to assess the alternatives been made publicly available, a real discussion and debate could have taken place as it certainly should have done.

But in the event, the whole thing was shrouded in secrecy and a fundamental decision was taken, of profound importance to Britain, the aircraft industry—and, of course, Bristol."

The Effect of Nuclear Explosions on Stratospheric Nitric Oxide and Ozone

(By Harold Johnston, Gary Whitten, and John Birks, Department of Chemistry, University of California and Inorganic Materials Research Division, Lawrence Berkeley Laboratory, Berkeley, Calif.)

Abstract

Following the proposal by Foley and Ruderman that atmospheric nuclear bomb tests introduced significant quantities of nitric oxide into the stratosphere, we have carried out a detailed examination of the total-ozone data for the world. These data appear to show a statistically significant decrease of stratospheric ozone during the period of intense nuclear bomb testing, 1960–62, and a larger, statistically significant increase of total-ozone, 1963–70, after cessation of large scale atmospheric nuclear testing. Although these trends may have other explanations, their location and timing are consistent with the distribution of carbon-14 and strontium-90 in the stratosphere. The magnitude of the ozone decreases and increases, about 5%, is consistent with what one expects from injections according to Foley and Ruderman's model if consideration is given to the uncertainty with which those quantities are known.

Introduction

Foley and Ruderman (1972) examined the question of the formation of nitric oxide from the air heated by nuclear explosions during the period of large scale atmospheric testing, 1952–1962. They evaluated the upper limit of the rate of NO injection into the stratosphere and compared it to the rate of production of NO by supersonic transports (SST).

They published considerations concerning 29 ozone-observing stations, including graphs (their Figures 4 and 5) pertaining to 300 monthly averages and a short table (their Table 6) averaging 216 monthly average data points from *Ozone Data for the World* (1960–70). They said that "large catalytic ozone reduction from such NO injection was not observed". However, the total set of *Ozone Data for the World* (1960–70) involves over 90 different stations, over 8000 monthly averages, and over 178,000 observation-days. In this report we utilize all of these data, and we find a statistically significant decrease of global ozone in the period 1960–62 and a larger, statistically significant increase in ozone after bomb tests stopped in 1962 over the period 1963–70. The location and timing of these changes are consistent with the stratospheric distribution of strontium-90 and carbon-14, products of nuclear explosions. Of course, changes in atmospheric quantities can arise from many sources, and there may be other causes for these decreases and then increases of ozone.

The calculation by Foley and Ruderman is carried out to one significant figure with neglect of a 15 percent term, with recalling to be 1.4 for air at 2006 γ K whereas it is 1.3, and with rounding up to the next whole number. These approximations cause their final formula for the number of molecules of NO to be a factor of two too high. As they discuss, uncertainties about the detailed mechanism of the entrainment-cooling of the rising fireball gives an uncertainty of a factor of 6 in the final result. All of their yields of nitric oxide employ the upper limit, and the values quoted are between a factor of two and a factor of 12 too high. The observed decrease in ozone (1960–62) and later increase (1963–70) are about the magnitude that would be expected from a mid value within the uncertainty in Foley and Ruderman's calculation.

This article reviews what we regard as the error in Foley and Ruderman's thermodynamic data, the uncertainty arising from the detailed chemical kinetics of forming nitric oxide in the fireball, and a consideration of possible short-term and long-term changes in ozone from nuclear explosions.

THERMODYNAMICS

Foley and Ruderman assumed that one third of the energy of nuclear bombs went to heat air to 2000°K; they implicitly assumed that the temperature was held at 2000°K long enough (tens of seconds) to attain equilibrium for nitric oxide formation

$$N_2+O_2\rightleftarrows 2NO$$

They neglected adiabatic cooling of the fireball, since it was merely 15 per cent of the cooling process. The number of nitric oxide molecules formed from nuclear bombs was found by combining their equations 2, 3, and 4 to give

$$N_{NO}=\frac{\left(\frac{4}{3}\times 10^{22}Y_{MT}\right)(8\times 10^{-3})(\gamma-1)}{(1.38\times 10^{-16})(2000)}$$

$$=3.86\times 10^{32}Y_{MT}(\gamma-1)$$

They took γ to be 1.4, so that $\gamma-1$ is 0.4, and the number of nitric oxide molecules is $1.55\times 10^{32}Y_{MT}$, which they rounded up to 2 to give Equation 5

$$N_{NO}=2\times 10^{32}Y_{MT}$$

The quantity γ is the ratio of heat capacity at constant pressure C_P to the heat capacity at constant volume C_V, which is the gas constant R less than C_P. According to the JANAF tables at 2000°K the heat capacities of nitrogen and oxygen are

	C_P	C_V	γ
N_2	8.601	6.614	1.300
O_2	9.029	7.042	1.282
Average for air			1.295

The value of γ is 1.30, not 1.40. This seems to be a small matter, except for the rounding up process. With $\gamma=1.30$ the number of nitric oxide molecules produced is

$$N_{NO}=3.86\times 10^{32}Y_{MT}(0.30)=1.16\times 10^{32}Y_{MT}$$

If the 15 per cent effect of adiabatic cooling is acknowledged, this number is reduced to $1.01\times 10^{32}Y$, which is a factor of two less than Foley and Ruderman's figure. Thus it is necessary to rewrite their Equation 5 as

$$N_{NO}=1.0\times 10^{32}Y_{MT}$$

A better method of calculating the energy required to heat air to 2000°K involves the integral of the heat capacity at constant pressure between 298° and 2000°K. Tabulated values of $H^{\circ}_T-H^{\circ}_{298}$ make this calculation easy to carry out. For air the average value of $H^{\circ}_{0200}-H^{\circ}_{298}$ is 13.56 kcal mole^{-1}. Glasstone (1964) gives the energy of a nuclear bomb as

$$E_{total}=10^{12}\text{ kcal }Y_{MT}$$

If one third goes to form hot air, its value is

$$E_{HA}=33\times 10^{10}\text{ kcal }Y_{MT}$$

If there is a 15 percent cooling by adiabatic expansion of the rising fireball, the residual energy is

$$E_{HA}' = 28.4 \times 10^{10} \text{ kcal } y_{MT}$$

Dividing this energy by the enthalpy function for air at 2000°K, one finds

$$\text{moles of hot air} = 2.09 \times 10^{10} \text{ Y}$$
$$\text{molecules of hot air} = 12.6 \times 10^{33} \text{ Y}$$
$$\text{molecules of NO at } 0.8\% = 1.01 \times 10^{37} \text{ Y} = N_{NO}$$

CHEMICAL KINETICS

The initial nuclear explosion is at temperatures far above 10^6°K, and the black-body emission of radiation is largely in the region of soft X-rays, which are strongly absorbed by air to produce high temperatures. The fireball grows by emission and absorption of short wave-length radiation, and it cools by emission of radiation transparent to air, that above about 185 nm. Within a few seconds a strong shock wave has carried away about one-third of the bomb energy, and radiation transmitted by air has carried away another one-third of the energy. The residual fireball at an average temperature of about 6000°K contains one-third of the energy largely as dissociated oxygen and as thermal energies of the molecules and atoms; also there is about one per cent nitric oxide and smaller amounts of nitrogen atoms, ions, and electrons. This residual fireball undergoes its further cooling by rising and mixing with law temperature ambient air.

There are two mechanisms whereby nitric oxide is formed from hot air. If air is held at a high temperature for a time long enough to attain chemical equilibrium and then cooled down, there will come a point where the cooling rate is faster than the nitric oxide relaxation rate, and at that temperature the equilibrium concentration of nitric oxide will be "frozen in". This mechanism applies to internal combustion automobile engines, to the furnaces of power plants, and to the fireball at 6000°K which later rises, mixes, and cools. The volume of air in the original 6000°K fireball is sure to have a nitric oxide concentration frozen in corresponding to that at about 2000°K, regardless of the mechanism of cooling if the time of cooling is a matter of about 10 seconds. The amount of nitric oxide formed changes slowly with freeze-out temperature, as Foley and Ruderman pointed out, and thus it is relatively insensitive to the cooling rate and cooling mechanism.

The other mechanism involves heating cold air up to a high temperature for a time short compared to attainment of chemical equilibrium with nitric oxide and then cooling to a lower temperature. This mechanism operates in jet aircraft engines, where chemical equilibrium is not reached. Also this mechanism operates in the coolant air of the rising fireball following a nuclear explosion. The amount of nitric oxide produced is kinetically controlled by a process with a very high activation energy, and it is enormously sensitive to the precise history of temperature and time. A sample of gas heated to 2000°K and cooled to 1900°K within a second would form very little nitric oxide. A sample of gas heated up to 1500°K while cooling a portion of the original fireball would form no additional nitric oxide beyond the frozen equilibrium in the original fireball. The first sample of gas entrained in the 6000°K fireball might very well attain chemical equilibrium above 2000°K, but a sample of gas entrained by the 3000°K fireball probably never attains 2000°K. A jet of hot air injected into the surrounding cold air could be cooled below 2000°K without any coolant air attaining a temperature high enough to form additional NO. This situation will apply if 6000°K air is rapidly mixed with a six-fold or more excess of coolant air. Foley and Ruderman assumed that the maximum possible amount of entrained air that could be heated to 2000°K was indeed brought to that temperature and held at a high temperature long enough to attain chemical equilibrium. This model produces five times as much nitric oxide in the coolant entrained air as in the air of the original fireball. They acknowledge that this effect creates a factor of 6 uncertainty in the amount of nitric oxide formed by nuclear bombs (the paragraph after their equation 5).

Thermodynamics requires Foley and Ruderman's estimate of the NO production from nuclear bombs to be reduced by a factor of 2.0. The chemical kinetics of the detailed temperature history of the mixing process in the rising fireball gives a further factor of 6 uncertainty in Foley and Ruderman's estimate. Their Equation 5 should read

$$N_{NO} \approx (0.17-1.0) \times 10^{32} y_{MT}$$

In addition there is another factor that acts to reduce the amount of NOx introduced into the stratosphere by nuclear bombs. The rising bomb cloud containing entrained moist troposheric air eventually cools to stratospheric temperatures. In general the bomb cloud acts like a thunder-storm cloud, and copious quantities of water condense out and much of it precipitates out of the lower stratosphere back into the troposphere. The oxides of nitrogen, especially NO_2, coprecipitated NO and NO_2, and HNO_3, are highly soluble in water and would be washed out of the startosphere to some extent. Surface level bomb tests mix large quantities of soil or water with the bomb cloud, and such material should further remove some oxides of nitrogen from the bomb cloud.

Short-Term Local Effects

Foley and Ruderman give equations for calculating the expected height and size of the cloud following nuclear bomb tests. For a time 30 minutes after detonation, the cloud sizes for 0.5, 5.0 and 50 megaton (MT) explosions are indicated by Figure 1, which includes a standard ozone profile at 45° latitude. The overlap of the ozone profile and the stabilized bomb cloud is strongly dependent on the yield of the bomb. For a standard ozone profile at the equator, this overlap is indicated by cross hatches in Figure 2. A bomb of 0.2 MT remains essentially within the tropical troposhere. A 1 MT bomb overlaps the ozone profile in the lower stratosphere, but it does not reach the level of maximum ozone concentration. A 10 MT bomb overlaps the maximum ozone. A 58 MT bomb, on the other hand, goes far above the ozone maximum, and it overlaps only a relatively small band of ozone. Table 1 gives the percentage of ozone vertical columns overlapped by bombs of various sizes. For short-term effects in the equatorial band, the maximum ozone reduction should be given by a 10 MT bomb, where a 65 percent overlap of the ozone column is indicated. With consideration of the finite rate of the catalytic destruction of ozone by NO_x, one could expect approximately a 30 to 50 per cent reduction of ozone within the bomb cloud during the first week or two of its existence. There would be a small effect for both larger and smaller bombs.

TABLE 1.—PERCENT OVERLAP OF VERTICAL OZONE COLUMNS BY NUCLEAR BOMB CLOUDS OF VARIOUS SIZES

Latitude and season	Bomb yield (megaton)								
	0.2	0.5	1	2	5	10	20	30	58
0° spring	5	8	12	25	52	65	60	50	31
45° spring	16	25	33	41	46	42	33	27	16
45° fall	9	18	26	39	52	62	43	35	21
75° spring	26	37	44	47	41	30	28	16	10
75° fall	24	35	41	43	40	32	25	20	13

As the fireball cooled by radiation-emission, that radiation between 185 and 242 nm would dissociate oxygen and make ozone in a broad region surrounding the point of detonation. For bombs fired well above the ground, this mechanism would form some ozone directly in the stratosphere, and for large bombs the artificial ozone layer would lie under the stabilized cloud. This layer of ozone would act to confuse the information to be expected on the ground directly under a bomb cloud during its first few days of existence. We carried out a numerical integration of the distribution of radiation from the cooling fireball of a 20 kiloton bomb, and the energy emitted as radiation between 186 and 242 nm was about one percent of the total energy of the bomb. We assume that this quantity scales linearly with bomb yield. In that case, the amount of ozone generated from ultraviolet radiation in the Herzberg continuum would be

$$N_{ozone} \approx 3 \times 10^{31} y_{MT}$$

Thus about one third as many molecules of ozone are produced as the (kinetically possible) upper limit estimate of nitric oxide production. This ozone would not make a significant contribution to the total global amount, but it is 40 percent of the ozone column subtended by a 30 minute old bomb cloud.

The principal USSR atmospheric tests were at Novaya Zemlya at 75°N. The largest tests were in late fall and winter so that there was little or no sunlight to support the photochemical reactions that destroy ozone. Ozone in the polar regions is formed in tropical and temperate zones and brought there by transport. Thus the ozone reductions from the big USSR are expected to be delayed until high elevation NO has time to be moved into the temperate zones and the ozone formed there moved back to the polar region at a lower elevation.

The size of a 30 minute old bomb cloud is only about 10^{-4} the area of the earth. Thus the chance of a given ozone station observing a young cloud is small. The ozone collar photochemically produced by the bomb itself would confuse the information anyhow. Winds would be expected to shear the bomb cloud and move sheets of it in different directions at different elevations. Once the cloud is sheared and spread around the world at one latitude, the concentration of NO is reduced to such values that the effect of NO reduction of ozone is slow (months). Thus one should look for long term global effects of the nuclear bomb tests on stratospheric ozone, not for short-term local effects.

Long-Term Global Effects

At a given observing station of total ozone, there is a substantial variation from day to day as illustrated by data from Aspendale, Australia in Figure 3. There are systematic, rather well-understood annual trends with a peak in the spring and a minimum in the fall, illustrated for the southern hemisphere by data from Aspendale in Figure 3 and illustrated in the northern hemisphere by data from Messina and Moscow in Figure 4. With the day-to-day fluctuations and the large seasonal cycle, it is difficult to detect a systematic trend in total ozone at any one station or on a global basis. Pittock (1971) analyzed the detailed data at Aspendale, and by using the two-sided Students'-t-test he calculated how many years (N) of observation would be required to establish or disprove (at the 95% confidence level) the occurrence of a real trend of magnitude *b* per cent per decade. His results are reproduced at Figure 5. Note that if there were a real increase or decrease of ozone at the rate of 30% per decade, it would require three years of observation to establish the trend with a 95% confidence level if one has the noise spectrum given by the observed ozone data at Aspendale. An extrapolation of Pittock's curve indicates that it would take almost 2 years to establish the presence of a real trend of 10 per cent per year.

Foley and Ruderman (1972) presented graphs of total ozone from five stations for the period 1960 and 1964 with data tabulated by the Meteorological Branch, Department of Transport of Canada, in 11 volumes of *Ozone Data for the World* (ODW), 1960–1970. These graphs are analogous to those given by Figures 3 and 4, and any possible systematic trend is superimposed on the strong seasonal variations. For five years of observation, Pittock showed that it requires a careful statistical analysis to establish a trend of 20 per cent per decade to the 95 per cent confidence level. It is necessary to factor out the seasonal variations in order to detect real, long term, global trends of the expected size from the NO_x input from nuclear bomb tests.

A method of factoring out the seasonal trends has been presented by Komhyr *et al* (1971). They analyzed ozone data of the world for the time interval 1961–70 (inclusive) for 10 stations. They evaluated the "mean monthly total ozone deviations from monthly normals, based on the periods of record. . . . The ozone trend lines [linear change with time] were fitted to the data by the least squares method". Table 2 reproduces their results, and in Table 2 the error range is two standard deviations (2σ) or three times the computed probable error. The seven stations show a linear increase in ozone between 2.4 and 10.0 per cent per decade, well within the 95 per cent confidence level (2σ).

We have adopted the method of Komhyr *et al* (1971), with one extension, to examine all the total ozone data in the published volumes of Ozone Data for the World (1960–70). For the stations considered by Komhyr *et al* ozone was observed at least 25 days per month in almost every case. In considering all the data from all stations, there are some cases where ozone was observed only once or twice a month. In our extension of Komhyr's method, we weighted the monthly means by the number of observations made that month. In agreement with Komhyr *et al* (1971), we find a statistically significant ($5.1 \pm 1.2\%$) increase in ozone between the period 1961–70 for 93 stations with 169000 observation days. We considered the increase of all stations for various time spans 1960–71, 1961–70, 1962–70, etc. These are listed in Table 3. A comparison of one interval with another is complicated by the different number of stations in the various periods.

A plot of monthly deviations against time is given for all stations in the appendix. The plots are organized in terms of latitude, starting at the north pole and moving to the south pole.

TABLE 2.—SUMMARY OF DATA ANALYSES BY KOMHYR ET AL. (1971)

Station	Mean O_3 m-atm-cm	Percent increase per decade (1961–70)
Huancayo, Peru	262	6.0±1.2
Kodaikanal, India	257	10.0±1.2
Mauna Loa, Hawaii	276	2.4±1.8
Brisbane, Australia	289	6.6±1.8
Nashville, United States	332	8.8±2.1
Arosa, Switzerland	333	4.1±3.0
Oxford, England	354	8.9±3.0

TABLE 3.—GLOBAL CHANGES OF OZONE FOR VARIOUS TIME INTERVALS

[β is rate of increase of ozone percent per decade]

Time period	Years	Stations	Observation days	β	2σ	$\frac{\beta \text{ year}}{10}$
1960–70	11	93	178,000	4.5	1.2	4.9
1961–70	10	93	169,000	5.1	1.2	5.1
1962–70	9	92	159,000	4.8	1.3	4.3
1963–70	8	89	147,000	4.6	1.4	3.7
1964–70	7	89	132,000	4.9	1.6	3.4
1965–70	6	86	111,000	4.6	2.0	2.8

Foley and Ruderman (1972) plotted the total ozone data for Marcus Island, and they stated that the total ozone data showed no effect from nuclear bombs. The data for Marcus Island are presented both as monthly means and as deviations of the monthly mean from the ten-year norms in Figure 6. The Marcus Island data start in February 1960 and end in June 1963. When analyzed by the method of Komhyr *et al* (1971), these data show a *decrease* of ozone of 18±16 per cent per decade, contrary to Foley and Ruderman's statement. Also shown on Figure 6 is a set of data from a station that started observations in September 1963, after the bomb testing had stopped. The total ozone data and the monthly deviations show a strong *increase* in ozone over the next several years. Large nuclear bomb testing extended from 1952 through 1962, and then stopped. Komhyr *et al* found ozone from seven stations to increase from 1961–70. One plausible explanation of Komhyr's trend is that it represents the ozone of the world returning to normal after the perturbation (1952–62) of nitric oxide injections from nuclear bomb tests. To test the reasonableness of this hypothesis, one must look in detail at the history and magnitude of the bomb debris in the stratosphere.

Foley and Ruderman have demonstrated that nuclear bombs probably inserted significant quantities of nitric oxide into the stratosphere. Although nitric oxide from the bombs was not analyzed, very extensive analyses were made of strontium-90, excess carbon-14, and other radiactive products from the bombs. The fission yield of nuclear bombs is proportional to Sr-90 production, and Sr-90 was extensively sampled in the stratosphere. However, over the period 1952-62 there was a variation in the rato of total yield to fission yield; also Sr-90 is lodged in, particulate matter and may be subject to faster removal from the stratosphere than gaseous substances such as NO. Excess C–14 is in the form of a gas and it is proportional to total yield from nuclear bombs. However, as the level of C–14 drops to a low value, there is feedback from the troposphere, the ocean, and the biosphere. As tracers for probable duration and location of bomb-produced nitric oxide in the stratosphere, the advantages and disadvantages of Sr-90 and C–14 are complementary. The total global stratospheric burden of Sr-90 and C–14 are given as a function of time between 1951 and 1971 in Figure 7. The data were from Glasstone (1964) and Telegadas (1967, 1971), and Krey and Kajewski (1971).

The trends in Figure 7 refer to global stratospheric bomb debris. The detailed distribution of artificial nitric oxide in the stratosphere is as important as the absolute amount (Johnston, 1971). The distribution of C–14 with latitude and elevation is given by Figures 8–13. Figure 8 gives the distribution of excess C–14 in March-May 1960, the beginning of the observed ozone series in ODW. Figure 9 gives C–14 just before the 1961–62 bomb series started. Figure 10 in March-May 1962 shows a large quantity of C–14 in the north polar region, and Figure 11 in March-May 1963 is just past the peak of C–14 for the globe. The amount of C–14 has decreased notably by May 1964 (Figure 12), and the distribution of May 1966 (Figure 13) is closed to that of 1960 (Figure 8). The Figures 8–13 show that relatively little C–14 entered the stratosphere in the southern hemisphere.

The data of Figure 7 show the carry-over of nuclear debris in the stratosphere from the 1952–58 tests into the period of ozone observations after 1960, and before the major series of tests in 1961–62. The peak of C–14 at February 1963 was about four times the value of C–14 on January 1960. The peak of Sr–90 (also February 1963) is six times the residual value of Sr–90 in the stratosphere in January 1960. The 1963 peak of Sr–90 fell to the January 1960 value by July 1965, but the gaseous C–14 returned to its 1960 value only by 1970. If artificial nitric oxide from nuclear bombs is correlated with Sr–90 and C–14, one expects ozone to decrease between 1960 and early 1963 and to increase from 1963 to the late 1960's. These trends would be superimposed on the daily noise pattern (Figure 3)and the seasonal trends (Figures 3, 4, 6). These trends should be much more pronounced in the northern hemisphere than in the southern hemisphere (Figures 8–13).

During the years 1960–62, there were 30 ozone-observing stations that measured total ozone during at least 30 out of 36 months. These stations are entered in Table 4. At 23 out of 30 stations, ozone decreased during the years 1960–1962, and it increased at only 7 stations. The average change per decade is —10.8 per cent. Of the 30 stations in Table 4, 27 of them had at least 30 months of observations (20 had over 80 months of observations) between 1963 and 1970. Of these 27 stations, 22 showed an increase in ozone. Of these 27 stations, two thirds of them showed both a decrease between 1960-62 and an increase 1963–70. The average increase for these stations is 7.2 per cent per decade.

TABLE 4.—STATIONS WITH AT LEAST 30 MONTHS OF OBSERVATION IN THE PERIOD 1960–62, AND IN 1963–70

[k, OZONE INCREASE PER DECADE, PERCENT]

Station	1960–62			1963–70		
	Number of observations	k	2s	Number of observations	k	2s
Aarhus, Denmark	36	−12.7	14.9	92	−8.9	7.6
Abustamani, U.S.S.R	35	−36.1	34.0	29		
Ahmedabad, India	36	+12.3	11.3	82	+8.0	3.7
Alma Ata, U.S.S.R	30	−9.1	23.5	91	+25.9	11.5
Arosa, Switzerland	36	−5.8	18.4	90	+4.6	5.0
Aspendale, Australia	36	−3.7	17.7	92	−4.3	2.4
Brisbane, Australia	36	−4.3	11.7	92	+1.2	2.4
Camborne, United Kingdom	36	−11.8	19.2	38	+17.2	9.2
Cagliari-Elmas, Italy	36	−3.4	12.5	92	+13.5	4.2
Edmonton, Canada	36	−16.0	13.6	92	+3.3	4.3
Eskdalemuis, United Kingdom	36	−32.8	23.3	7		
Fort Collins, United States	31	−5.8	9.6	36	+18.0	12.8
Kagoshima, Japan	36	+55.9	19.3	92	0	4.8
Karadag, U.S.S.R	31	−89.3	22.6	36	+6.9	37.4
Kiev, U.S.S.R	31	−11.4	29.8	92	+9.5	8.4
Kodaikanal, India	36	−.6	8.4	90	+12.4	1.9
Leningrad, U.S.S.R	30	−7.0	29.3	84	+12.8	8.4
Lerwick, United Kingdom	36	−26.7	15.9	79	+7.5	4.7
Marcus Island, Japan	36	−38.8	16.1	6		
Messina, Italy	36	−32.5	11.3	92	+8.2	3.2
New Delhi, India	36	+15.0	16.1	92	−5.6	3.3
Oxford, United Kingdom	36	−18.2	17.9	92	+6.8	4.5
Port-Aux-Francaise	30	+2.0	24.8	70	+29.0	19.0
Quetta, Pakistan	36	−7.0	17.0	37	+4.5	10.1
Resolute, Canada	35	−32.1	19.1	83	+4.1	6.2
Sapporo, Japan	36	+1.0	16.6	92	+4.1	3.2
Tateno, Japan	36	+10.7	16.7	92	−.9	4.2
Toronto, Canada	36	−11.6	18.8	88	+1.7	4.4
Tromso, Norway	30	+11.1	31.0	64	+10.6	7.8
Vigna di Valle, Italy	36	−15.2	14.6	90	+4.1	4.4
Average per decade, percent		−10.8			+7.2	
Percent in interval		−3.3			+5.8	

A close examination of the Komhyr plots in the appendix shows a number of stations with positive deviations in the early 1960's, a minimum in the middle 1960's, and high values again in the late 1960's, for examples: Aarhus, Alma Ata, Moscow, Murmansk, Riga, Kuibyshev, Mont-Louis, Messina, Yakutsk, Port-aux-Francaise, Resolute. This conspicuous minimum of ozone in the middle 1960's is a recurring pattern.

The average change in ozone as a function of time interval and latitude is given in Table 5. In combining different stations involving widely different numbers of observations and widely different standard errors of estimate of the linear change function, we used the reciprocal of the square of the standard deviation as a weighting factor. This method suppresses the contribution from stations that covered only a short time span, that had relatively few observations, and that had large scatter of points. Table 5 should be studied in comparison with Figures 8–13. These figures (and other data from the HASL reports, Telegadas 1967, 1971) show relatively little change of C–14 in the southern hemisphere. Table 5 shows no significant change in stratospheric ozone in the southern hemisphere. In the northern hemisphere there was a significant decrease in ozone during the period 1960–62, followed by an increase in 1963–70. Then Figures 8–13 show the largest concentration and persistence of carbon–14 in the northern part of the northern hemisphere. Table 5 shows a much larger decrease in total ozone for stations north of 50°N than for the entire hemisphere or for the globe. The geographical pattern of ozone changes (decreasing 1960–62, increasing 1963–70) shown in Table 5 are consistent with the temperal and geographical trends shown by carbon–14 in Figures 7–13.

TABLE 5.—GEOGRAPHICAL VARIATION OF OZONE CHANGES FOR THE 2 TIME INTERVALS 1960–62, 1963–70

Latitude	Time period	Percent increase per decade	2σ	Number of stations	Number of measurable days
50N–90N	1960–62	−12.6	10.6	20	11,000
	1963–70	+7.6	3.2	28	47,000
	1960–70	+6.5	2.4	29	57,000
0–90N	1960–62	−7.6	7.0	42	28,000
	1963–70	+5.6	1.5	74	129,000
	1960–70	+5.3	1.2	75	156,000
0–90S	1960–62	−3.6	18.8	9	4,200
	1963–70	−1.2	3.1	15	19,000
	1960–70	+.2	2.3	17	23,000
All stations	1960–62	−7.1	6.5	51	32,000
	1963–70	4.6	1.4	89	147,000
	1960–70	4.5	1.2	93	178,000

Correcting Foley and Ruderman's thermodynamics by a factor of 2 and showing the factor of 6 uncertainty range arising from considerations of chemical kinetics in the rising fireball, one obtains for the production of nitric oxide from nuclear bombs

$$N_{NO} = (0.17-1.0\times10^{32}\ Y_{MT}$$

According to tables given by Foley and Ruderman, the total nuclear bomb yield from 1952 to 1962 was 513 MT. Thus the total number of molecules of nitric oxide produced by nuclear bombs between 1952 and 1962 is expected to be between the limits

$$N_{NO} = (0.8-5.1)\times10^{34} \text{ molecues}$$

One American SST operating normally for 10 years produces 4.8×10^{32} molecules of NO. Thus the decade of bomb testing had the average effect equivalent to the number of SST

$$N_{SST} \text{ (10 year average)) } = 18 \text{ to } 103$$

Alternatively it is as if SST flights had started in 1952 and increased linearly until 1962 to reach the total

$$N_{SST} \text{ (1962 max.) } = 36 \text{ to } 206$$

and then all flights stopped. The ozone data of the world then showed a significant increase after the cessation in 1962 of about 5 per cent. If ramping up from 0 to 36 SST caused the ozone of the world to decrease by 5 per cent (the magnitude of the later rebound), then the effect of NO on stratospheric ozone is *greater* than that previously predicted (Johnston, 1971), which would be about 3 or 4%. If ramping up from 0 to 206 SST caused the ozone of the world to decrease by only 5 per cent, then the effect is somewhat smaller than the central value predicted (Johnston, 1971). Such a ramp model for the introduction of 200 SST was expected to reduce ozone by about 10 per cent in terms of the previous model, although a wide range of effect was regarded as possible. It may be that the oxides of nitrogen from nuclear bomb tests of 1952–62 constituted a measurable injection experiment and the consequent reductions of ozone may be ascribable (perhaps only in part) to this injection experiment.

This is not to say that we accept at face value the explanation of the trends shown in Tables 4 and 5 in terms of the effect of nuclear bombs. There are a large number of reasons for meteorological and climatological changes. The Ozone Data of the World may be unreliable because of instrumental or operational difficulties. The points made here are three: (1) The expected reduction in ozone from the nuclear tests of 1952–62 are a matter of a few per cent. (2) There was a significant decrease in total ozone between 1960–62 and a significant increase of total ozone between 1963–70. (3) These trends are consistent with the expectations of the effect of nuclear bombs, but there may also be other explanations.

Foley and Ruderman's examination of the statistics of ozone changes in the period before and after the bomb tests was inadequate. They looked at too few data, and they did not use a sensitive method to analyze for long-term trends. There are long term trends, and these trends may be due to the injection of NO by nuclear bombs.

ACKNOWLEDGMENT

This work was supported by the Climatic Impact Assessment Program by means of an interagency agreement between the Department of Transportation and the Atomic Energy Commission. We thank the many students who contributed their services in transcribing the Ozone Data for the World from the red books to tables suitable for computer processing.

REFERENCES

1972. Foley, H. M., and M. A. Ruderman, "Stratospheric Nitric Oxide Production from Past Nuclear Explosions and Its Relevance to Projected SST Pollution" Paper p. 894. Institute for Defense Analyses, JASON, 400 Army-Navy Drive, Arlington, Virginia, pages 1–25.

1964. Glasstone, S., *The Effects of Nuclear Weapons*, U.S. Atomic Energy Commission, U.S. Government Printing Office, p. 486.

JANAF Thermochemical Tables (Second Edition) NSRDS–NBS–37.

1971. Johnston, H. S., "Catalytic Reduction of Stratospheric Ozone by Nitrogen Oxides" UCRL–20568, pp. 1–114.

TID–4500. "Reduction of Stratopheric Ozone by Nitrogen Oxide Catalysts from Supersonic Transport Exhaust" *Science*, *173*, 517–522.

1971. Komhyr, W. D., E. W. Barrett, G. Slocum, and H. K. Weickmann, "Atmospheric Ozone Increase during the 1960s" *Nature 232*, 390–391.

1971. Krey, P. W. and B. T. Kajewski, "Updating Stratospheric Inventories to February 1971" Health and Safety Laboratory Report 245, pp. 103–124.

1960–70. *Ozone Data for the World*, Department of Transport, Meteorological Branch in Cooperation with the World Meteorological Organization.

1972. Pittock, A. B., "Evaluating the Risk to Society from the SST" *Search 3*, 285–289.

1967. Telegadas, K., "The Seasonal Stratospheric Distribution of Cadmium–109, Plutonium–238, and Strontium–90" Health and Science Laboratory Report—184. U.S. Atomic Energy Commission, pp. 53–118.

1971. Telegadas, K., "The Seasonal Stratospheric Distribution and Inventories of Excess Carbon–14 from March 1955 to July 1969" Health and Safety Laboratory Report–243. U.S. Atomic Energy Commission, pp. 3–86.

Titles to Figures

Fig. 1. Elevation and dimension of nuclear bomb clouds 30 minutes after detonation according to formulas by Foley and Ruderman. A standard ozone profile at 45° latitude is shown.
Fig. 2. Overlap of standard tropical ozone profile with bomb clouds 30 minutes after detonation.
Fig. 3. Total ozone columns at Aspendale showing daily fluctuations and seasonal variations.
Fig. 4. Total ozone columns at Moscow and at Messina.
Fig. 5. Graph showing the number of years N of observation required to determine a trend *b* (% ozone change per decade) to the 95% confidence level at Aspendale, Australia (Pittock, 1972).
Fig. 6. Total ozone column and monthly deviations (method of Komhyr et al, 1971) for Marcus Island and for Bolshaya-Elau.
Fig. 7. The variation with time of total stratospheric inventory of strontium–90 and carbon–14, with periods and yields (MT) of nuclear explosives.
Figs. 8–13. Contour maps of zonal average, excess carbon 14 in the stratosphere in units of 10^5 atoms of carbon–14 per gram of air.
Figs. 14–32. Monthly deviations of total ozone column for all stations. The stations are listed in order of latitude from 90°N to 90°S.

FIGURE 1

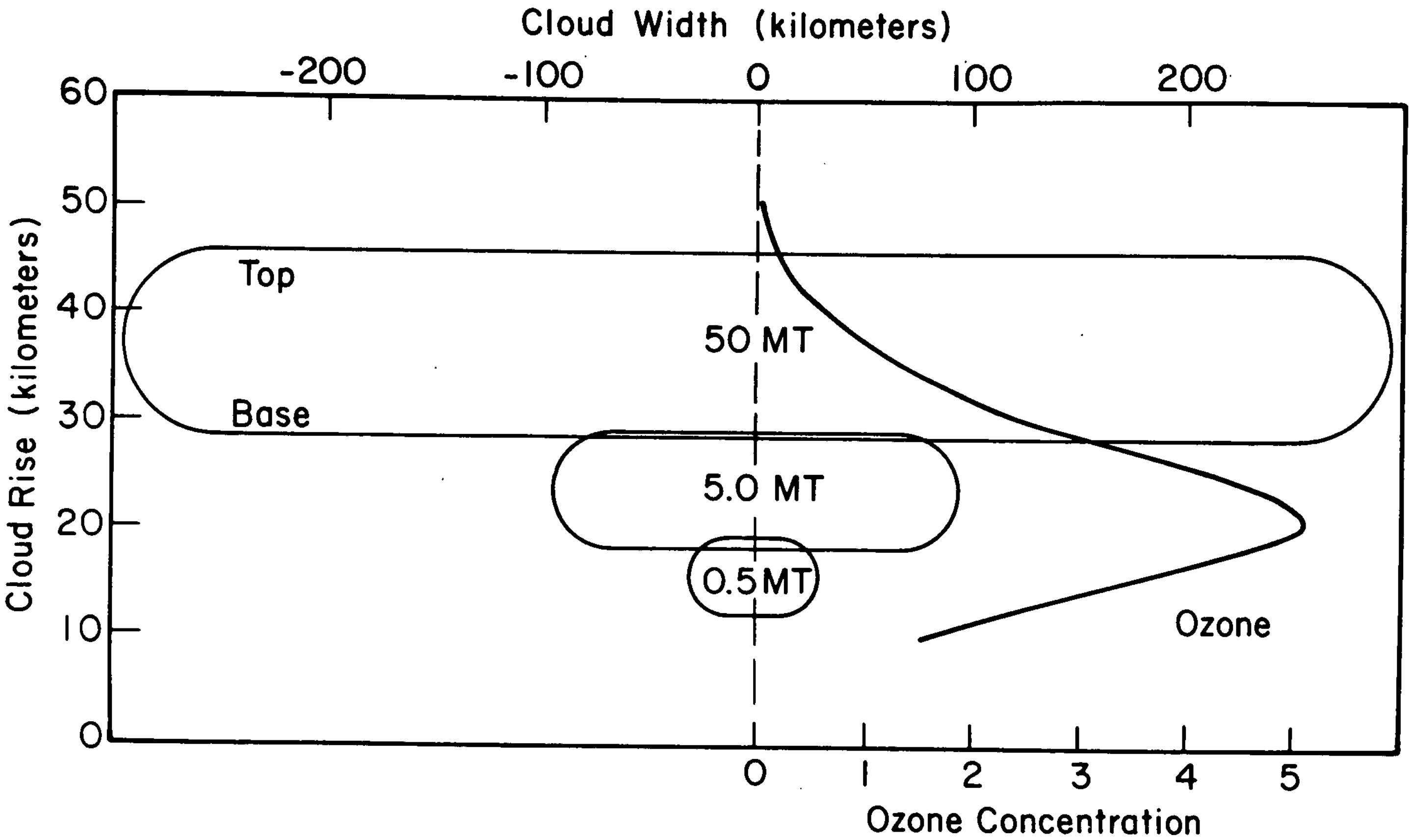

Cloud Width (kilometers)
-200
-100
0
100
200
60
50
40
30
20
10
0
Cloud Rise (kilometers)
Top
Base
50 MT
5.0 MT
0.5 MT
Ozone
0
1
2
3
4
5
Ozone Concentration

FIGURE 2

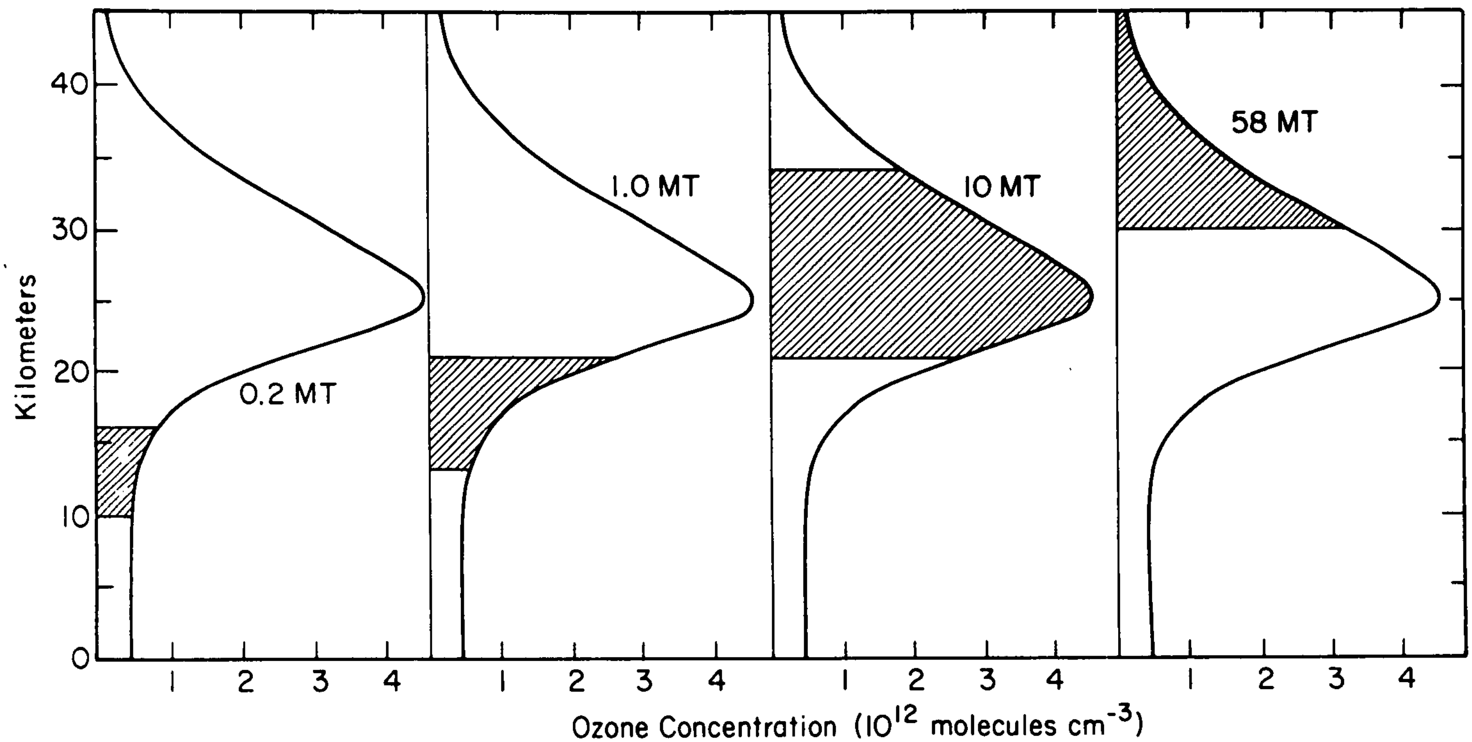

Kilometers
0
10
20
30
40
0.2 MT
1.0 MT
10 MT
58 MT
1
2
3
4
Ozone Concentration (10^12 molecules cm^-3)

FIGURE 3

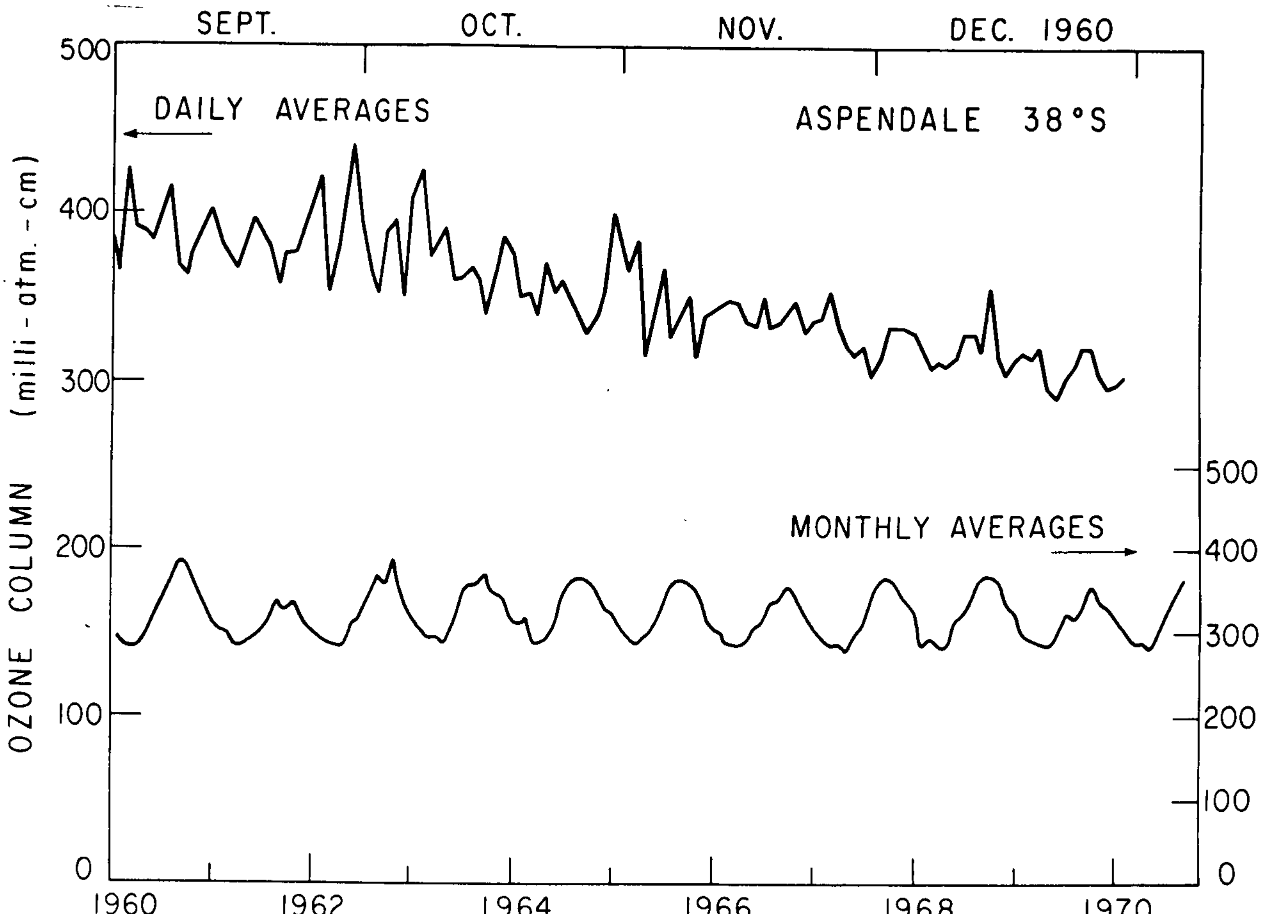
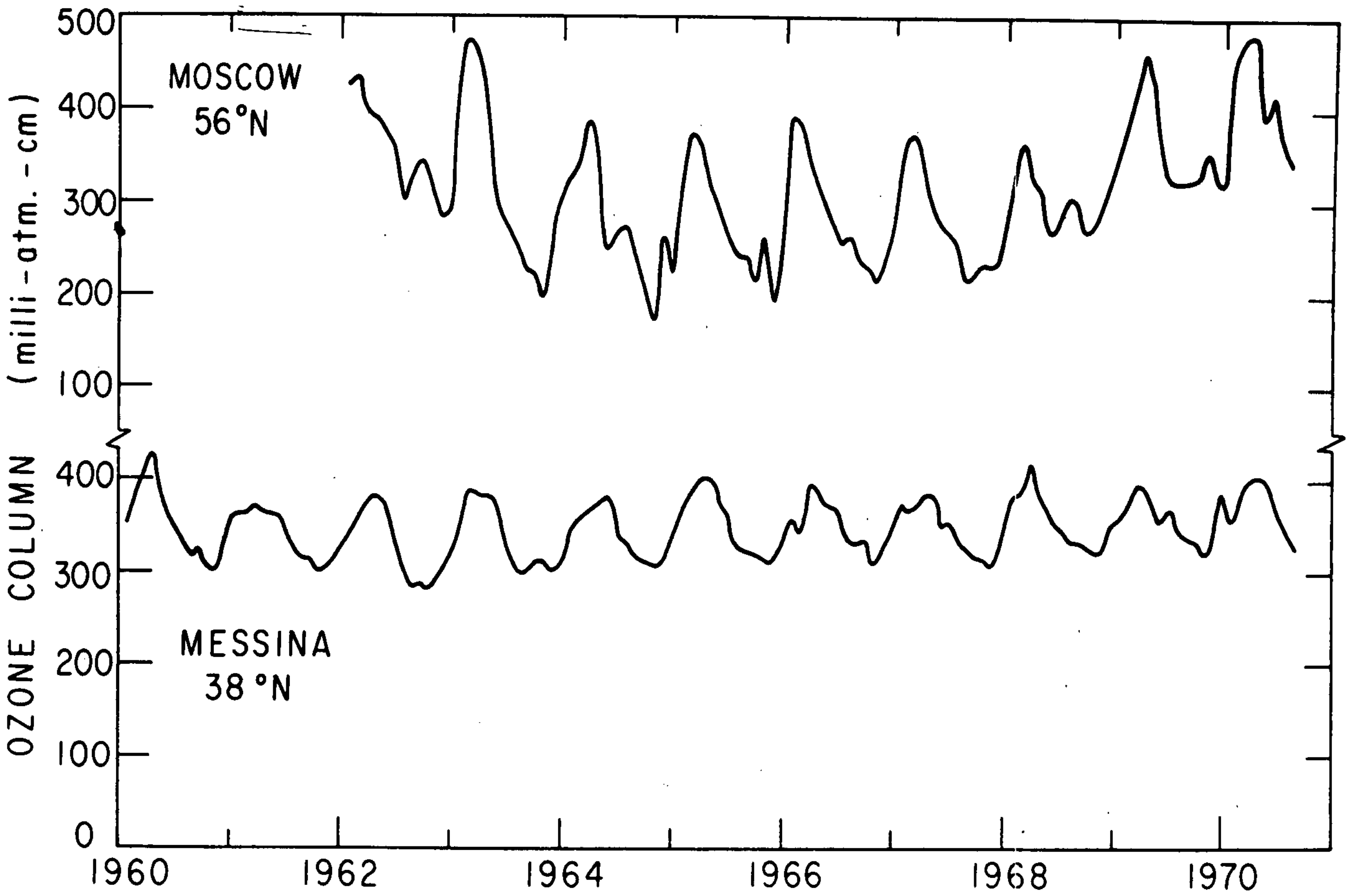

SEPT.
OCT.
NOV.
DEC. 1960
DAILY AVERAGES
ASPENDALE 38°S
OZONE COLUMN (milli - atm. - cm)
500
400
300
200
100
0
MONTHLY AVERAGES
500
400
300
200
100
0
1960
1962
1964
1966
1968
1970

FIGURE 4



90-912 O - 73 - 13

FIGURE 5

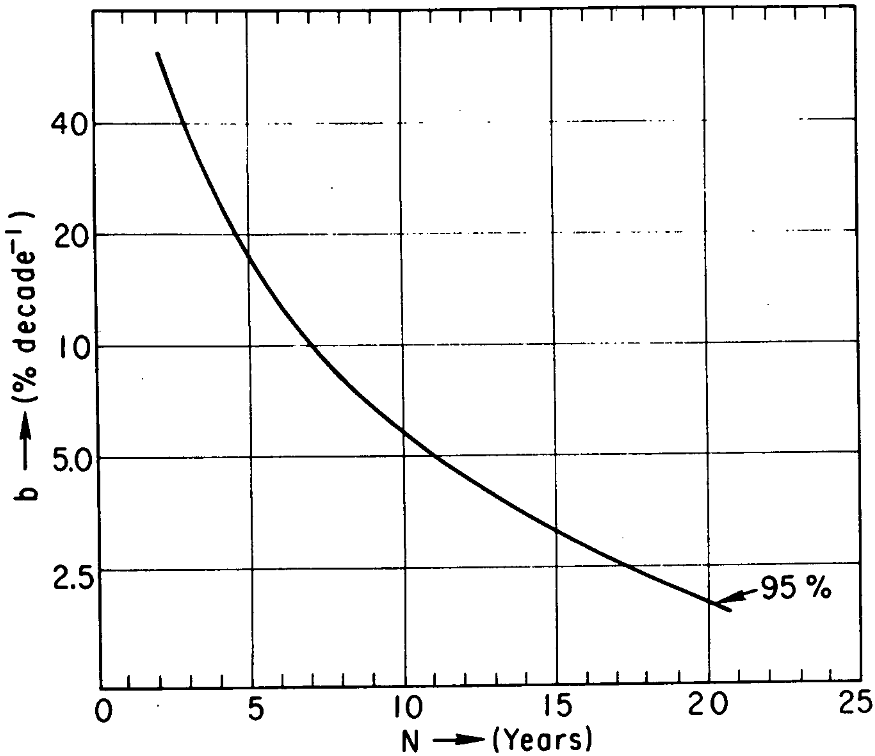


FIGURE 6

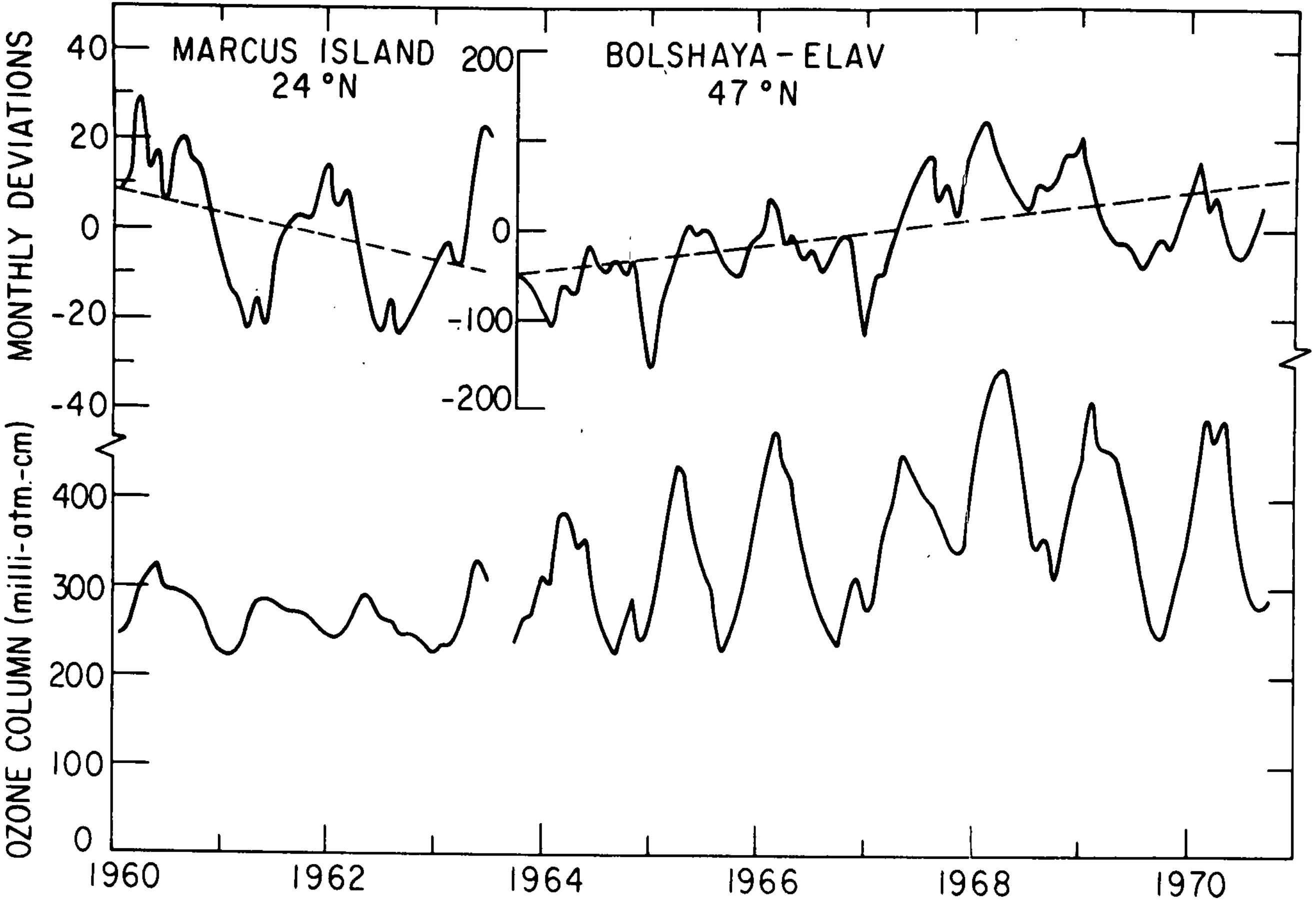

MARCUS ISLAND
24°N
BOLSHAYA-ELAV
47°N
MONTHLY DEVIATIONS
40
20
0
-20
-40
200
0
-100
-200
OZONE COLUMN (milli-atm.-cm)
400
300
200
100
0
1960
1962
1964
1966
1968
1970

FIGURE 7

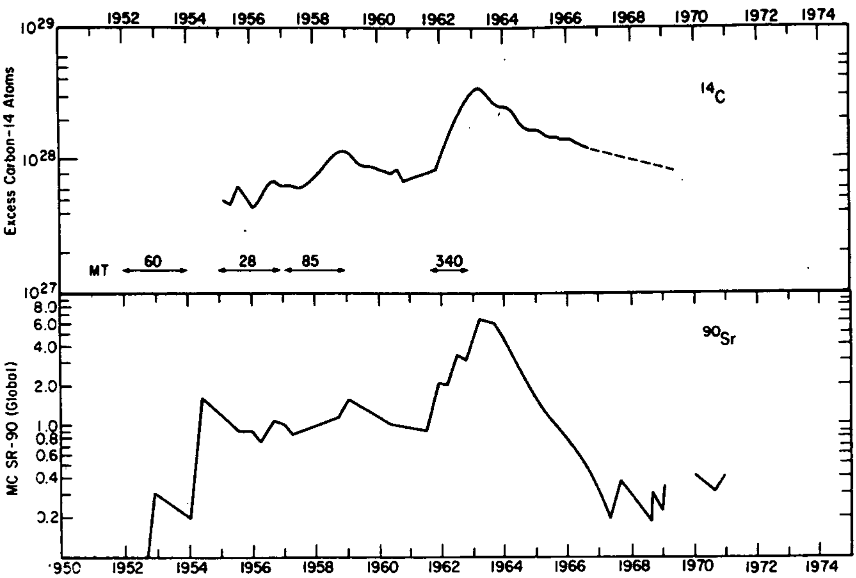

Excess Carbon-14 Atoms
MC SR-90 (Global)
^{14}C
^{90}Sr
MT
60
28
85
340
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
10^{29}
10^{28}
10^{27}
8.0
6.0
4.0
2.0
1.0
0.8
0.6
0.4
0.2

FIGURE 8

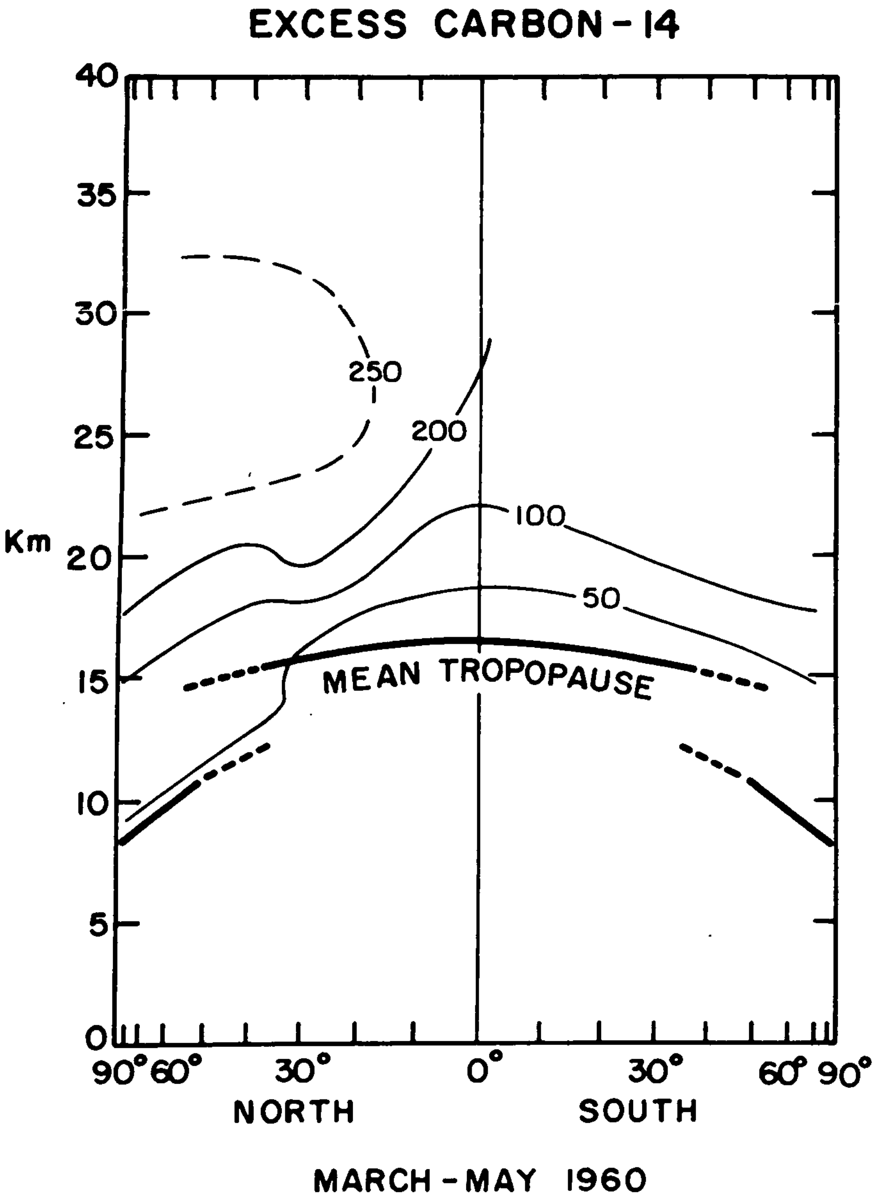

EXCESS CARBON-14
40
35
30
25
20
15
10
5
0
Km
250
200
100
50
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH-MAY 1960

FIGURE 9

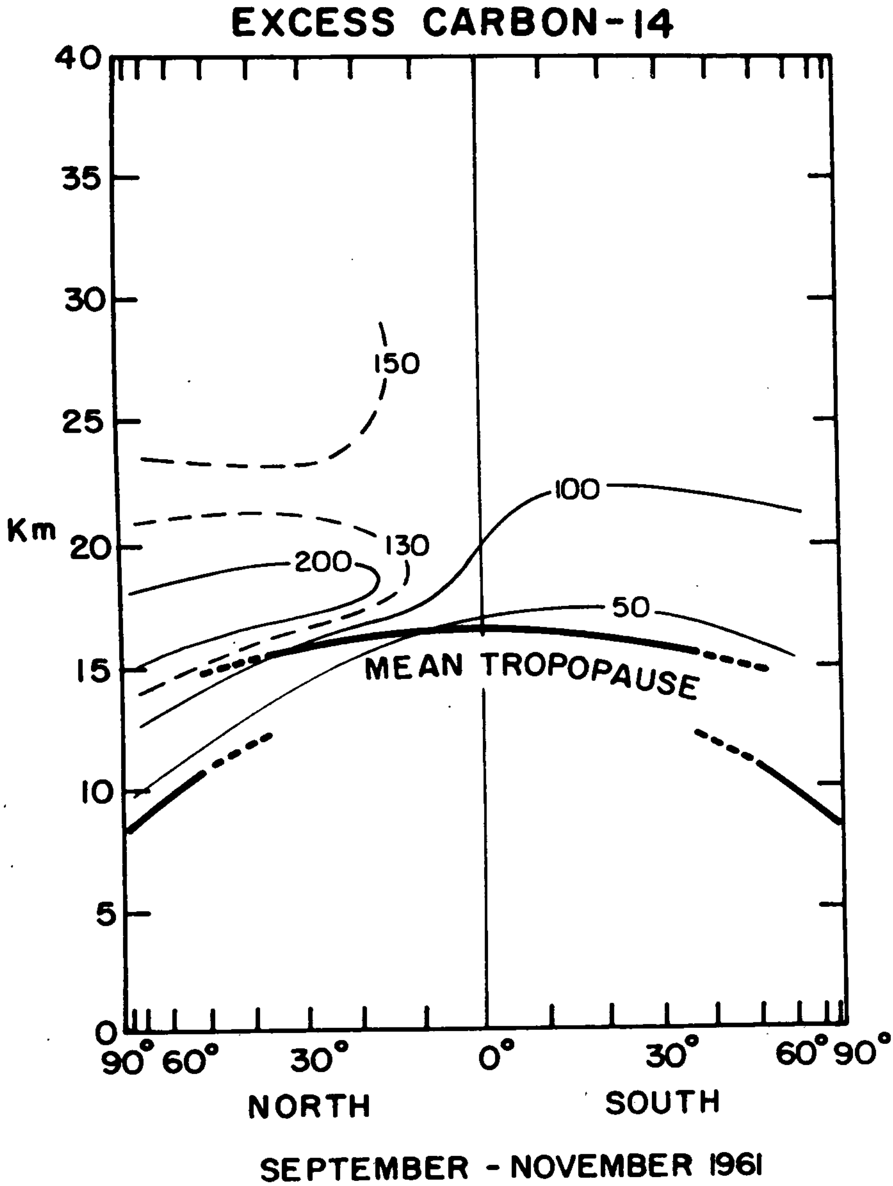

EXCESS CARBON-14
Km
40
35
30
25
20
15
10
5
0
150
130
200
100
50
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
SEPTEMBER - NOVEMBER 1961

FIGURE 10

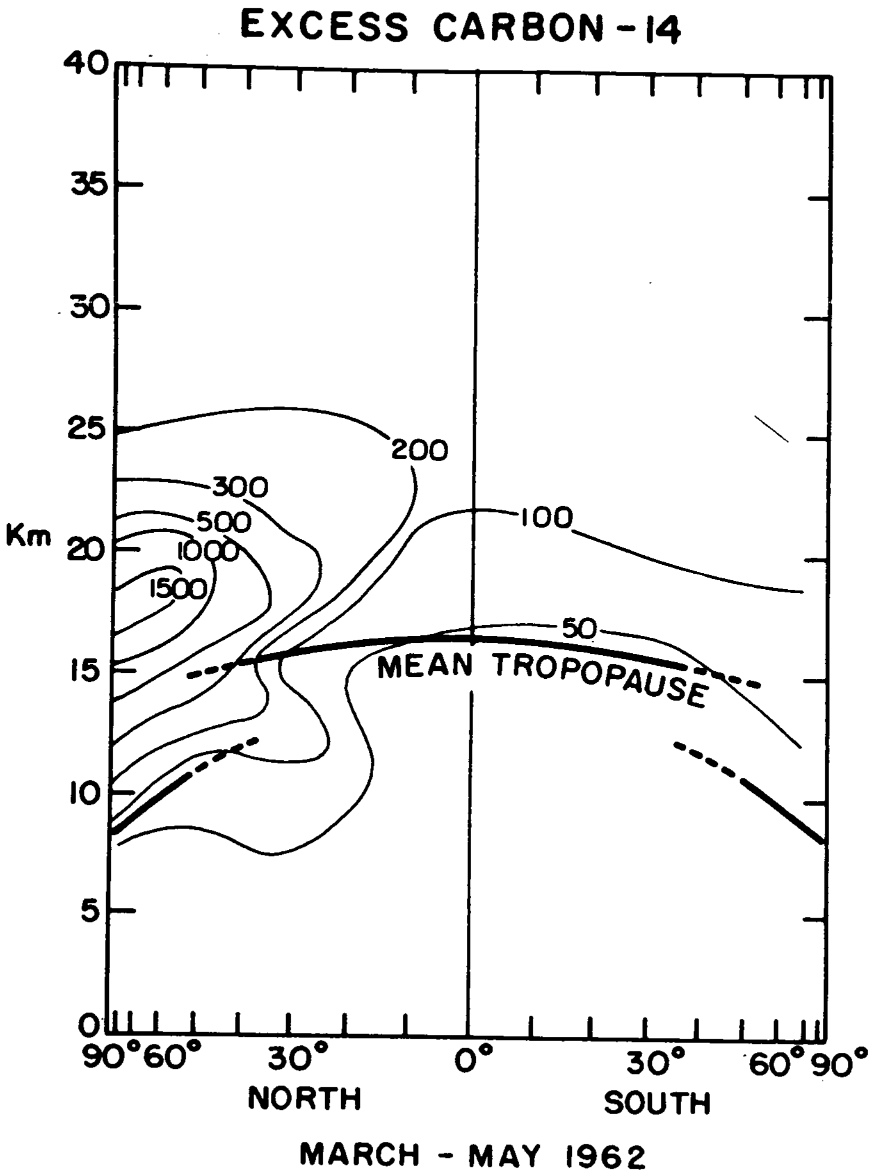

EXCESS CARBON-14
Km
40
35
30
25
20
15
10
5
0
200
300
500
1000
1500
100
50
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH - MAY 1962

FIGURE 11

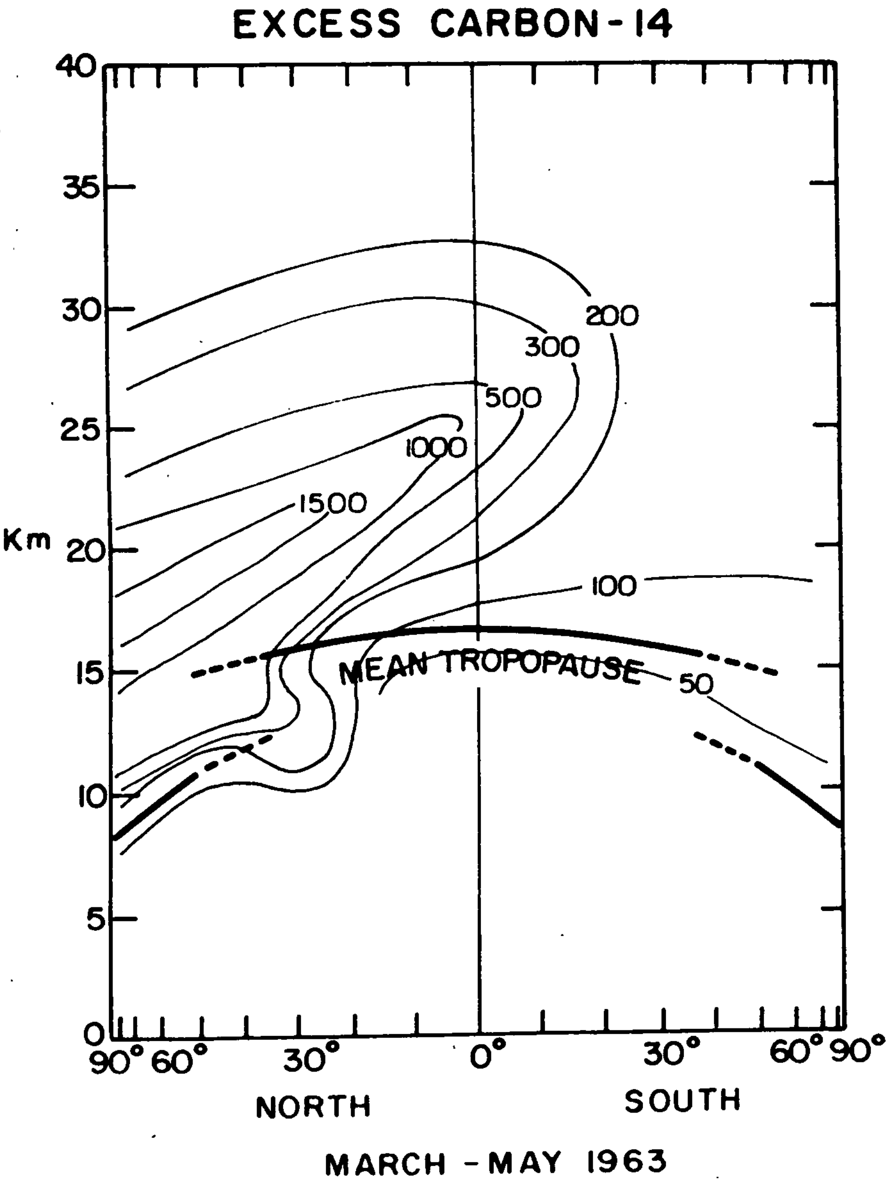

EXCESS CARBON-14
40
35
30
25
20
15
10
5
0
Km
200
300
500
1000
1500
100
MEAN TROPOPAUSE
50
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH - MAY 1963

FIGURE 12

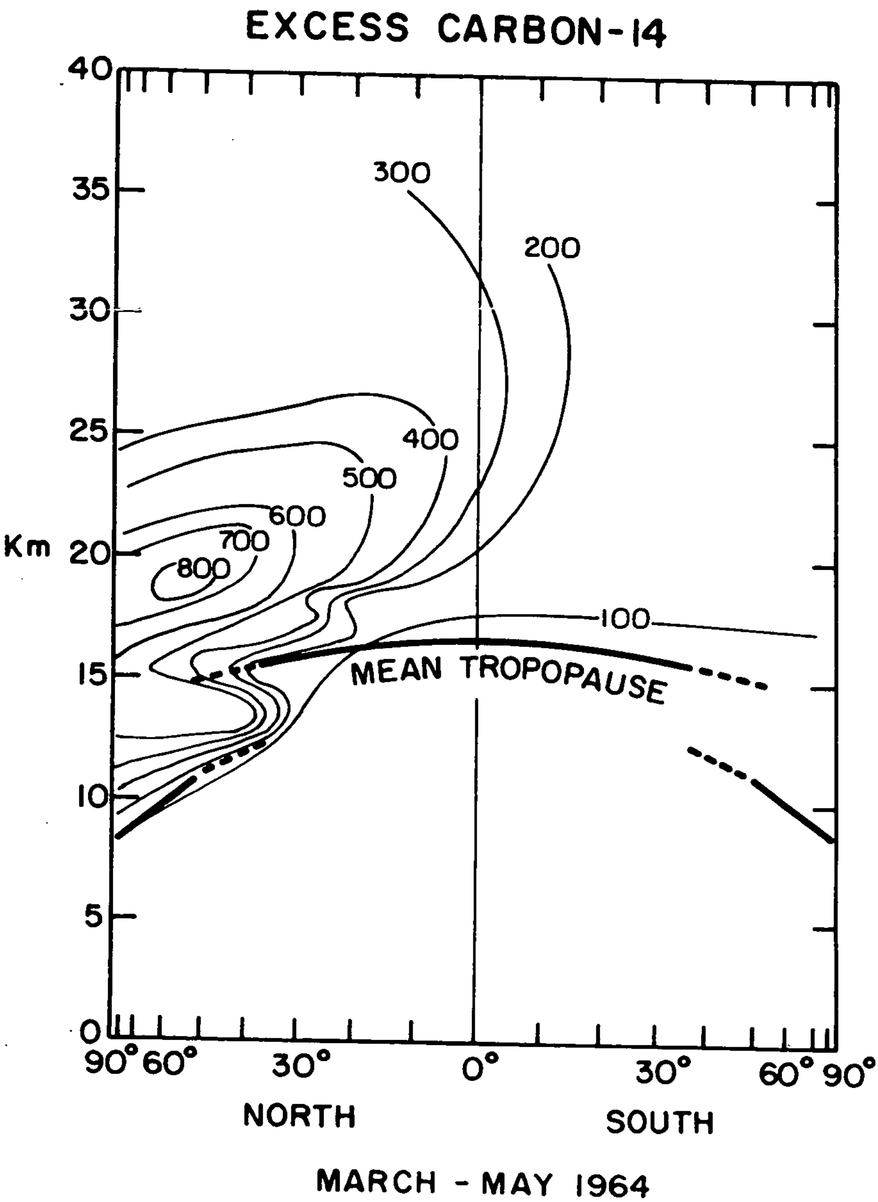

EXCESS CARBON-14
40
35
30
25
20
15
10
5
0
Km
300
200
400
500
600
700
800
100
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH - MAY 1964

FIGURE 13

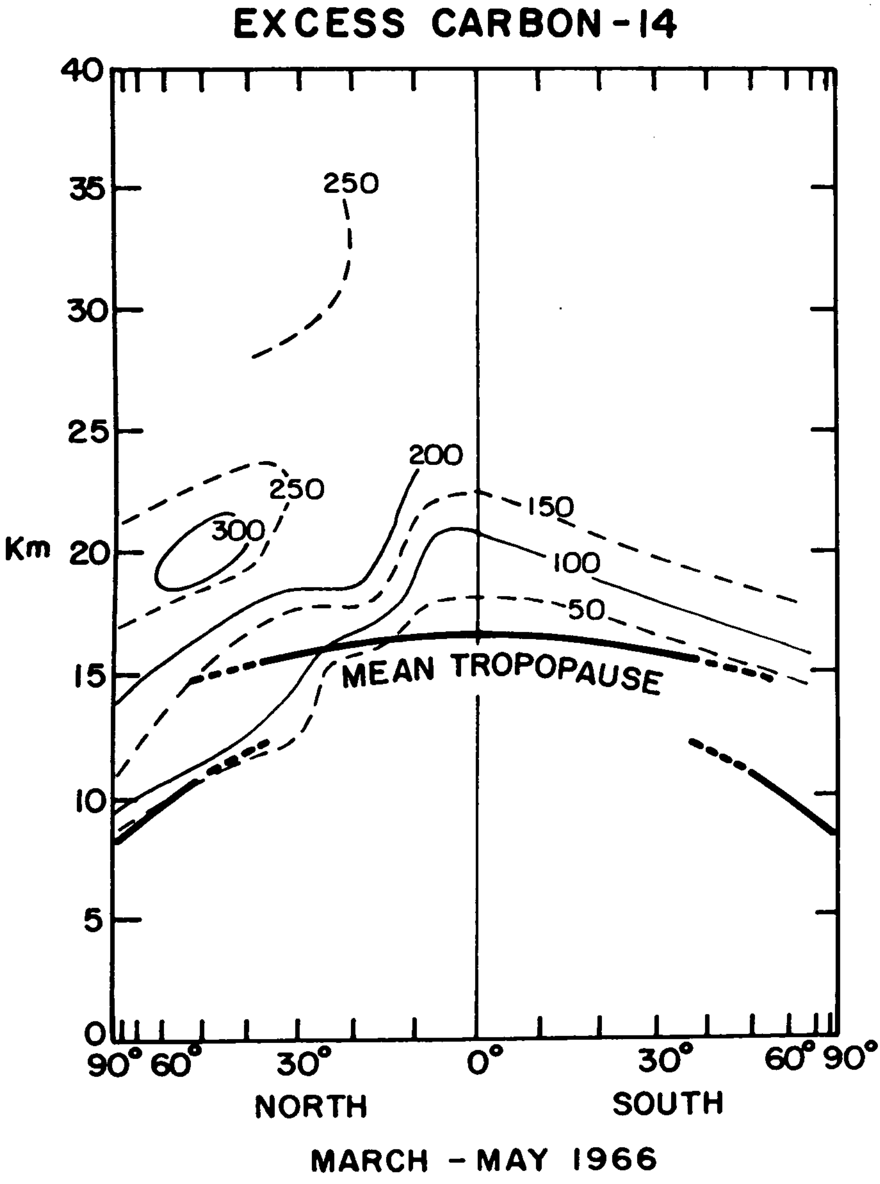

EXCESS CARBON-14
Km
40
35
30
25
20
15
10
5
0
250
200
250
300
150
100
50
MEAN TROPOPAUSE
90° 60°
30°
0°
30°
60° 90°
NORTH
SOUTH
MARCH - MAY 1966

FIGURE 14

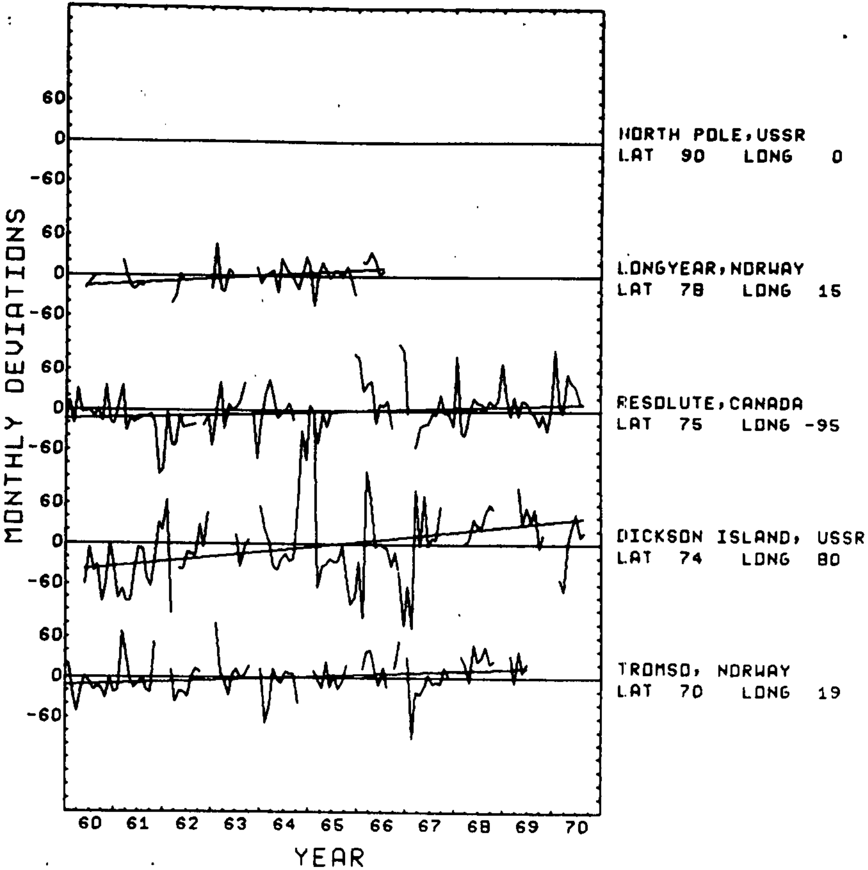
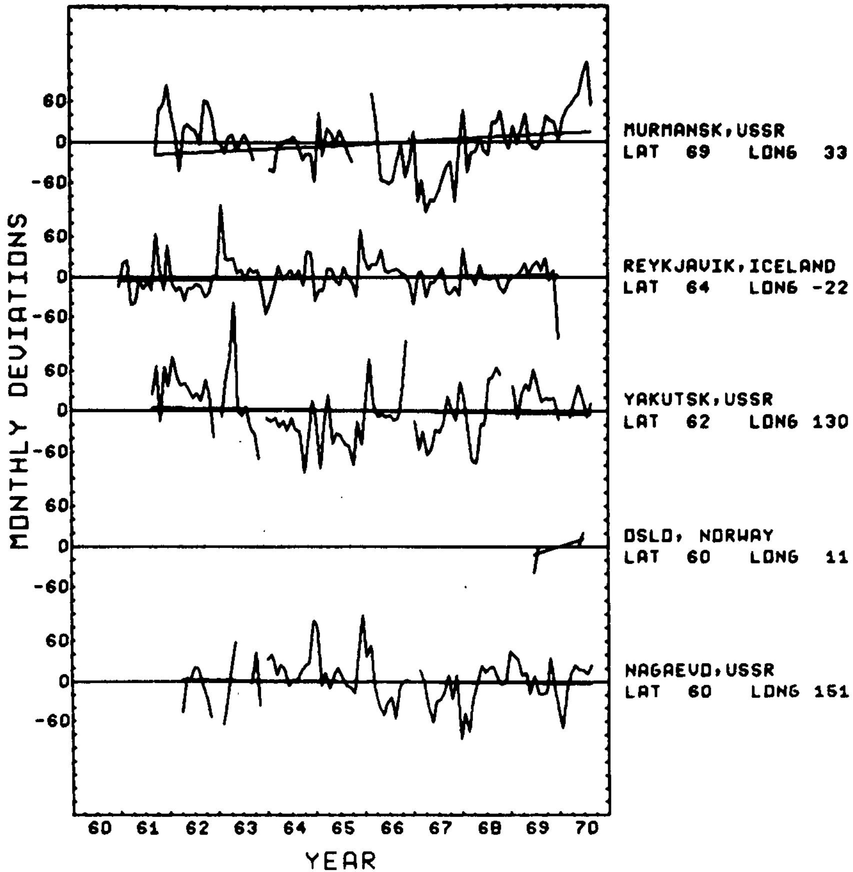

MONTHLY DEVIATIONS
60
0
-60
NORTH POLE, USSR
LAT 90 LONG 0
LONGYEAR, NORWAY
LAT 78 LONG 15
RESOLUTE, CANADA
LAT 75 LONG -95
DICKSON ISLAND, USSR
LAT 74 LONG 80
TROMSO, NORWAY
LAT 70 LONG 19
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 15



MONTHLY DEVIATIONS
YEAR
60 61 62 63 64 65 66 67 68 69 70
60
0
-60
MURMANSK, USSR
LAT 69 LONG 33
REYKJAVIK, ICELAND
LAT 64 LONG -22
YAKUTSK, USSR
LAT 62 LONG 130
OSLO, NORWAY
LAT 60 LONG 11
NAGAEVO, USSR
LAT 60 LONG 151

FIGURE 16

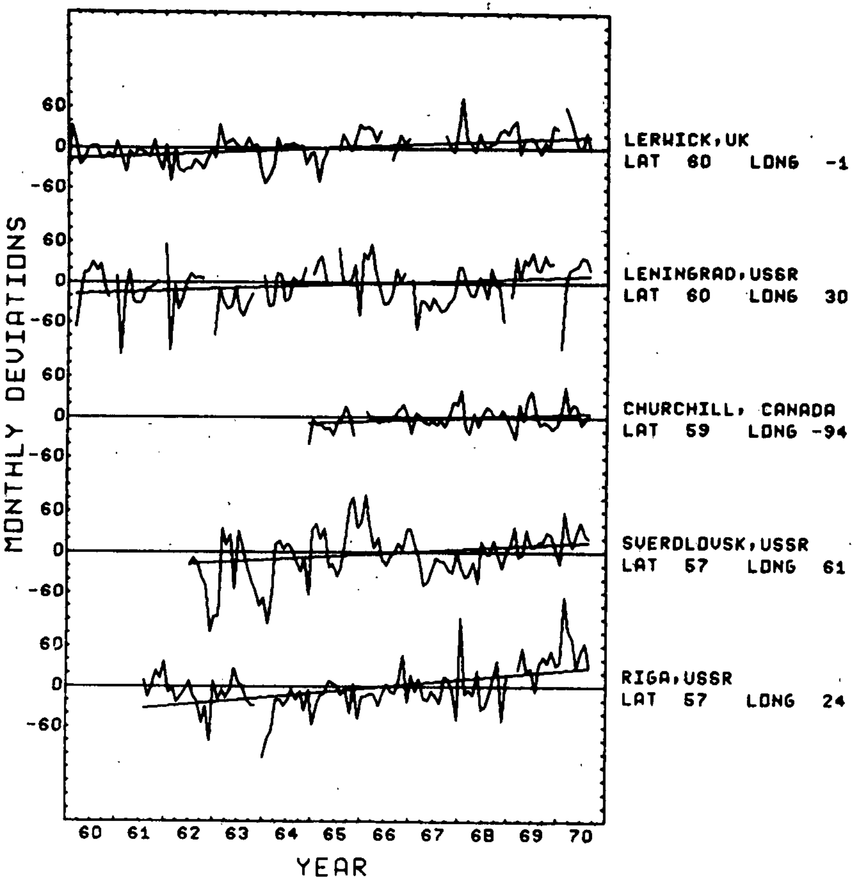

MONTHLY DEVIATIONS
60
0
-60
LERWICK, UK
LAT 60 LONG -1
LENINGRAD, USSR
LAT 60 LONG 30
CHURCHILL, CANADA
LAT 59 LONG -94
SVERDLOVSK, USSR
LAT 57 LONG 61
RIGA, USSR
LAT 57 LONG 24
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 17

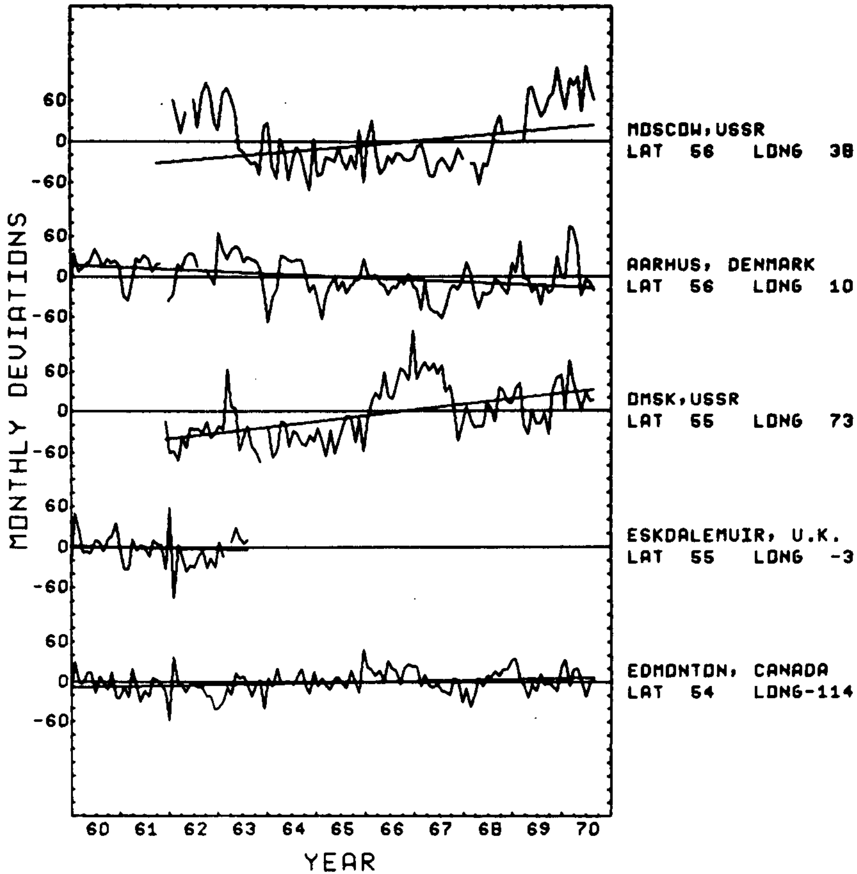

MONTHLY DEVIATIONS
60
0
-60
60
0
-60
60
0
-60
60
0
-60
60
0
-60
60 61 62 63 64 65 66 67 68 69 70
YEAR
MOSCOW, USSR
LAT 56 LONG 38
AARHUS, DENMARK
LAT 56 LONG 10
OMSK, USSR
LAT 55 LONG 73
ESKDALEMUIR, U.K.
LAT 55 LONG -3
EDMONTON, CANADA
LAT 54 LONG-114

FIGURE 18

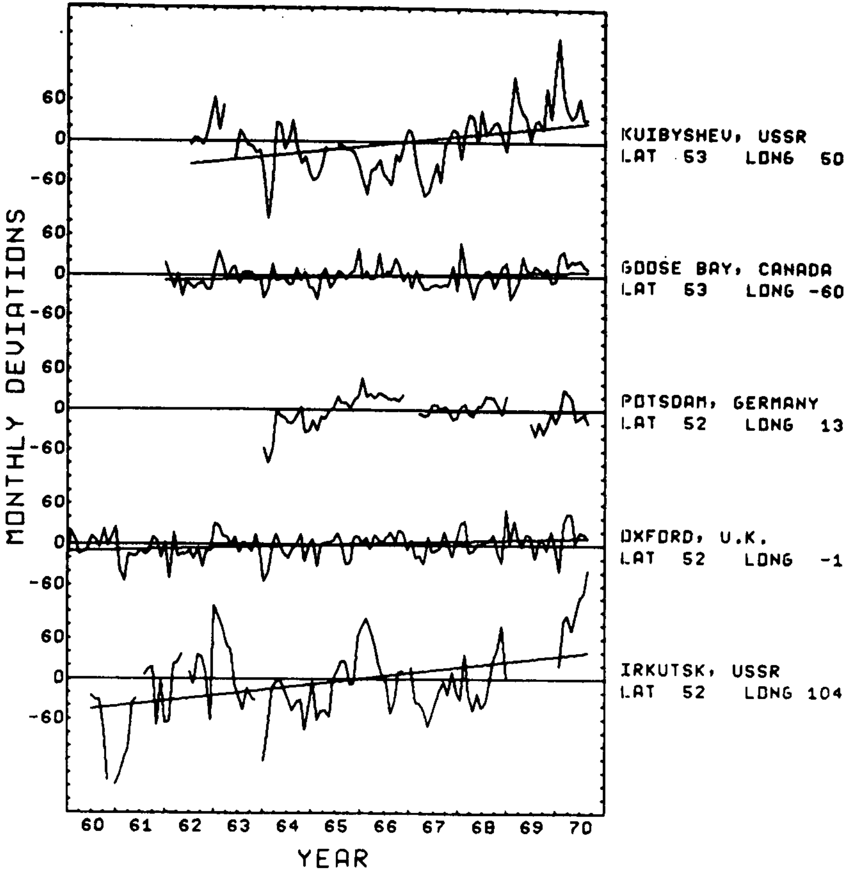
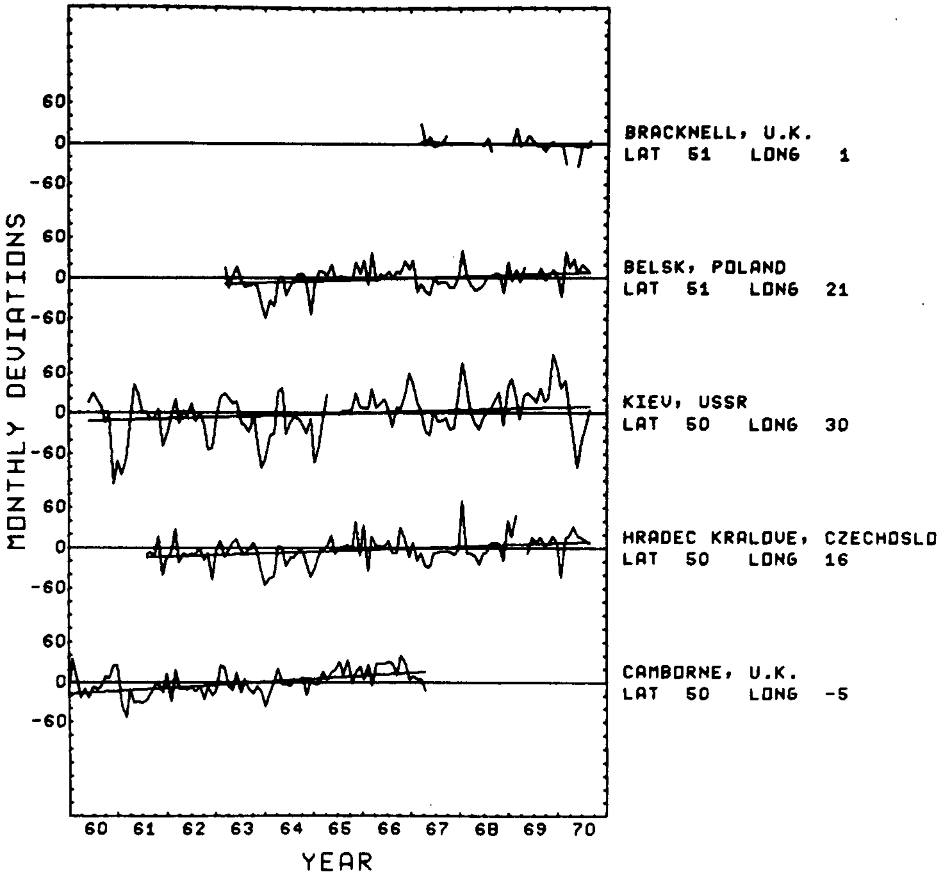

MONTHLY DEVIATIONS
60
0
-60
KUIBYSHEV, USSR
LAT 53 LONG 50
GOOSE BAY, CANADA
LAT 53 LONG -60
POTSDAM, GERMANY
LAT 52 LONG 13
OXFORD, U.K.
LAT 52 LONG -1
IRKUTSK, USSR
LAT 52 LONG 104
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 19


60
0
-60
MONTHLY DEVIATIONS
BRACKNELL, U.K.
LAT 51 LONG 1
BELSK, POLAND
LAT 51 LONG 21
KIEV, USSR
LAT 50 LONG 30
HRADEC KRALOVE, CZECHOSLO
LAT 50 LONG 16
CAMBORNE, U.K.
LAT 50 LONG -5
60 61 62 63 64 65 66 67 68 69 70
YEAR

90-912 O - 73 - 14

FIGURE 20

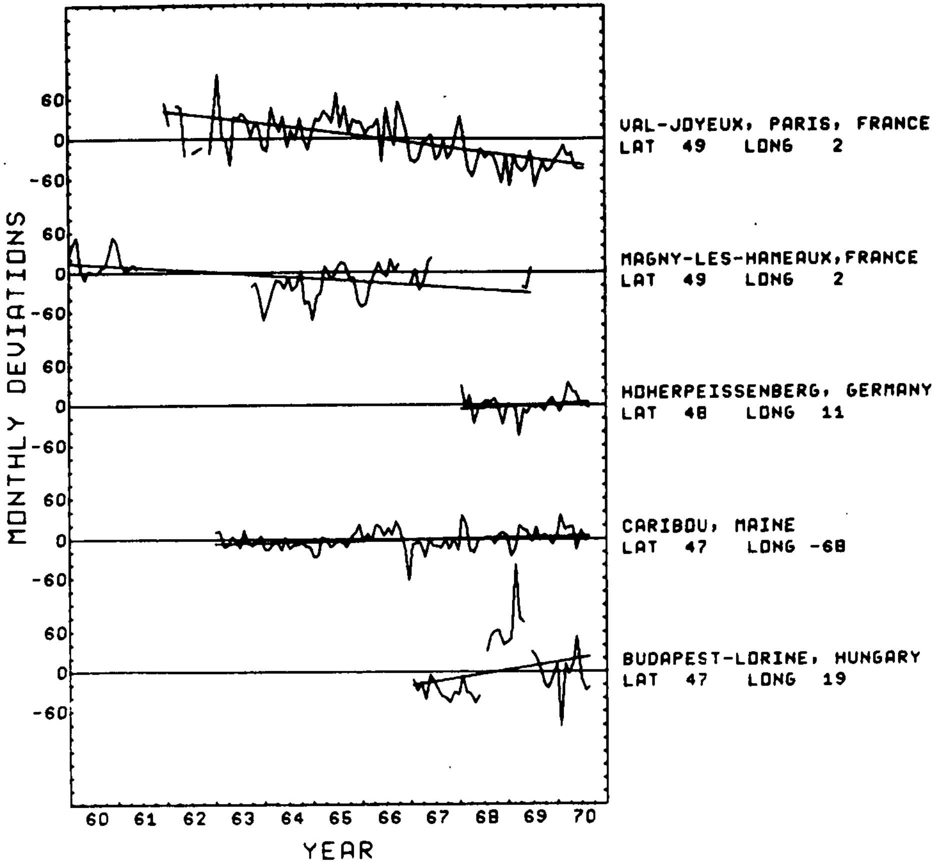


FIGURE 21

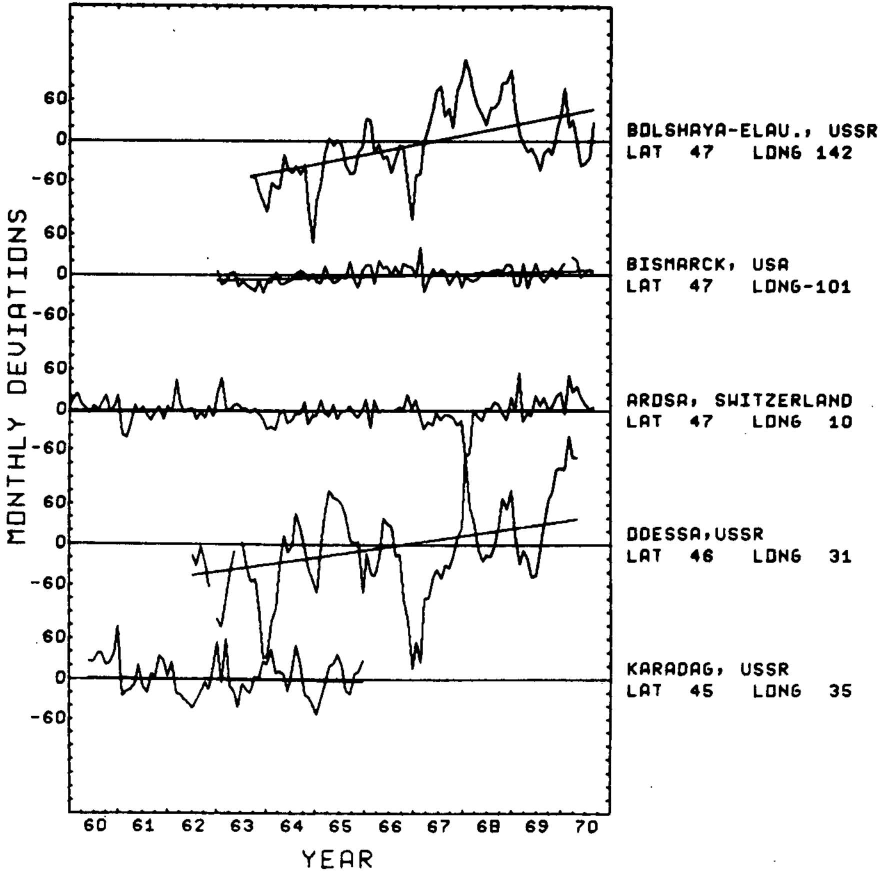

MONTHLY DEVIATIONS
60
0
-60
BOLSHAYA-ELAU., USSR
LAT 47 LONG 142
BISMARCK, USA
LAT 47 LONG-101
ARDSA, SWITZERLAND
LAT 47 LONG 10
ODESSA, USSR
LAT 46 LONG 31
KARADAG, USSR
LAT 45 LONG 35
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 22

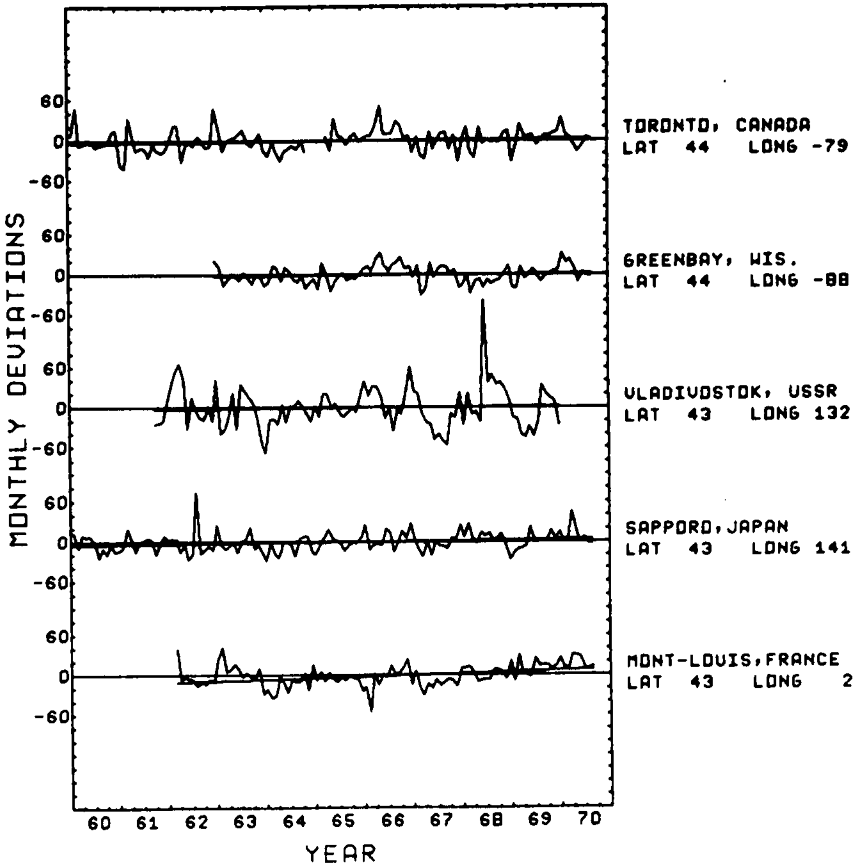

MONTHLY DEVIATIONS
60
0
-60
TORONTO, CANADA
LAT 44 LONG -79
GREENBAY, WIS.
LAT 44 LONG -88
VLADIVOSTOK, USSR
LAT 43 LONG 132
SAPPORO, JAPAN
LAT 43 LONG 141
MONT-LOUIS, FRANCE
LAT 43 LONG 2
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 23

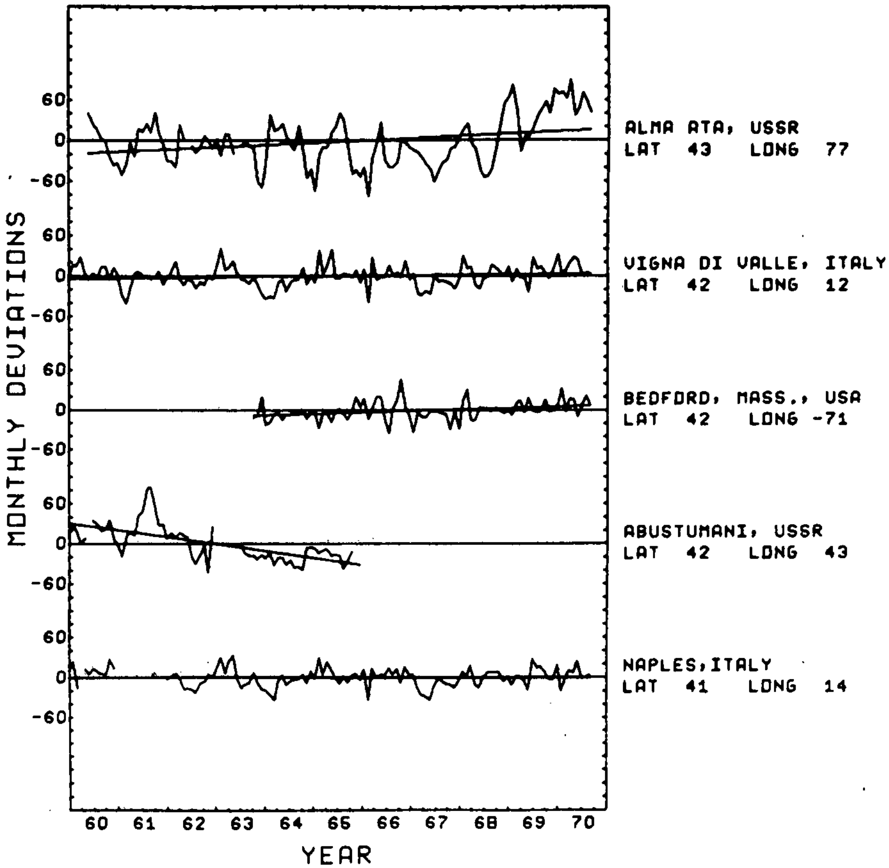

60
0
-60
60
0
-60
60
0
-60
60
0
-60
60
0
-60
MONTHLY DEVIATIONS
60 61 62 63 64 65 66 67 68 69 70
YEAR
ALMA ATA, USSR
LAT 43 LONG 77
VIGNA DI VALLE, ITALY
LAT 42 LONG 12
BEDFORD, MASS., USA
LAT 42 LONG -71
ABUSTUMANI, USSR
LAT 42 LONG 43
NAPLES, ITALY
LAT 41 LONG 14

FIGURE 24

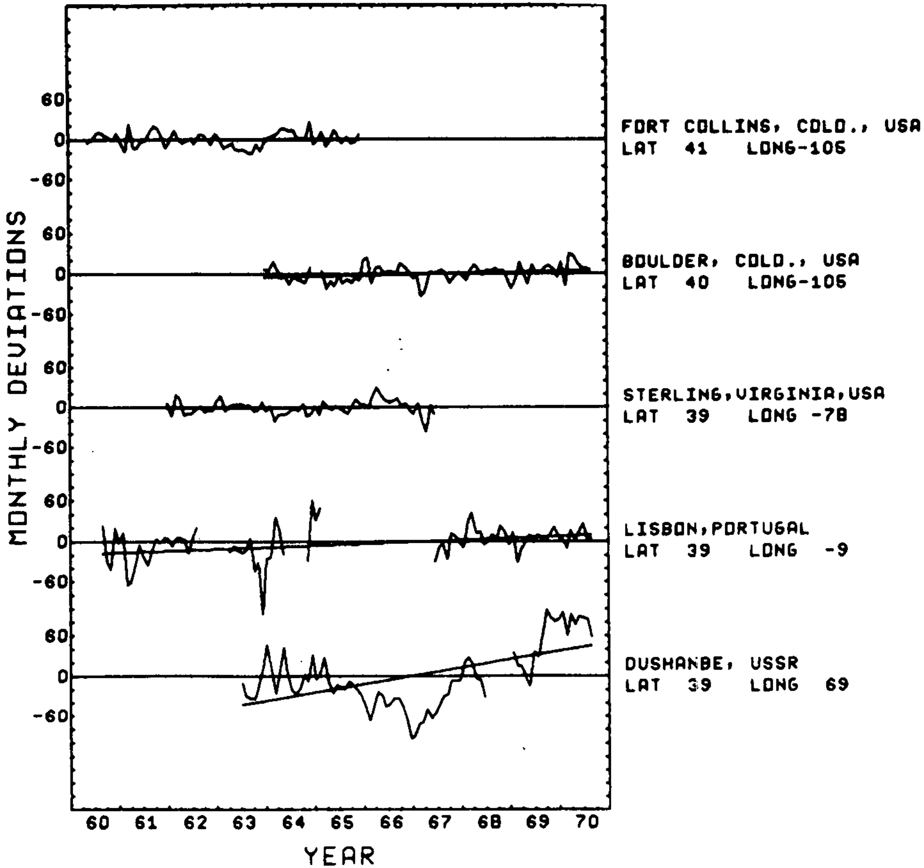

60
0
-60
60
0
-60
60
0
-60
60
0
-60
60
0
-60
MONTHLY DEVIATIONS
60 61 62 63 64 65 66 67 68 69 70
YEAR
FORT COLLINS, COLO., USA
LAT 41 LONG-105
BOULDER, COLO., USA
LAT 40 LONG-105
STERLING,VIRGINIA,USA
LAT 39 LONG -78
LISBON,PORTUGAL
LAT 39 LONG -9
DUSHANBE, USSR
LAT 39 LONG 69

FIGURE 25

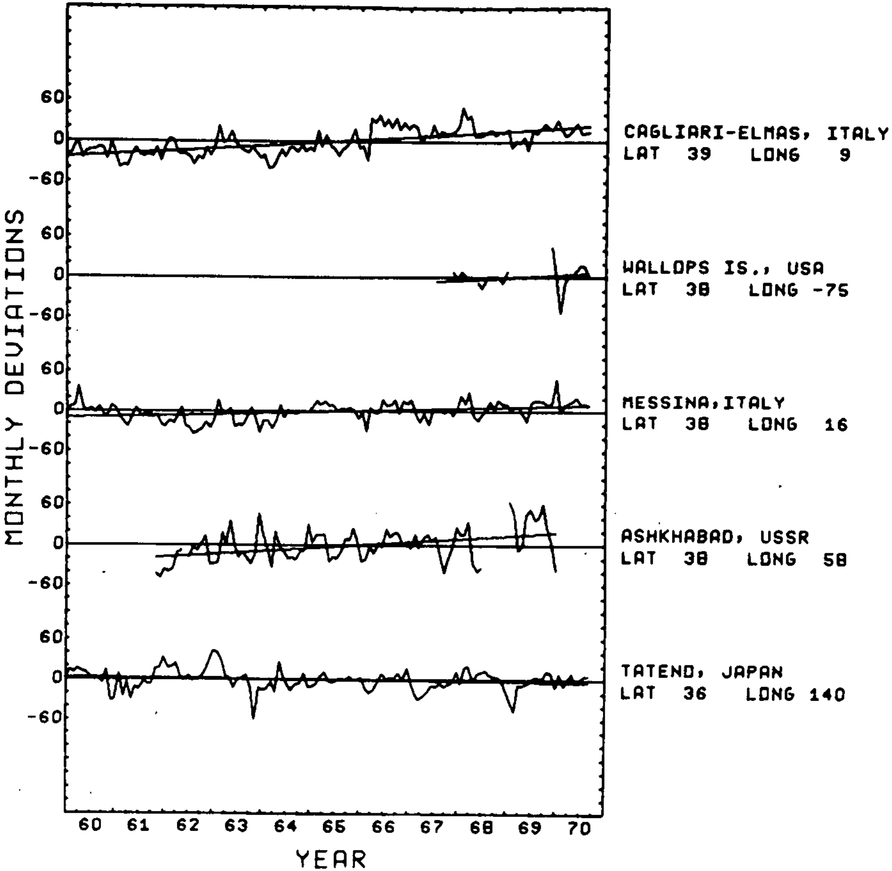

MONTHLY DEVIATIONS
60
0
-60
YEAR
60 61 62 63 64 65 66 67 68 69 70
CAGLIARI-ELMAS, ITALY
LAT 39 LONG 9
WALLOPS IS., USA
LAT 38 LONG -75
MESSINA, ITALY
LAT 38 LONG 16
ASHKHABAD, USSR
LAT 38 LONG 58
TATENO, JAPAN
LAT 36 LONG 140

FIGURE 26

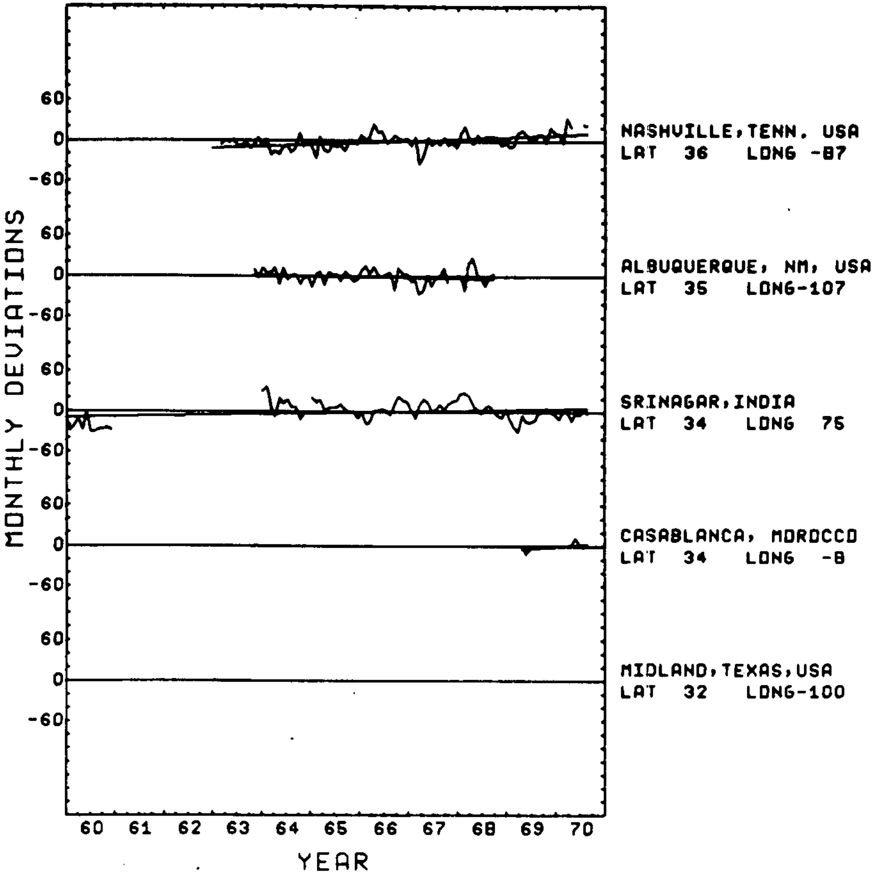
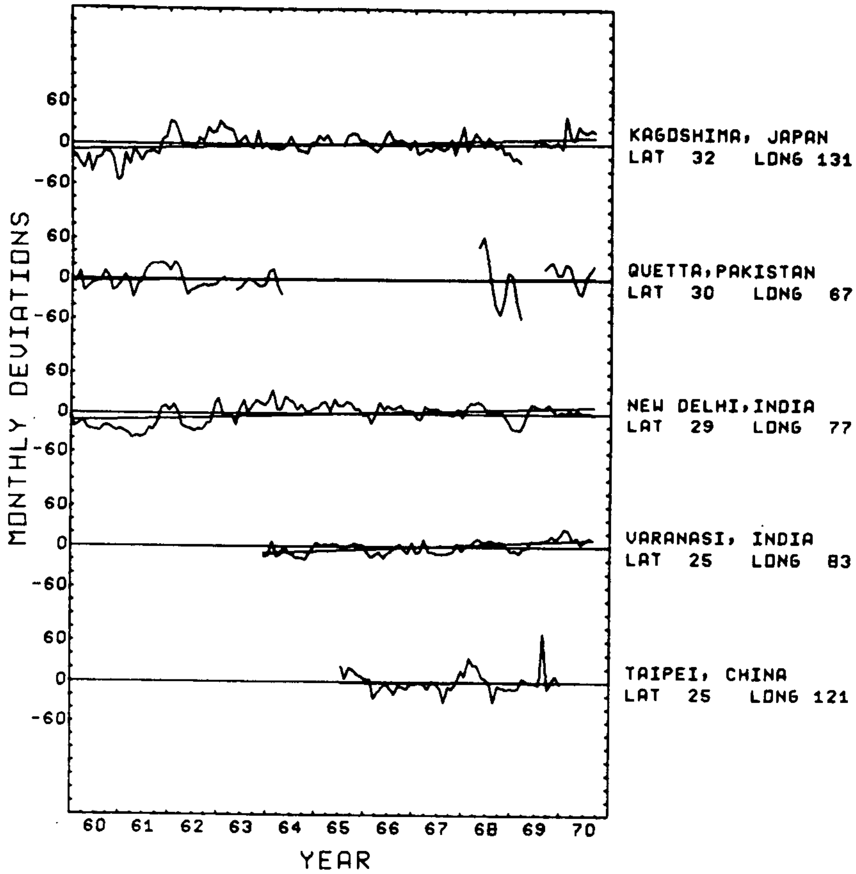

MONTHLY DEVIATIONS
60
0
-60
YEAR
60 61 62 63 64 65 66 67 68 69 70
NASHVILLE, TENN. USA
LAT 36 LONG -87
ALBUQUERQUE, NM, USA
LAT 35 LONG-107
SRINAGAR, INDIA
LAT 34 LONG 75
CASABLANCA, MOROCCO
LAT 34 LONG -8
MIDLAND, TEXAS, USA
LAT 32 LONG-100

FIGURE 27



MONTHLY DEVIATIONS
60
0
-60
KAGOSHIMA, JAPAN
LAT 32 LONG 131
QUETTA, PAKISTAN
LAT 30 LONG 67
NEW DELHI, INDIA
LAT 29 LONG 77
VARANASI, INDIA
LAT 25 LONG 83
TAIPEI, CHINA
LAT 25 LONG 121
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 28

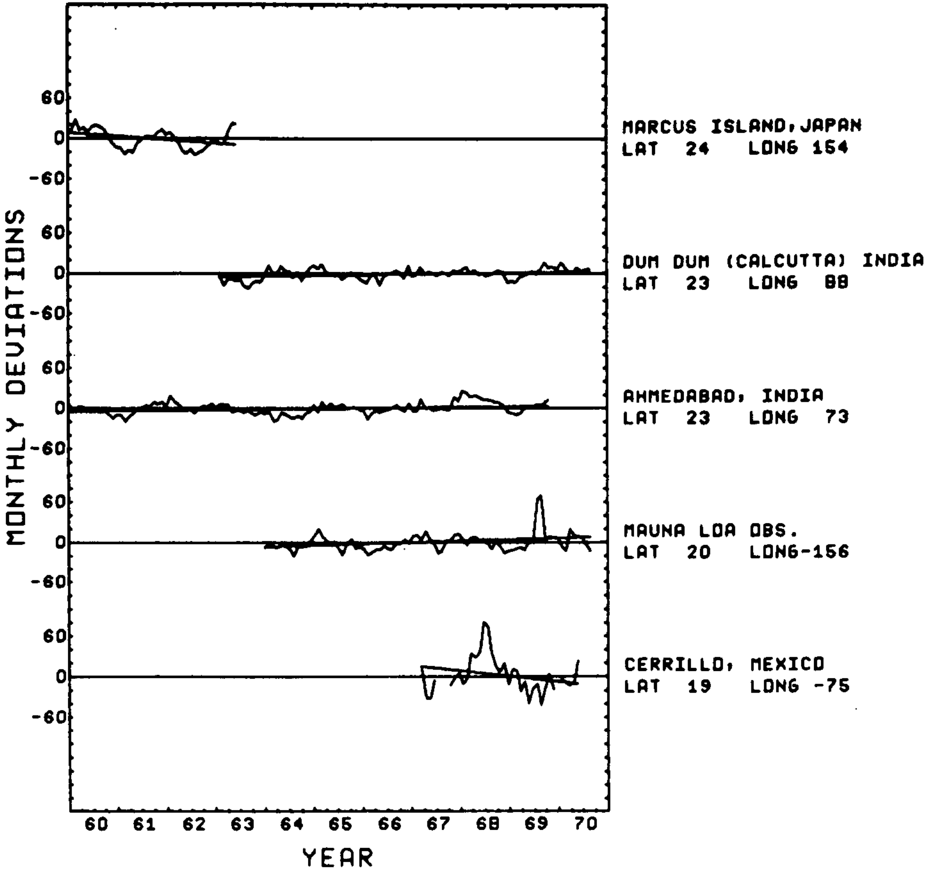

MONTHLY DEVIATIONS
60
0
-60
MARCUS ISLAND, JAPAN
LAT 24 LONG 154
DUM DUM (CALCUTTA) INDIA
LAT 23 LONG 88
AHMEDABAD, INDIA
LAT 23 LONG 73
MAUNA LOA OBS.
LAT 20 LONG-156
CERRILLO, MEXICO
LAT 19 LONG -75
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 29

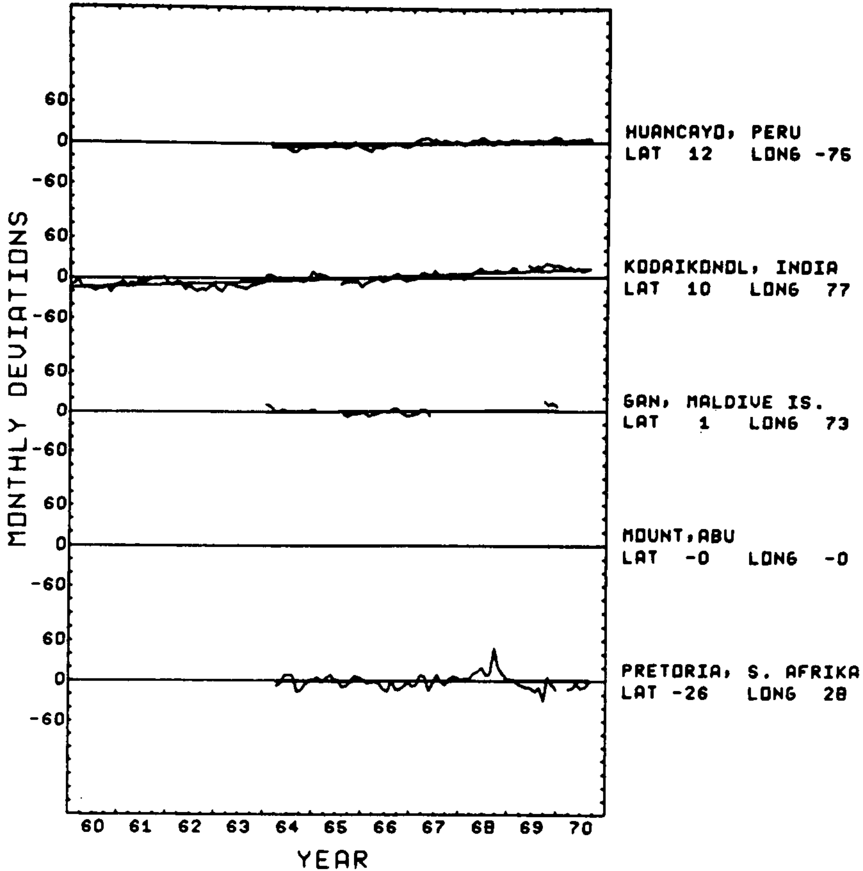

MONTHLY DEVIATIONS
60
0
-60
HUANCAYO, PERU
LAT 12 LONG -76
KODAIKONOL, INDIA
LAT 10 LONG 77
GAN, MALDIVE IS.
LAT 1 LONG 73
MOUNT,ABU
LAT -0 LONG -0
PRETORIA, S. AFRIKA
LAT -26 LONG 28
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 30

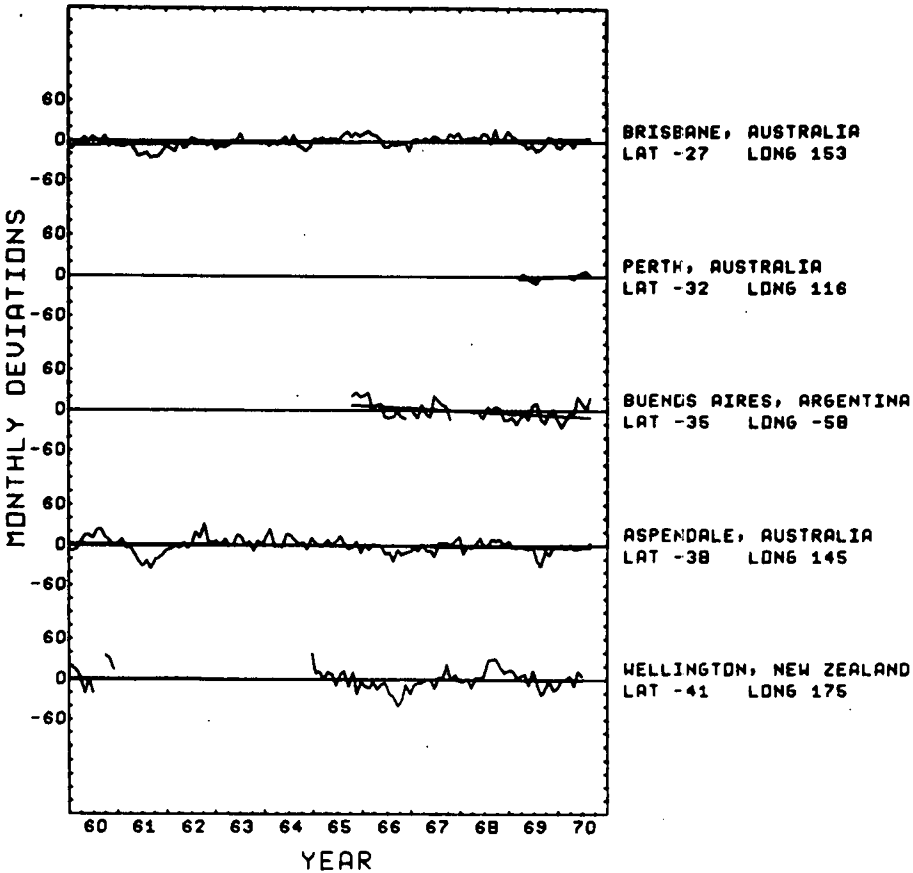

60
0
-60
60
0
-60
60
0
-60
60
0
-60
60
0
-60
MONTHLY DEVIATIONS
60 61 62 63 64 65 66 67 68 69 70
YEAR
BRISBANE, AUSTRALIA
LAT -27 LONG 153
PERTH, AUSTRALIA
LAT -32 LONG 116
BUENOS AIRES, ARGENTINA
LAT -35 LONG -58
ASPENDALE, AUSTRALIA
LAT -38 LONG 145
WELLINGTON, NEW ZEALAND
LAT -41 LONG 175

FIGURE 31

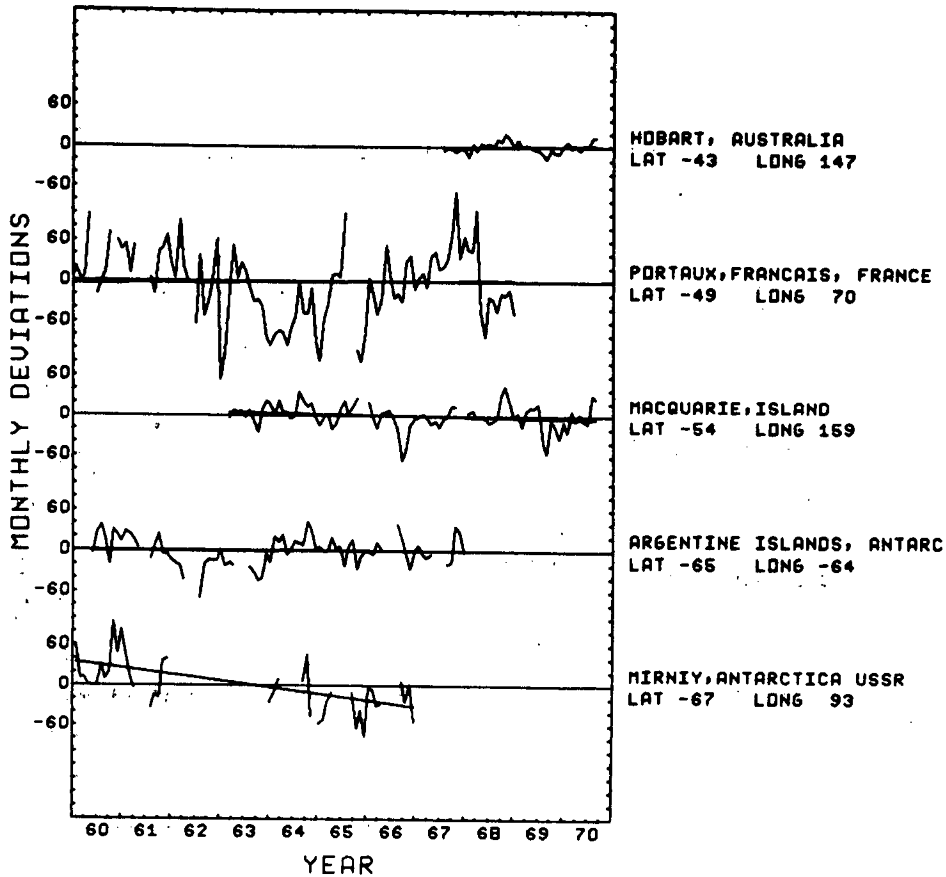
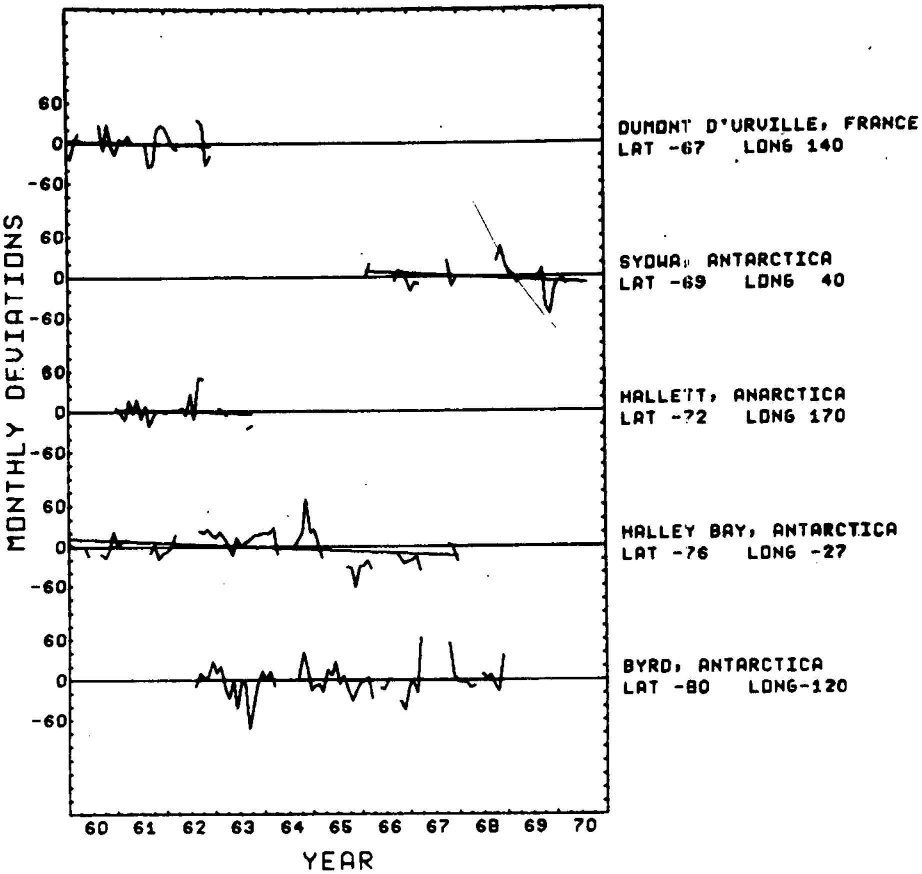

MONTHLY DEVIATIONS
60
0
-60
HOBART, AUSTRALIA
LAT -43 LONG 147
PORTAUX,FRANCAIS, FRANCE
LAT -49 LONG 70
MACQUARIE,ISLAND
LAT -54 LONG 159
ARGENTINE ISLANDS, ANTARC
LAT -65 LONG -64
MIRNIY,ANTARCTICA USSR
LAT -67 LONG 93
60 61 62 63 64 65 66 67 68 69 70
YEAR

FIGURE 32



60
0
-60
MONTHLY DEVIATIONS
DUMONT D'URVILLE, FRANCE
LAT -67 LONG 140
SYOWA, ANTARCTICA
LAT -69 LONG 40
HALLETT, ANARCTICA
LAT -72 LONG 170
HALLEY BAY, ANTARCTICA
LAT -76 LONG -27
BYRD, ANTARCTICA
LAT -80 LONG-120
60 61 62 63 64 65 66 67 68 69 70
YEAR

ENVIRONMENTAL DEFENSE FUND,
Washington, D.C., January 11, 1973.

Mr. WILLIAM COX,
Joint Economic Committee, Congress of the United States,
Washington, D.C.

DEAR MR. COX: I am enclosing a revised copy of Robert Fink's study, for the record of the Committee's hearings on civilian supersonic aircraft (SSTs).

Sincerely yours,

JOHN HELLEGERS.

Enclosure.

CONCORDE'S TRANS-ATLANTIC SCENARIO—ECONOMIC ASPECTS

(By Robert Fink, December 1972)

INTRODUCTION

1. It may be that the Concorde, contrary to the predictions of its critics, can be profitably operated.

2. It may be that claims by the Concorde's manufacturers are correct, that the aircraft can be highly profitable with low break-even points.

3. But statements (1) and (2) are at least correct as abstractions, not as guides to the real world, since the plane can be profitable *only* if the total number of Concordes in operation is severely limited—to the point where the manufacturers cannot possibly recover their investment.

4. Making every assumption in favor of the Concorde, the North Atlantic market might support as many as 16 planes.

5. But some of the assumptions that have to be made in favor of the Concorde to reach even this figure are highly questionable (although they are made for the purposes of the discussion herein). For example:

(*a*) That the manufacturer's hourly depreciation figure for the Concorde is realistic, so that the resale value and useful life of Concorde are equivalent to those of competitive subsonic aircraft. (In terms of resale value on the used aircraft market, it is clear that the Concorde's worth will be near zero to secondary and charter carriers, due to its high unit cost characteristics and the very limited number of routes on which it can even approach economical operation. In terms of useful life, expressed in productive flight hours, it is unlikely that the Concorde will have a life span comparable to that of competitive subsonic aircraft, since (i) aircraft stress is more a function of take-offs and landings than of actual hours flown, and the Concorde can fly less than half as many hours without refueling; and (ii) the extreme kinetic heating/cooling cycle inherent in every Concorde flight will probably further shorten the Concorde's life span in comparison with that of competitive subsonic aircraft.)

(*b*) That its contemplated daily productivity can be achieved. (The complexity of the aircraft, and the resultant difficulty of servicing it, will very likely require abandonment of the highly ambitious scheduling now contemplated.)

What is clear, then, is that the purchase of even one or a very small number of Concordes is a highly risky undertaking, which entails the possibility of heavy losses. It is also clear that any such purchases would preclude any conceivable further supersonic acquisitions (thus, by the way, eliminating any trans-Atlantic market for an American SST) until such time as the present over-capacity problem is resolved *and* it can be conclusively shown that any supersonic transport can compete on a unit cost basis with existing wide-bodied subsonic aircraft. On the basis of present knowledge, the latter appears to the aerodynamically impossible.

What follows is a scenario for the Concorde on the North Atlantic route, making all assumptions in favor of the manufacturer's claims for the plane, except where hard evidence to the contrary is available.

I. IT'S JANUARY 1975

The trans-Atlantic first class passenger market, relatively unchanged since

1969, has levelled off at 500,000 one way trips;[1] some 50 percent of these are between New York and London/Paris. In anticipation of Concorde commencing commercial service in spring, Air France and BOAC announce they will discontinue first class subsonic service when Concorde arrives: first class service will now offer a differene!

Businessmen and many other potential first class travelers who have not been traveling first class on subsonic aircraft these past few years because they could not justify the expense when no time saving was achieved, switch to Concorde: the first class market between New York and London/Paris doubles to 500,000 annual passengers. Connecting and onward passengers traveling to and from points beyond these cities add another 100,000 passengers: some of these emanate from several trans-Atlantic carriers not having Concorde, carriers not even flying between New York and London/Paris having decided to eliminate their first class service.[2]

This annual market of some 600,000 passengers, circa 1975, relatively evenly distributed throughout the year, represents a daily average of approximately 1,650 one way travelers. The standard first class fare remains: there will be no surcharge for flying Concorde, the "differential" being the one existing between first class and economy/promotional fares, which is substantial. With an average of 825 first class passengers flying each way daily between New York and London/Paris, eight Concordes can profitably operate.

Optimally, each aircraft will nominally perform two round trips daily, with two of the eight only making one trip, allowing for extended servicing and back-up reshuffling availability. With this schedule pattern, average annual utilization will be just under 4,500 hours. The fourteen daily round trips will provide, in all first class 108-seat configurations, 1,512 seats in each direction, or load-factors of approximately 55 percent. Of course, prior to this flight frequency level being obtained, load factors will be considerably higher: probably near to 100 percent when only four Concordes are flying.

For optimum passenger convenience combined with maximum aircraft utilization, all flights will adhere within fairly confined limits to the following schedule, which is expressed in local times:[3]

	Flight No.—			
	1	3	4	2
Leave New York	9 a.m	10 p.m		
Arrive London/Paris	5:30 p.m	6:30 a.m		
Leave London/Paris			8:30 a.m	9:30 p.m.
Arrive New York			7 a.m	8 p.m.

These can be considered as three good flights and one bad—that one being flight number 1, the morning departure from New York, which with the 5 hour

[1] IATA first class North Atlantic passenger traffic (cf. Appendix I attached) was:

1969: 460,720 passengers.
1970: 483,528 passengers.
1971: 464,522 passengers.

In a 1970 IATA forecast (quoted in IATA North Atlantic Study, Commercial Research Committee, June 1971, p. 9, Table 3), first class passenger traffic was predicted as:

1971: 521,000 passengers.
1972: 584,000 passengers.
1973: 644,000 passengers.

Insofar as there seems little justification for the IATA predictions (which have an inherent weakness inasmuch as they are composite statistical data from forecast submissions of individual carriers—and not an independent overall analysis), they are not used herein. *They are used, however, by Concorde's manufacturers to project the viability of their aircraft.*

[2] Average number of first class passengers on scheduled North Atlantic flights have been consistently low and remarkably consistent, notwithstanding introduction of the Boeing 747 in February, 1970:

1964: 6.0 passengers.
1965: 6.0 passengers.
1966: 6.3 passengers.
1967: 5.9 passengers.
1968: 6.5 passengers.
1969: 6.0 passengers.
1970: 6.1 passengers.
1971: 6.3 passengers.

Calculated from Appendix I attached.

[3] Concorde proponents argue that one of its prime advantages is that it will offer a frequency and flexibility of service the businessman desires but cannot get on subsonic jets. But if Concorde is going to be utilized anything near the extent the manufacturer claims, this will simply not be possible—unless passengers arrive and leave at hours which are conventionally considered unsaleable. Since it is unlikely that airlines will schedule arrivals or departures at 3:00 a.m., flight times will perforce be similar to those supplied herein, except on those services on which the aircraft are doing more than flying back and forth across the Atlantic; e.g., around the world.

time change, occupies all of the business day. (Actually, neither eastbound flight offers the business traveler any definitive advantage over present subsonic flights, and no eastbound flight, however scheduled, can). To trace the movement of this aircraft, the same schedule expressed in Greenwich time is:

1. Leave New York	1400
Arrive London/Paris	1730
2. Leave London/Paris	2130
Arrive New York	0100
3. Leave New York	0300
Arrive London/Paris	0630
4. Leave London/Paris	0830
Arrive New York	1200

This schedule allows a turnaround time of two hours between flights, with a four hour period between 5:30 PM and 9:30 PM local time on London/Paris for more extensive servicing. The equivalent American carrier operating schedule would only need delay the morning departure from 9:00 AM (New York time) to 11:00 AM, for a transference of this four hour maintenance period to New York.[4]

Economics:

According to the cost analyses provided by British Aircraft Corporation, aircraft cost per statute mile, based on the utilization given, approximates $4.12.[5] Aircraft cost mile per New York to London trip therefore approximates $14,550,000.[6] (This compares to estimate by B.A.C. of $24,000 for the same journey via Boeing 747.)[7] Cost per available seat mile on Concorde approximates 3.81¢ [8] (vs. 2.14¢ on the Boeing 747).[9] These figures include all operating expenses, direct and indirect, as well as anticipated finance charges; they exclude profits.

(Present) first class fare New York-London is $421.00 one way, with no discount for round trip. With 55 percent load factor envisioned above, revenue generated is 24,$007.40.[10] Break-even load factor is 32 percent.[11] (An equivalent load factor computation for the Boeing 747 is meaningless, insofar as an all first class configuration is inconceivable.) Though the unit costs of operation on the Concordes are substantially greater than that of wide-bodied jets such as the Boeing 747, the idea that the Concorde cannot be operated profitably is laid to rest. Moreover, it can be profitable without any surcharge.

II. It's August 1977

Between New York and London/Paris there are 210 Concorde round trip flights per week: 30 per day, using 17 aircraft. However accurate or inaccurate the 1972 estimates of first class travel were between New York and London/Paris at the existing 1972 fare level, these estimates are now irrelevant: there are now more flights available than first class passengers can reasonably fill, when the aircraft are restricted to first class seating. Therefore, since early in the year most Concordes have been re-configured to have 112 seats: 36 first class and 76 economy class. Though the airlines have noted some drop in first class traffic now that supersonic economy class exists, available first class seats have somewhat decreased from a year ago, and first class load factors remain high. This unique state of affairs is exacerbated by the "first class standby fare" inaugurated by BOAC, and quickly adopted by its competitors: it features a 10 percent discount from the first class fare for those potential first class passengers who cannot be guaranteed a first class seat prior to departure, and are willing to conditionally accept economy class, but are finally accommodated in first class when boarding the aircraft.

The North Atlantic market and tariff structure changes that were foreseen in 1972 have materialized. This year the anticipated passenger level on IATA carriers is 16,000,000 one way journeys, more than double the 1971 total of 7.5

---

[4] Manufacturers insist the Concorde turnaround time after a trans-Atlantic flight is only one hour, but carriers dare not operate such a tight schedule, and the two hours supplied here is considered a realistic minimum.

[5] Calculated from Appendix II. Throughout, all amounts are in 1972 dollars.

[6] $4.12 × 3,530 miles. Distance equals Concorde track mileage plus 1%.

[7] $7.20 × 3,530 miles; the $7.20 is calculated from Appendix II.

[8] Calculated from Appendix II.

[9] $7.20 divided by 337 seats (per Appendix II.

[10] 59.4 passengers (55 percent of 108 seats) × $421.00.

[11] 34.55 seats at $421.00.

million.[12] The basic first class and economy tariffs are all but unchanged from five years ago,[13] but percentage-wise fewer and fewer passengers pay these rates due to the increasingly extensive promotional fare structure, combined with the loose charter regulations now operative.[14]

In effect, two distinct travel markets have evolved on the North Atlantic: (1) the business/diplomat/luxury market that "goes and returns when it wants to," and (2) the flexible pleasure tourist market, into which a substantial portion of the "individual purpose travelers" are also able to accommodate themselves.

Type (1) travelers will virtually always use Concorde on those routes it is in service, paying a fare of approximately 12.5¢ per mile first class, and 8.5¢ per mile economy class; approximately 10 percent, or 1,600,000 North Atlantic one-way travelers, are expected to use these services.[15] Type (2) travelers will account for the remaining 14,400,000 one-way passengers, and it is anticipated they will be paying an average of about 4¢ per mile, i.e., $280-300.00 New York-London/Paris round trip, with many paying substantially less. (Indeed, the 4¢ average "low class" passenger yield is already in sight: IATA estimates it will be 4.27¢ in 1972/73, with the underlying trend downward.)[16] This traffic will all be carried on subsonic aircraft. To offset low yields per revenue passenger mile, load factors will be somewhat higher, and seating configurations somewhat tighter, than in 1972.

Economics:

210 round trip flights per week in 112 seat configurations equals approximately 1,125,000 trans-Atlantic seats in each direction, annually. Air France and BOAC are only flying from their capitals to New York and Boston, but Pan Am, the only other trans-Atlantic carrier to receive delivery to date is, in addition to flying to London and Paris from New York and Boston, also flying Concordes to Amsterdam, Brussels, Copenhagen, Frankfurt, Hamburg, Lisbon, and Madrid; the bulk of trans-Atlantic markets, covering approximately 75 percent of the North Atlantic passenger market, are now available to supersonic flight.

1,200,000 [17] one way passengers—plus perhaps 50,000 additional connecting and onward passengers traveling to and from points beyond these cities—are available for supersonic flight: 625,000 in each direction, utilize the 1,125,000 seats available in each direction, in 1977. The resulting load factor is 55.5 percent,

---

[12] Coefficients of price elasticity have proved to be, at best, calculated guesses. In the recently completed Domestic Passenger Fare Investigation, the range was from lows of −0.4 and −0.5 submitted by some carriers, to a high of −1.25 submitted by the CAB's own Bureau of Economic Research. The CAB stated there was such a range of expert opinion they merely split the difference, in effect admitting they didn't know the coefficient. What is clear is that (1) potential pleasure travelers are highly responsive to major fare reductions, (2) major fare reductions are necessary to fill up some of the ever-increasing number of empty seats, and (3 they are being brought about by maintaining the basic tariff levels while concurrently offering innovations such as the Travel Group Charter. Under such conditions an annual traffic growth increase of 15 per cent is reasonable—perhaps even conservative—and it is on this basis the 1977 total of 16,000,000 passengers is offered. (For 1972/1973, IATA actually forecast a 17 percent traffic "low class" growth. Quoted in IATA Cost Committee Report, Geneva, June 1972, Table A-3).

[13] Whether the basic first class and economy tariffs are in fact moderately increased or decreased is a relatively unimportant determinant to passenger growth rates, when only a small percentage are paying the straight published rates; what is far more crucial is the accessibility of the promotional and charter fares, and the level at which they are set. With the introduction of such innovative regulations as the United States Travel Group Charter scheme, and Great Britain's equivalent Advanced Booking Charter scheme, there is every indication that broadly based low fares (incorporated within the pre-established higher tariff structure), are here to stay, and will possibly be expanded still further. Indeed, the percentage of passengers paying "full fare" on the North Atlantic has been dropping drastically the past few years.

[14] Among IATA carriers operating scheduled flights on the North Atlantic, examination of individual company records of the recent past indicate that approximately 6 percent of all scheduled passengers are now traveling first class, and approximately 20 percent are paying full economy fares; the remaining 74 percent are traveling on some type of fare discounted below the established economy level. These statistics do not include charter passengers; when charter passengers traveling on IATA carriers are included, first class passengers drop to just over 5 percent of the total, and full economy" to about 17 percent of all travelers on IATA carriers. If the supplemental charter carriers were to be included, the percentage of travelers paying full fares would drop considerably lower.

[15] The estimate of 1,600,000 is arrived at arbitrarily, but not at random. Since slightly more than 22 prcent of all IATA passengers—or about 1,950,000—in 1971 used full first class or economy fares (cf. footnotes 14 and 25), it logically follows that as the differential between these fares and the promotional/charter fares becomes greater, and the lower fares become more accessible, not only will the percentage of travelers using the standard fares decrease, but also the absolute total will decrease due to the deletion of some full tariff passengers switching to promotional/charter fares.

[16] IATA Cost Committee Report, Geneva, June 1972; see p. 5 and Table A-3.

[17] 75 percent times 1,600,000 passengers.

virtually identical to that achieved two years earlier when only eight Concordes were in service; the break-even point is raised, however, above the earlier 32 percent load factor, due to the aircraft now having most of its seats in economy class. If it is (generously) assumed that 40 percent of the passengers are in first class and paying $421.00 for a one way New York-London journey, and the remaining economy class passengers are paying $275.00 (approximately 10 percent higher than the present average full economy fare), revenue generated is $20,724.15,[18] and the break-even point is raised to approximately 40 percent[19]—assuming the $4.12 cost per aircraft mile is maintained.

But in this pattern of profitability a cul-de-sac is fast being approached. The input of additional Concordes will soon wipe out profitability, as the total passenger market willing and able to pay the full fares is definitely limited. Yet, Concorde cannot participate in "the other market" which is growing by leaps and bounds, since at $4.12 per aircraft mile on the North Atlantic, its available seat cost per mile is 3.81¢, just a shade under the average revenue yield of "the other market." To make the barest of profits it would have to constantly fly at a 100 percent load factor, a patent impossibility.

Hence, as more Concordes appear, the only alternative is to fill up the entire fleet's empty seats with promotional supersonic fares that (1) touch upon "the other market", and (2) cover seat operating costs, with profits emanating from the maintenance of high load factors on the remaining seats being sold to regular fare paying passengers. *To ensure that Concorde operations remain in the black, airlines possessing Concorde must make every effort to restrict the total numbr of Concorde aircraft flying North Atlantic routes, or each of them will incur major financial reverses.*

III. IT'S DECEMBER 1972

Analysis of the operating cost estimates prepared by British Aircraft Corporation, and presented in Appendix II, indicates they are considerably understated. When confronted with this assertion, a senior B.A.C. representative acknowledged that the operating cost numbers submitted to potential airline customers are higher. The root of the discrepancies apparently emanates from the figures supplied for Concorde hourly fuel consumption, from Concorde's indirect expenses, and the amount of flight utilization considered.

In the B.A.C. report, the total cost of fuel for a New York–London trip for the Boeing 747 works out to $2,619.90, whereas the total for Concorde works out to $2,131.80.[20] But between New York and London these two aircraft use similar quantities of fuel, the Boeing consuming about 25,000 gallons and the Concorde about 10 percent less. Insofar as the Boeing 747 figure is based on data supplied in C.A.B. reports (reflecting current fuel prices), and considered correct, the equivalent Concorde figure should be on the order of $694 per hour, rather than the $627 supplied by B.A.C.

In the B.A.C. report, total indirect expenses for the Boeing 747 work out to $14,221.30, whereas the total for Concorde works out to only $6,810.20.[21] A Civil Aeronautics Board statistical planning analyst of long experience, having examined the indirect operating expenses in the B.A.C. report, has stated there is no way the indirect hourly cost of these two aircraft can be equal: if the figure for the Boeing 747 is reasonably accurate, which it is, the figure for the Concorde could likely be 30 percent higher than stated, i.e., $2,603.90 vs. the $2,003.03 supplied by B.A.C.

A comparably experienced Federal Aviation Administration economist, somewhat more conservative, has observed that estimates of Concorde's indirect expenses have been consistently understated, though it is impossible to say to what extent until the aircraft is in commercial service. The understatement is primarily a result of the manufacturers' treating these expenses as being similar to

---

[18] See the following table:

55.5 percent times 112 seats equals 62.16 seats occupied.	
62.16 times 40 percent equals 24.864 1st class seats times $421	$10, 467. 75
62.16 times 60 percent equals 37.296 economy seats times $275	10, 256. 40
Total	20, 724. 15

[19] At the same 40/60 first/economy class ratio, gross revenues at 40 percent load factor (17.92 first class, 26.88 economy class seats sold), equal $14,936.00 vs. cost of $14,550.00—at $4.12 per aircraft mile.

[20] $369 per hour times 7.1 hours equals $2,619.80.
$627 per hour times 3.4 hours equals $2,131.80.

[21] $2,003 per hour times 7.1 hours equals $14,221.30.
$2,003 per hour times 3.4 hours equals $6,810.20.

those incurred by a Boeing 707, insofar as the two aircraft are more or less similar in size and carry approximately the same number of passengers. He adds that, in practice, this "indirect cost equivalence" can hardly be the case, largely because Concorde is a far more expensive and complex machine, needing more extensive ground support systems.

The daily performance of two round trips between New York and London is considered overly ambitious by some carriers. To responsibly maintain their schedules they find it difficult to program two round trips in a 24 hour cycle, feeling that 27 hours are necessary, i.e., two hours for turn-around after each of three flights, plus a seven hour ground period after each second round trip. Such a flight program would reduce overall annual utilization to approximately 4,000 hours, when major maintenance time and unprogrammed difficulties are taken into account. On this basis alone the $4.12 operating cost per aircraft mile used throughout this paper would be raised to B.A.C.'s $4.24.[22] Moreover, a new study entitled *Concorde General Economics*, by British Aircraft Corporation and Aerospatiale France, indicates Concorde's operating costs per aircraft mile on a 3,000 statute mile stage length, are $4.56 *exclusive of interest charges.*[23] This comparable number of the New York-London distance is $4.43, again exclusive of interest charges.[24]

The combined objections noted above reflect Concorde operating costs in excess of $5.00 per mile on the North Atlantic route, and indeed, one carrier has explicitly informed this writer that this is the case according to their best calculations. The combined study of BAC/Aerospatiale, showing high hourly direct operating costs of $3,256 and hourly indirect operating costs of only $1,543 (at the aforementioned 3,000 statute miles stage length), inadvertently lends credence to this belief.[25] If, as seems reasonable, a $5.20 cost per aircraft mile is assumed, the profitability and break-even points given in the 1975 and 1977 scenarios change dramatically:

	Cost per flight per aircraft-mile—		Profitability [26]		Break-even load factors (percent)	
	at $4.12	at $5.20	at $4.12 cost	at $5.20 cost	$4.12	$5.20
1975 example	$14, 550	$18, 356	$9, 457. 40	$5, 651. 40	32	44
1977 example	14, 550	18, 35C	6, 174. 15	2, 368. 15	40	50

[26] 1975 example: Gross revenues of $24,007.40 minus $14,550 equals $9,457.40; gross revenues of $24,007.40 minus $18,356 equals $5,651.40. 1977 example: Gross revenues of $20,724.15 minus $14,550 equals $6,174.15; gross revenues of $20,724.15 minus $18,356 equals $2,368.15.

The crucial importance of the $5.20 cost per aircraft mile figure appears most vividly when expressed in terms of costs per available seat mile: 4.82¢ when Concorde is in a 108 seat all first class configuration, and 4.64¢ in a mixed 112 seat configuration. Such costs will not even cover the envisaged fare levels of "the other market" at 100 percent load factor, and when transformed to cost per revenue passenger mile—assuming an unprecedentedly high load factor of 65 percent to give Concorde the benefit of any doubt—is in excess of 7¢. This equals a New York-London round trip fare of over $490.00 (without any profit included)—almost double the anticipated fare level of "the other market." The should come as no surprise, insofar as the 4.64–4.82¢ cost per available seat mile is more than double the 2.19¢ supplied in the B.A.C. report.[27]

British Aircraft Corporation and Aerospatiale France have based their Concorde sales efforts on the aircraft's speed, and the concept that a significant part of the market—"the discriminating business and first class passenger," to use their terminology—is willing and able to pay the price over and above the low fare promotional and charter passengers flying on subsonic aircraft. The key questions are, (1) how many are willing to pay the higher price?, and (2) how much differential does "the higher price" involve?

---

[22] Appendix II.

[23] Cf. "Supersonic Economics." *Flight International*, 5 October 1972, pp. 466–67, quoting *Concorde General Economics*, British Aircraft Corporation, and Aerospatiale France, 1972. Calculated from (unnumbered) tables giving hourly direct and indirect operating expenses: i.e., total operating expenses of $4.799 per hour times 2.85 hours equals $13,677.15 divided by 3,000 statute miles equals $4.56.

[24] *Ibid.;* calculated from (unnumbered) graph, p. 46.

[25] *Ibid.:* (unnumbered) tables p. 467.

[27] Appendix II.

Concorde's economic viability is irrevocably tied to the yield generated from the subsonic tariff structure, and the regulations applied thereto. Speaking to the latter question first, i.e., the differential between "the higher price" and "the other market price," it seems wholly reasonable that the average subsonic revenue envisaged in the 1977 scenario is realistic—and possibly even on the high side in view of the trend toward regulations promoting round trip fares to Europe, from the East Coast, on the order of $175–225, and their liberal accessibility to the public. In effect, the Concorde fare differential will be substantial: a premium of at least $100 in each direction, and usually more.

The only way in which Concorde can be economically viable is if, by a set of fortuitous circumstances of unprecedented world-wide business prosperity, there is a dramatic reversal in the declining number of full tariff passengers who are willing to forego greater and more accessible bargain fares than are presently available—and the number of Concordes put into service is strictly curtailed to quantities far below those presently planned by the manufacturers, and some of their airline customers.

Despite the manufacturers' claims concerning low break-even points and high profitability, the echoes of these claims in the trade press, and Prime Minister Heaths' assertion that "no airline will be able to do without one," the projection of market trends is diametrically opposed to extensive commercial application of a high unit cost aircraft, like Concorde. The percentage of IATA scheduled North Atlantic passengers paying full fare—the only passengers in this market viably available to Concorde—has been dropping steadily for the past seven years, and there are *fewer full fare passengers today than in 1965.*[28] Moreover, the fact that current trends of increasing average first class passenger yields relate to stagnant traffic growth, while corresponding yields for economy passengers are decreasing and relate to dynamic traffic growth,[29] reflects price elasticity prevailing even in "the discriminating business and first class passenger" market. Almost everybody loves a bargain; it bodes ill for Concorde.

Too many unknown variables exist to estimate with any precision the quantity of Concordes that can be profitably utilized, given the limitations of their market appeal, but the number is certainly a minute fraction of the manufacturers' assertion that "initial Concorde sales are expected to reach 250 aircraft." [30] This is sheer sophistry. So too is the suggestion made by the manufacturers, that the introduction of Concorde will revive and salvage an otherwise stagnating air transport industry.[31] Economically, for at least the foreseeable future, there can be little doubt that the airlines would be better served if

[28] See the following table:

	Number of full fare passengers	Percentage of total IATA scheduled passengers
1965	2, 264, 269	62. 7
1966	2, 375, 813	56. 5
1967	2, 678, 234	53. 7
1968	2, 650, 130	50. 4
1969	2, 662, 329	44. 4
1970	2, 340, 851	32. 5
1971*	*1, 948, 302	*26. 0

Sources:
1965–70: IATA North Atlantic Study, Commercial Research Committee, June 1971, table 5.
*1971: Estimated, 26 percent (cf. footnote 14 above) × 7,531,929 (cf. app. I attached).

[29] App. III attached.

[30] "Concorde Background Brief," British Aircraft Corp. and Aerospatiale France, dated May 22, 1972, p. 8.

[31] "The Scheduled Carriers—Quo Vadis," British Aircraft Corp. and Aerospatiale France, undated, p. 7.

Concorde and the entire concept of supersonic transport with its substantially higher unit costs, did not exist. But it does exist and carrier, perforce, view the Concorde as a "milking machine" draining off the relatively few price-inelastic high-revenue passengers they have. By this very fact the manufacturer is issuing a *scotto voce* threat to each and every carrier: if you don't switch the revenues in your subsonic pocket to the supersonic pocket we are offering you, somebody will take it all away. Concorde is "sending 'em a message," and the carriers feel damned if they do, and damned if they don't.

It would be inconceivable, for example, for Pan Am and TWA not to have supersonic transport, while BOAC and Air France carry most of the first class and full economy fare traffic on round-the-world routes. But it should be far less tenable for each company to have a total of too many aircraft, the sum-total of which cannot generate sufficient revenue for any to cover operating expenses. It's a dilemma in which not even the manufacturers can win, for however great Concorde's technological achievement, they cannot possibly generate sufficient sales to recoup their costs.

Appendix I

DEVELOPMENT OF IATA MEMBERS' NORTH ATLANTIC TRAFFIC 1961–71

[The table below illustrates the development of North Atlantic air traffic over the 1961–71 period. Statistics of IATA members' traffic between North America (United States and Canada) and Europe, which includes traffic over the polar route, are presented on the following pages. They cover the operations of the following IATA Member airlines: Aerlinte Eireann, Air Canada, Air France, Air-India, Alitalia-Lai, BOAC, CP Air, Deutsche Lufthansa, El Al, Finnair, Iberia, JAL, KLM, Olympic, Pan American, PIA[1], Qantas, Sabena, SAS, Seaboard World, Swissair, TAP and TWA]

	1961	± percent	1962	± percent	1963	± percent	1964	± percent	1965	± percent
Airlines	18		18		19		18		18	
Scheduled operations:										
Flights:										
First		−100.0								
Economy	2,353	−10.4	3,682	+56.5	37,350	+8.1	39,208	+5.0	45,996	+17.3
Mixed	27,833	+15.5	30,858	+10.9						
Cargo	4,036	+27.4	4,512	+11.8	4,503	−.2	4,598	+2.1	5,308	+15.4
Total	34,222	+13.3	39,052	+14.1	41,853	+7.2	43,806	+4.7	51,304	+17.1
Seating capacity:										
First	653,710	+12.4	644,954	−1.3	648,075	+.5	666,874	+2.9	748,590	+12.3
Economy	3,093,742	+44.9	3,761,573	+21.6	4,286,884	+14.0	4,672,149	+9.0	5,612,119	+20.1
Total	3,747,452	+36.7	4,406,527	+17.6	4,934,959	+12.0	5,339,023	+8.2	6,360,709	+19.1
Passengers:										
First	244,870	−20.0	208,175	−15.0	192,522	−7.5	235,876	+22.5	277,661	+17.7
Economy	1,674,564	+15.9	2,063,988	+23.3	2,229,745	+8.0	2,833,302	+27.1	3,333,613	+17.7
Total	1,919,434	+ 9.0	2,272,163	+18.4	2,422,267	+6.6	3,069,178	+26.7	3,611,274	+17.7
Average load factor (percent)	51.2	−13.0	51.6	+.4	49.1	−2.5	57.5	+8.4	57.1	−.4
Cargo (in tons):										
Passenger flights	35,184	+33.0	44,157	+25.5	52,943	+19.9	60,842	+14.9	86,519	+42.2
Cargo flights	27,667	+41.1	35,510	+28.4	37,214	+4.8	49,187	+32.2	74,899	+52.3
Total	62,851	+36.5	79,667	+26.8	90,157	+13.2	110,029	+22.0	161,418	+46.7
Mail (in tons):										
Passenger flights	14,180	+15.2	16,798	+18.5	18,703	+11.3	19,862	+6.2	21,133	+6.4
Cargo flights	5,947	+56.8	5,910	−.6	4,974	−15.8	4,519	−9.1	5,345	+18.3
Total	20,127	+25.0	22,708	+12.8	23,677	+4.3	24,381	+3.0	26,478	+8.6

Charter flights:										
Flights	2,733	+28.6	2,883	+5.5	3,741	+29.8	4,138	+10.6	3,721	−10.1
Passengers	256,478	+52.5	315,209	+22.9	414,165	+31.4	482,010	+16.4	480,496	−.3
Cargo (in tons)	1,790	+126.9	1,474	−17.7	2,310	+56.7	1,904	−17.6	1,436	−24.6
Mail (in tons)	11	+57.1		−100.0	2	+100.0		−100.0		
All operations:										
Flights	36,955	+14.3	41,935	+13.5	45,594	+8.7	47,944	+5.2	55,025	+14.8
Passengers	2,175,912	+12.8	2,587,372	+18.9	2,836,432	+9.6	3,551,188	+25.2	4,091.770	+15.2
Cargo (in tons)	64,641	+38.0	81,141	+25.5	92,467	+14.0	111,933	+21.1	162,854	+45.5
Mail (in tons)	20,138	+25.0	22,708	+12.8	23,679	+4.3	24,381	+3.0	26,478	+8.6

	1966	± percent	1967	± percent	1968	± percent	1969	± percent	1970	± percent	1971	± percent
Airlines	19		20		21		22		22		22	
Scheduled operations:												
Flights:												
First												
Economy	51,464	+11.9	61,988	+20.4	68,848	+11.1	76,218	+10.7	78,978	+3.6	73,910	−6.4
Mixed												
Cargo	5,910	+11.3	7,660	+29.6	9,268	+21.0	11,725	+26.5	12,241	+4.4	11,225	−8.3
Total	57,374	+11.8	69,648	+21.4	78,116	+12.2	87,943	+12.6	91,219	+3.7	85,135	−6.7
Seating capacity:												
First	804,965	+7.5	987,352	+22.7	1,109,003	+12.3	1,241,484	+11.9	1,465,981	+18.1	1,600,775	+9.2
Economy	6,336,392	+12.9	7,688,422	+21.3	8,751,625	+13.8	9,792,707	+11.9	11,563,176	+18.1	13,345,696	+15.4
Total	7,141,357	+12.3	8,675,774	+21.5	9,860,628	+13.7	11,034,191	+11.9	13,029,157	+18.1	14,946,471	+14.7
Passengers:												
First	322,929	+16.3	354,957	+9.9	383,748	+8.1	460,720	+20.1	483,528	+5.0	464,552	−3.9
Economy	3,874,621	+16.2	4,632,443	+19.6	4,874,447	+5.2	5,536,143	+13.6	6,717,524	+21.3	7,067,377	+5.2
Total	4,197,550	+16.2	4,987,400	+18.8	5,258,195	+5.4	5,996,863	+14.0	7,201,052	+20.1	7,531,929	+4.6
Average load factor (percent)	58.8	+1.7	57.5	−1.3	53.3	−4.2	54.3	+1.0	55.3	+1.0	50.4	−4.9
Cargo (in tons):												
Passenger flights	98,083	+13.4	101,185	+3.2	125,886	+24.4	160,467	+27.5	163,623	+2.0	217,282	+32.8
Cargo flights	102,132	+36.4	128,619	+25.9	175,067	+36.1	256,278	+46.4	241,545	−5.7	229,466	−5.0
Total	200,215	+24.0	229,804	+14.8	300,953	+31.0	416,745	+38.5	405,168	−2.8	446,748	+10.3
Mail (in tons:)												
Passenger flights	23,717	+12.2	26,704	+12.6	29,289	+9.7	33,899	+15.7	33,560	−1.0	35,688	+6.3
Cargo flights	7,655	+43.2	8,927	+16.6	11,914	+33.5	13,121	+10.1	13,281	+1.2	13,293	+.1
Total	31,372	+18.5	35,631	+13.6	41,203	+15.6	47,020	+14.1	46,841	−.4	48,981	+4.6

See footnote at end of table, p, 228.

Appendix I—Continued

DEVELOPMENT OF IATA MEMBERS' NORTH ATLANTIC TRAFFIC 1961-71—Continued

[The table below illustrates the development of North Atlantic air traffic over the 1961-71 period. Statistics of IATA members' traffic between North America (United States and Canada) and Europe, which includles traffic over the polar route, are presented on the following pages. They cover the operations of the following IATA Member airlines: Aerlinte Eireann, Air Canada, Air France, Air-India, Alitalia-Lai, BOAC, CP Air, Deutsche Lufthansa, El A, Finnair, Iberia, JAL, KLM, Olympic, Pan American, PIA[1], Qantas, Sabena, SAS, Seaboard World, Swissair, TAP and TWA]

	1966	± percent	1967	± percent	1968	± percent	1969	± percent	1970	± percent	1971	± percent
Charter flights:												
Flights	3,627	−2.6	3,689	+1.7	3,845	+4.2	5,791	+50.6	5,803	+.2	7,263	+25.2
Passengers	502,896	+4.7	517,080	+2.8	495,143	−4.2	779,738	+57.5	816,554	+4.7	1,059,046	+29.7
Cargo (in tons)	1,026	−28.6	2,272	+121.4	8,162	+261.4	12,255	+50.1	5,793	−52.7	11,645	+101.0
Mail (in tons)												
All operations:												
Flights	61,001	+10.9	73,337	+20.2	81,928	+11.7	93,734	+14.4	97,022	+3.5	92,398	−4.8
Passengers	4,700,446	+14.9	5,504,480	+17.1	5,753,338	+4.5	6,776,601	+17.8	8,017,606	+18.3	8,590,975	+7.2
Cargo (in tons)	201,241	+23.6	232,076	+15.3	309,163	+33.2	429,000	+38.8	410,960	−4.2	458,393	+11.5
Mail (in tons)	31,373	+18.5	35,631	+13.6	41,233	+15.6	47,020	+14.1	46,841	.4	48,981	+4.6

1 August and September 1963 only.

Source: "1971 World Air Transport Statistics," IATA, Geneva, pp. 18-19.

BRITISH AIRCRAFT CORPORATION (U.S.A.), INC.,
Arlington, Va., November 2, 1972.

Mr. ROBERT FINK,
2512 "I" Street NW.
Washington, D.C.

DEAR MR. FINK: Attached is the analysis of Concorde's operating costs promised to you last night.

Wherever possible, I have used the 747 costs contained in the CAB Document you gave to me yesterday. There are two main exceptions to the statement. In the areas of investment, depreciation and insurance, every company has its own reporting standard and policy and it would be impossible for me to give you a Concorde figure exactly equivalent to that contained in the CAB Document. Consequently, I have used my own numbers in this area and have shown two cases. Case A assumes an annual utilization of 4000 block hours, whereas Case B is based on 5000 block hours.

The individual items are quite straightforward and you should be in a position to make any changes you think suitable for your future articles. It would be appreciated if you would read fairly closely the last page, titled "Comments of Fares and Yields".

If you require any further assistance with regard to Concorde economics, please let me know.

Yours sincerely,

RODGER T. MUNT,
Deputy Sales Manager—Concorde.

Enclosure.

APPENDIX II

ANALYSIS OF CONCORDE AND B747 OPERATING COSTS, 1972 DOLLARS

	Case A		Case B	
	B-747	Concorde	B-747	Concorde
Investment (in millions):				
Unit cost	$23.6	$37.5		
Spares at 20 percent	4.7	7.5		
Total	28.3	45.0		
Duty	(1)	2.3		
Total	28.3	47.3		
Depreciation:				
14 Yrs. at 15 percent; Case AU equals 4,000 hrs.; Case BU equals 5,000 hours.	28.3m×0.85 (14×4000).	47.3m×0.85 (14×4000).	28.3m×0.85 (14×5000).	47.3m×0.85 (14×5000).
Cost per hour	$430	$718	$344	$574
Insurance	23.6m×1% (4000).	37.5m×1.05 ×1% (4000).	23.6m×1% (5000).	37.5m×1.05 ×1% (5000).
Cost per hour	$59	$98	$47	$79
CREW	CAB	CAB+5%		
Cost per hour	$276	$290		
Fuel and oil	CAB	CAB+70%		
Cost per hour	$369	$627		
Maintenance	CAB	CAB + 25%		
Cost per hour	$535	$669		
Total flying operations (crew, fuel & oil, insurance)	$704	$1,015	$692	$996
Total maintenance—flight equipment	535	669	535	669
Total depreciation	430	718	344	574
Subtotal (cost per hour)	1,669	2,402	1,571	2,239
IOC cost per hour	2,003	2,003	1,885	1,885
Total operating expenses [2]	3,672	4,405	3,456	4,124
Total cost per hour	3,672	4,405	3,456	4,124
Total cost per mile:				
New York-London	7.39	4.24	6.95	3.97
Los Angeles-Honolulu	7.51	4.42	7.07	4.14
Total cost per available seat-mile:				
New York-London	¢2.19	¢3.79	¢2.06	¢3.54
Los Angeles-Honolulu	¢2.23	¢3.95	¢2.10	¢3.70

Notes: See the following table:

	LAX-HNL	JFK-LHR
Distance	2,590	3,530
B747 time (hours)	5.3	7.1
Concorde time (hours)	2.6	3.4
Available seats:		
B747	337	337
Concorde	112	112

[1] Nil.
[2] Indirects: Composed of interest payments, departure items, pass. items, hourly items, available seat items, ramp and baggage handling, etc. Work with all the major carriers and the FAA formula indicates this figure is virtually the same per hour for the 747 and Concorde. This approximates to 120 percent of the 747 hourly cost.

Comments on Fares and Yields

Care must obviously be exercised in determining B.E.L.F.'s based on fares when analysing two different standards of aircraft.

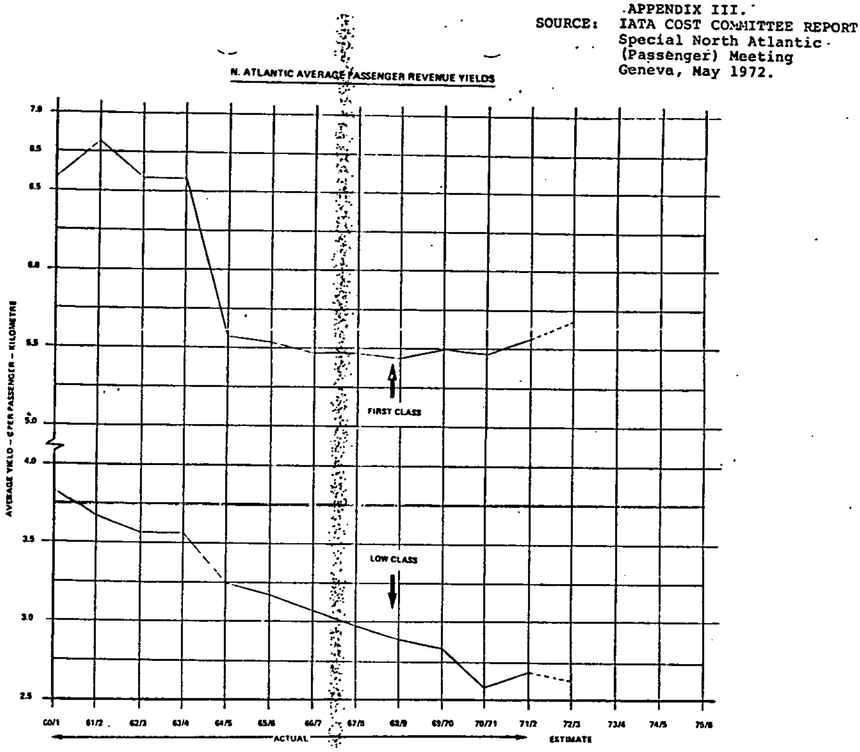
One of the major carriers operating on the West Coast—Hawaii network, in 1971, had an average yield of 3.6¢ per R.P.M. However, the average fare (F/Y/K) was 4.36¢ per R.P.M. This represented a dilution of 17.5%. After a considerable amount of research and discussion, it was agreed that the average dilution for SST services would be only 8%—mainly as a result of no promotional fares and very few family fares. In an all economy layout, the resulting dilution of the B747 fares increased to 20.8%.

For Concorde, we envisaged a mixed class configuration of approximately 36F+76Y=112, depending on the carrier and the market under consideration. Using today's regular first class and economy fares for LAX-HNL we get for Concorde:

	Case A	Case B
Yield at standard fares (r.p.m.)	¢4.9	¢4.9
BELF (percent)	81	76
Yield at standard fare plus 10 percent (r.p.m.)	¢5.4	¢5.4
BELF (percent)	73	69
Yield at standard fare plus 20 percent (r.p.m.)	¢5.9	¢5.9
BELF (percent)	67	63

A similar sum can be computed for the Atlantic operation, but there the yield tends to be better than for Hawaii.

APPENDIX III



THE ANTI-CONCORDE PROJECT,
January 9, 1973.

Senator WILLIAM PROXMIRE,
Joint Economic Committee,
Washington, D.C.

DEAR SENATOR PROXMIRE: As promised in my letter to you, 7 January, I am now sending you (enclosed) a statement[1] which gives some additional information upon certain of the points in the evidence to the Committee from Dr. Lundberg and Mr. Wilson—and in one or two cases provides answers to your questions (as for example on the likely results of a referendum or opinion poll on Concorde in Britain or France), on which I have been able to quote the results of opinion polls taken in both countries).

I offer this statement in the hope that it may be included in the record of the Hearings of 27 and 28 December 1972; and in the hope that the information may be of use to you in your effort to prevent the revival of the U.S. SST project.

Yours sincerely,

RICHARD WIGGS, *Secretary.*

Enclosure.

---

[1] Also herewith: a copy of our latest full-page advertisement (published in *The Times* 4 December 1972). [See fold-in following p. 162.] This was prepared with much help from Dr. Lundberg, from Dr. William Shurcliff of Cambridge, Massachusetts (Director, Citizens League against the Sonic Boom) and from the distinguished members of our Advisory Committee. It is thus the best statement (within the limits of space available) that we could devise on Concorde at that time. If you consider any of it to be suitable for addition to the record, we shall be pleased and honoured if this is done.

Statement of Richard Wiggs, Secretary of the Anti-Concorde Project, United Kingdom

CONCORDE

I shall make no attempt to go over again the ground so very ably covered by Dr. Bo Lundberg and by Mr. Andrew Wilson in their presentations to the Committee on 27 and 28 December 1972; my sole purpose here is to add a few footnotes to those presentations. May I say that to us it is refreshing and heartening that the Concorde has been the subject of hearings by your Committee. The House of Commons on 11 December had before it a motion to refer the Concorde Aircraft Bill (which authorises interest-free "loans" or investment of up to £350 m. of British government money to finance Concorde production) to a Select Committee, which would have heard and evaluated evidence from all sides. The government opposed this motion. During the debate a succession of pro-Concorde M.Ps. said that they opposed the motion because examination in Select Committee would result in information damaging to Concorde becoming available to the public and to prospective purchasers. No doubt it would. By a small majority (189–170) the motion was defeated.

Your Committee has done part of the work that would have been done by a Select Committee, and we thank you for this.

1. Mr. Wilson stated that "When work on the (U.S.) SST was stopped, those responsible for marketing Concorde expected to increase their sales prospects. But this did not happen. Instead there were a number of negative developments. . . ." Mr. Wilson remarked that the listed sales prospects of Concorde have diminished "by at least five since 1971". According to a recent statement in the House of Commons [1] by Mr. Cranley Onslow (one of the Ministers responsible for Concorde) the total of orders and options is now only 63 (orders from the British and French state airlines: 9; "preliminary purchase agreement" from China: 3; "letter of intent" from Iran: 2; "option" from Iran: 1; options remaining from the original 74 options: 48). The options that are missing are the 6 of United and the 4 of Air Canada (which have been publicly cancelled) and the residual 3 of BOAC and 4 of Air France (each of which held 8 options whereas they have ordered only 5 and 4 respectively).

Sabena is still listed by Mr. Onslow as holding 2 options, but its President has said that his airline "has given up all thoughts of buying Concorde" (*Financial Times* 25 Sept. 1972). Similarly Lufthansa is still listed although it "has no intension of exercising its three options" (*The Times* 8 August 1972).

Even so, on Mr. Onslow's figures, in spite of the immense efforts throughout the world of the large Concorde sales force, far from Concorde's sales prospects improving the total number of options etc. has dropped by 15%.

2. Mr. Wilson and Dr. Lundberg both referred to the airport noise problems of Concorde. It is well established that the prototype Concordes on the approach to land produce at the standard ICAO measuring point noise levels of 130 to 135 PNdB. Referring to the commercial model Concorde, Mr. F. W. Armstrong, Head of Acoustic Aerodynamic Research at the National Gas Turbine Establishment (the British government establishment that co-ordinates the national research into aircraft noise) wrote in a letter to me (16 October 1972) : "At the ICAO point the figure is about 123 PNdB, which corresponds to the 115 EPNdB quoted by the manufacturers."

Mr. Armstrong's figure of 123 is of course a prediction, not a measurement (no commercial model Concorde has yet been built). It is moreover an average, as are all such figures; but this fact has especial significance in the case of Concorde which, having poor aerodynamic performance at low speeds, approaches to land in a nose-up, tail-down posture high engine power: to maintain equilibrium the throttle setting is constantly adjusted by the auto-pilot, and this results in a series of "surges" alternating with throttlings-back (please see the chart, reprinted on next page). Thus the 123 PNdB quoted conceals the fact that on a substantial proportion of occasions the noise level will be substantially higher.

We are not entirely convinced that the noise-reducing mechanisms which will be fitted to later Concordes will bring the noise down even to an average of 123 PNdB—and if they do, as Mr. Wilson pointed out, such a level is very far from being acceptable.

---

[1] House of Commons, 30 November 1972. Official Report (Hansard), col. 232–233.

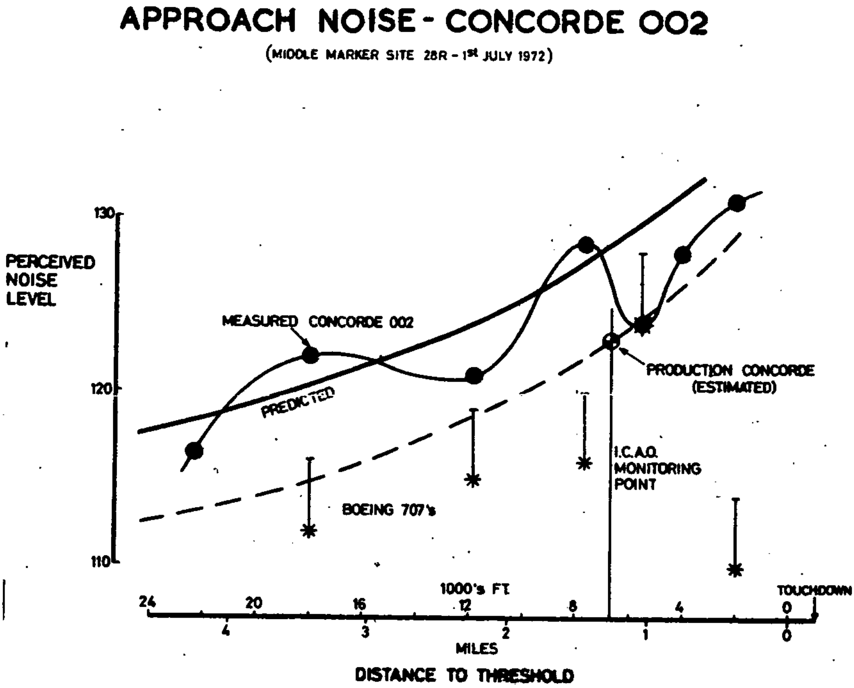


Chart received from Mr. F. W. Armstrong, Head of Acoustic Aerodynamics Department, The National Gas Turbine Establishment, Pyestock, Farnborough, Hampshire, England. Received by The Anti-Concorde Project 18 October 1972.

3. Mr. Wilson pointed out that the noise of Concorde should be compared not with the 707, DC–8 and VC–10, with the DC–10 and the Tristar. Even if the commercial Concordes meet the target level of 115 EPNdB on the approach to land, one Concorde would produce as much noise energy as 6 aircraft conforming to the international certification standard for aircraft of equivalent weight (107 EPNdB). The Tristar on the approach produces 102 EPNdB; Concorde on the approroach would make as much noise as about 20 Tristars landing simultaneously. This is of coarse not to say that Concorde would sound 20 times as *loud* as Tristar: as Mr. Wilson comments, it would *sound* twice as *loud* as Tristar; but the comparison in terms of *noise energy output* indicates the size of the problem of reducing Concorde's noise to anything like an acceptable level. The noise energy output of Tristar, producing 102 EPNdB, is only about 5% of that of Concorde producing 115 EPNdB. Thus to reduce Concorde's noise output to a level corresponding to 102 EPNdB would require the elimination of 95% of the noise output. But the predicted 115 EPNdB is itself the end product of three years of concentrated effort at noise reduction.

4. The fate of Concorde now apparently depends to a great extent—and perhaps conclusively—upon the position taken in the U.S. with regard to Concorde's airport noise.

The British press on January 5, 1973, reported the release of the report of President Nixon's Advisory Commission: *The Times* headlined its piece "Setback to Concorde sales hopes in U.S.", while *The Daily Telegraph* had the headline "Super sonic planes too noisy, says U.S.". We are aware that there is strong pressure in the U.S.—both from environmentalists and from airport operators—that the same noise standards should be applied to supersonics as to subsonic aircraft. If this is done, his bill will be just about fatal to Concorde. 32 of the surviving Concorde options are with U.S. airlines. The main item in the Concorde flight operations plans of Air France and BOAC is in each case the North Atlantic crossing. The already slight chance of Japan Air Lines ordering Concorde would be further diminished in the absence of U.S. landing rights. (Airport poise is almost as critical an issue in Japan as it is in the U.S. The visit of the Concorde prototype to Japan in June 1972 during its Far East "sales tour" was a fiasco—largely as a result of the noise—and from the sales point of view seems to have been substantially counter-productive).

5. With reference to Concorde operation on the North Atlantic, Mr. Wilson comments that whereas "such limited numbers as might be flown by Air France and BOAC might make a marginal profit . . . market research indicates that if another airline or airlines were to come into the operation, that profit would disappear". Sources inside BOAC and the British Airways Board inform us that their calculations show that if three airlines attempted Concorde operation on the north Atlantic all of them would make large losses. The FIATA Airfreight Institute, in a newspaper published in July 1972, made these comments: "The Institute does not believe that all first class passengers will want to fly in the SST. . . . IATA statistics for 1971 show that there were 464,552 first class passengers travelling across the North Atlantic—3.9 per cent less than in 1970. . . . Even assuming that 300,000 would switch to the SST would this be enough? . . . Three Concordes, operating two round-trips daily would be able to carry this traffic, and their seat load factor would only be close to 70%. If there were more Concorde flights sharing this traffic, the load factor would of course drop." (As Dr. Lundberg has shown, the attainment of two round-trips daily per Concorde is not likely; the same number of seat-journeys would be produced by 4 Concordes each making 3 crossings. But in terms of return on investment this would be far less satisfactory.).

6. Senator Proxmire's question to Mr. Wilson, "do you think that there is any prospect that Britain can get off this road to economic disaster, can finally say 'No' short of proceeding with the production of a substantial number of Concordes?" raises the interesting point that unless further orders are obtained soon, Britain and France will be faced with the embarrassment of having produced a number of Concordes which are evidently unsaleable: this in itself will be "bad for sales", and presumably there must be a limit to the number of unsellable Concordes that could be built and put on the shelf.

7. Senator Proxmire's question about the "second-generation Concorde" was answered very effectively by Mr. Wilson. Many politicians and various sections of the British press who still take the view that it is too late now to cancel the present Concorde, would utterly oppose the commencement of a further such project. I quote, as typically expressing this point of view, an editorial from *The Daily Telegraph* 29 December 1972, headed "Concorde and the taxpayer": "Almost certainly it is now too late to back out, but politicians of both major parties ought to be resolved never again to let the taxpayer in for a financial experience of this kind, especially when there are no overwhelming military or social reasons for doing so. Britain cannot afford it".

8. Senator Proxmire's question to Mr. Wilson on the possible result of a referendum on Concorde prompts me to offer the results of some public opinion polls in Britain and in France. My assistant Nigel Haigh was in France in October last and he saw on television a confrontation between Jean-Jacques Servan-Schreiber and a French Minister; the results of an opinion poll on Concorde were quoted by M. Servan-Schreiber and were shown on the screen. Mr. Haigh noted them:

	Percent
Strongly in favour of Concorde	8
Moderately in favour	39
Total	47
Don't know	11
Strongly against Concorde	13
Moderately against	29
Total	42

Although those in favor of Concorde were slightly more numerous than those who opposed it, the fact must be taken into consideration that in France the amount of public criticism of Concorde by politicians and by the press and others has been very much less than in Britain—and that in Britain there has been far less criticism of Concorde by politicians and press etc. than there has been in the U.S. relating to the SST. Thus the British are likely to be less well-informed than the Americans; and the French are even less informed.

We know of only one public opinion poll on Concorde in Britain: this was conducted in November 1970 by Louis Harris Research Ltd. for *The Daily Express* (a fanatically pro-Concorde newspaper).

To the question is *Concorde going to cost the country far too much to be worth while*, 51% said yes, 36% said no, 13% don't know.

To the question *whether the high costs of building Concorde are justified by the long-term benefits*, 42% said yes, 41% said no, 17% don't know.

Asked *what would be their attitude "if the Concorde was cancelled tomorrow"*, 49% said it would be "a bad thing", 28% said it would be "a good thing", 12% "wouldn't mind", 11% "don't know".

To the question *whether noise was going to be sufficient reason for cancelling Concorde*, 57% said no, 24% said yes. (Reported in *The Daily Express* 28 December 1970).

In 1970 there had been very little publicity about the noise of Concorde; the total predicted development cost was £600m of which it was expected that much would be recovered (the official estimate is now£970m; informed people know that this will be exceeded and that none of the development cost—with the possible exception of an infinitesimal fraction by way of a token—can be recovered).

Even now in early 1973 probably most people in Britain are confused about the cost and the prospects of Concorde. This is largely the result of the fact that most of the newspapers have a pronounced bias towards publishing reports favourable to Concorde and not publishing unfavourable ones. (For this reason—because it was impossible to get the facts that are unfavourable to Concorde into the papers in any other way—we were forced to publish a series of full-page and half-page advertisements in national newspapers, commencing in January 1968). We think it is likely that Mr. Wilson's view, that if a poll were taken now a majority would be against proceeding with Concorde, is correct.

9. Dr. Lundberg quoted from an article in *The Times* 28 November 1972: "There is no point in technological marvels if they do not make commercial and social sense. *Nobody disputes that Concorde is technically marvellous . . .*" (My emphasis) The italic statement is clearly disputable. Possibly nobody would dispute that the construction of an aircraft which can cruise at Mach 2 is a considerable technical feat; but it is equally indisputable that the Concorde is economically a failure. Among the factors contributing to its failure are its high fuel consumption, its small payload and restricted range, its sonic bang (which severely restricts its operability) and its high airport noise levels. All these are technical factors: Concorde's technical characteristics and performance are such as to contribute directly to its economic failure. In this context it is not unfair to say that Concorde is a technical failure.

Even on the most purely technical level—divorced from all considerations of purpose—the achievement of Concorde should not be overvalued. Of the total scheduled flight test program of 4,000 hours, only 1,000 hours have been flown. Introduction into commercial service was originally scheduled for 1969; this has now slipped to 1975. While it is obviously inappropriate and impossible to go into the details of Concorde's technical problems here, it may be of interest to mention some of the effects of the effort to reduce the airport noise levels. This effort was not started until 1969 (when it was commenced in response to the work of the critics of the SST's).

The effects have been (besides delay to the development program and cost rises) increased aircraft weight and therefore reduced payload/range, worsened operating economics and diminished sales prospects. The ramifications continue: the current *Flight International* (4 January 1973) reports that the first flight of the newest Concorde (02) has been delayed because the original carbon brakes have suffered structural failure (apparently during ground trials) and have had to be replaced with steel brakes; the reason for the failure is that the new Thrust Reverser Aft nozzle (developed as one of the main devices for reducing noise at airports) which is fitted to 02 "is a less efficient thrust reverser than that originally fitted to Concorde and a 23 per cent increase in brake energy has thus been built into the latest Dunlop (steel) brake." The carbon brake was of course developed to reduce weight: the return to steel adds to the weight problem. The next sentence in the *Flight* report quoted is: "Higher aircraft weights might require new brakes."

I recall that when I was in Washington, March 1971, at the time of the Appropriation Committee hearings on the SST, proponents of the SST were asserting that the Russian supersonic TU 144 would be in commercial service by the autumn of 1971—and that this was a challenge the U.S. must not ignore. In 1973, far from being in commercial operation, apparently the TU 144 has technical problems at least equal to those of Concorde. The current *Flight International* (4 January 1973) reports that "The TU–144 has sprouted retractable canard surfaces . . . Tupolev has also changed the brakes . . . to incorporate inboard disc units. Together with the other changes already reported in *Flight*—movement outboard of the powerplants, incorporation of canber on the wing, extension of the fuselage, a new undercarriage and removal of forward-vision panels in the visor—*these new features mark a major re-design of the aircraft*." (my emphasis). *Flight* comments: "Incorporation of the canards and the new brakes presumably reflects a higher gross weight and a need to maintain a reasonable airfield performance. . . . The prototype TU–144 has no thrust reversers and relies heavily on twin braking parachutes. It is not clear whether later aircraft have thrust reversers." The moustache canards should reduce take-off and landing speeds (brake energy varies as a square function of speed) and may improve maneuverability at low speed. On the debit side the canards are an additional complication and must be quite heavy.

It remains to be seen whether the Tupolev design bureau has fitted canard surfaces to the Tu-144 as a means of obtaining a genuine performance gain, or whether they have proved to be the only way out of a not unique problem with SST's—that of balancing a gross-weight (climbing in search of an adequate payload-range) with a reasonable airfield performance."

Air Commodore E. M. Donaldson, Air Correspondent of *The Daily Telegraph*, reports the same maters even more frankly (5 January 1973). His report, headed "Russia's 'Concorde' in Trouble," states: "The Russian Tu-144 supersonic airliner—Concorde's only rival—has sprouted wings on its nose. These are retractable at high speed and are used only for landing and take-offs, to give the plane better control at lower flying speeds. This indicates that the Russian attempt to produce a supersonic airliner ahead of Concorde has run into difficulties. The necessity to fit extra wings at great cost to give more lift and control can only mean that the TU–144 was landing and taking-off too fast. The plane . . . has a newly-designed undercarriage but its engines have no reverse thrust to help braking after landing. Thus it must rely heavily on extra large tail parachutes to slow it. The Russians still expect to have the plane in airline service in 1975, but this confidence is not shared by Western experts."

CONCLUSION

Mr. Wilson commented: "The Anglo-French strategy for selling Concorde is now one of blackmail". This is not the only blackmailing that is going on in the supersonic transport scene. While in the U.S. the "challenge of Concorde" is continually advanced as a reason why the Administration should support the development of an SST, in Britain and France the spectre of a "revived U.S. SST" is continually raised to support the plea that the Concorde should not be cancelled. When it suits them, SST-advocates on both sides of the Atlantic evoke the "challenge" of the Russian SST; presumably corresponding "arguments" are deployed in Russia whenever doubts are raised about the Tu–144.

The British, French (and presumably the Russian) governments are very willing to allow the facts about the SST's to be concealed beneath such verbiage. We hope and trust that your efforts to discover and to publish the facts will help to prevent the SST-advocates from persuading your Administration that an SST project is an enterprise that your country need or should undertake. As Dr. Lundberg so aptly said: the impact of the Concorde on a U.S. SST program should be that of a deterrent example.

CITIZENS LEAGUE AGAINST THE SONIC BOOM,
Cambridge, Mass., January 14, 1973.

DEAR SENATOR PROXMIRE: Regarding the recent hearings on SSTs' prospects, and preparations for the volume that will contain the witnesses' statements, etc.:

One of the most positive ways of showing a person the great inferiority of the Concorde SST relative to a new, wide-bodied, subsonic jet is to present a table, showing the key characteristics of a typical subsonic plane (DC–10, say) and the corresponding characteristics of the Concorde.

A few days ago I made such a table, preparing it carefully from the most authoritative sources. Here is a copy.

I respectfully submit this table for inclusion in the Hearings volume.

(Should you find that the table etc. needs slight shortening, please feel free to shorten it as you deem best.)

Sincerely,

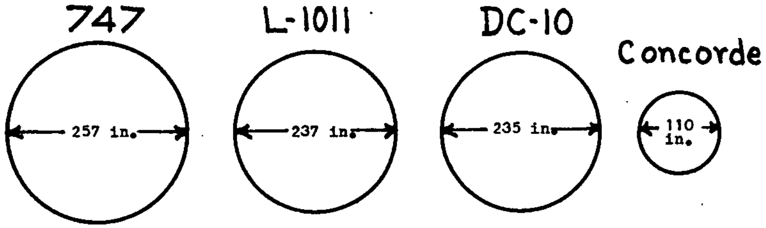
WILLIAM A. SHURCLIFF,
Director.

Enclosure.

THE CONCORDE

HOW DOES IT COMPARE WITH THE "BIG THREE" OF MODERN JET PLANES?

CROSS SECTIONS OF CABINS: Here are the cross sections,* drawn to same scale.



DETAILED COMPARISON OF DC-10 (for example) AND CONCORDE

	DC-10	Concorde
Speed	~550 mph	~1400 mph
Number of passengers	270	120
Designed to carry freight too?	Yes	No
Cabin has windows?	Yes. Large ones	No. has ~4x6 inch peepholes
Range	~6000 miles	~4000 miles
Payload	110,000 lb.	26,000 lb.
Medium-length runway suffices?	Yes	No
Airport sideline noise	97 epndb	111 epndb (see footnote a)
Produces sonic boom?	No	Yes. Damaging boom (b)
Threat to upper atmosphere?	No	Much concern (c)
Fuel used per ton of payload	Unusually little	Three times that of DC-10
Purchase price	~$22 million	~$59 million
Date of first routine use	~40 already in use	1975
Continuation of project assured?	Yes	No. May be abandoned (d)

Conclusion: Concorde, although speedy, is environmentally and economically a dud.

* Approx. dimensions inferred from official brochures, from Aircraft Engineering of May 1971, from Time, and other sources.

a: Such noise far exceeds US limits applicable to all new subsonic planes.

b: In twelve test flights over Cornwall, Wales, etc., the sonic boom damage to glass, plaster, etc., amounted to £ 35,622, per official statement TS/20/03 of Oct. 18, 1972, by British Dept. of Trade and Industry.

c: Concern is stressed in U.S. Nat'l Acad. Sci. 42-p report of July 1971 and in US Dept. Transp. 1-inch-thick report DOT-TSC-OST-72-13 of Sept. 1972.

d: Hansard transcript of House of Commons debates of Dec. & early Jan. reveal deep despair: after ten years, only 9 firm orders; no orders from US; if Pan Am and TWA decline to place orders, entire project may founder.

January 9, 1973

CITIZENS LEAGUE AGAINST THE SONIC BOOM
19 APPLETON STREET
CAMBRIDGE, MASSACHUSETTS 02138

SIERRA CLUB,
San Francisco, Calif., January 10, 1973.

Hon. WILLIAM PROXMIRE,
Chairman,
Joint Economic Committee,
Senate Office Building,
Washington, D.C.

DEAR SENATOR PROXMIRE: I am writing to express the Sierra Club's continuing opposition to the supersonic transport. As you undoubtedly recall, the Club worked diligently with other environmental and public interest groups to prevent the appropriation of federal funds to finance the construction of SST prototypes in the 92nd Congress. Our objections have centered on the sonic booms created by and related noise problems associated with such a plane traveling at supersonic speeds and the little known, but clearly ominous, environmental effects of this plane on our atmosphere's chemical composition, as well as the questions of federal funding priorities—whether the SST is not perhaps a gross misuse of these tax monies. The Club's opposition to the development of a SST also includes the following concerns:

(1) Excessive increase in airport noise levels;
(2) Increased air pollution in the communities adjacent to airports;
(3) Psychological nuisance and damage due to the sonic boom;
(4) Contamination of the stratosphere with combustion products which may influence world weather;
(5) Exposure of crew and passengers to occasional danger of solar flare radiation—this danger is particularly significant to unborn children;
(6) Increased vortex-turbulence danger to smaller aircraft; and
(7) Increased depletion rates of United States' and world oil reserves.

Since the Congress voted last year against funding a private SST prototype, a number of significant developments on this issue have surfaced about which you know and which the Sierra Club has been closely watching. The first of these developments was the alarming and persistent rumor that the Administration would seek to revive the SST, and although this has been denied by Administration officials, the Sierra Club does not believe their intentions are clear. We expect to see legislation introduced in the 93rd Congress which would establish a Federal subsidy to finance the construction of "high risk" aircraft—a category into which the SST would likely be placed. On January 5 the Federal Aviation Advisory Commission released a report recommending a $2 million, 2 year study of this possibility, and the Sierra Club anticipates that this report will be used to supplement legislative pressure to pass a bill of this nature. Unless the SST were prohibited specifically, the Sierra Club would oppose this legislation, should it be introduced.

Federal noise regulations for aircraft is the other major area in which the Club is presently quite interested insofar as supersonic airplanes are concerned. As you know, no regulations presently exist for supersonic aircraft, only regulations for subsonics which are 108 PNdB set by FAR Part 36. While the House-Senate Conference Committee deleted supersonic noise provisions from the Federal Noise Control Act of 1972, the Federal Aviation Administration is currently in the process of developing two sets of regulations affecting SSTs. One would prohibit civil aircraft from flying over the United States at supersonic speeds. We understand that the FAA is now drafting an environmental impact statement before promulgating the regulation. The Sierra Club supports this proposal. The second rule making procedure about which we have heard would set a maximum noise level permissable for supersonics at, initially, 108 PNdB, namely, the same as for subsonics. While this would definitely be a step in the right direction in terms of noise control from aircraft, the Sierra Club contends that a 10 dB reduction of equivalent perceived noise decibels is necessary for environmental protection and public health. Therefore, the Sierra Club believes that supersonic and subsonic levels should be set as a maximum level of 98 PNdB.

There are other considerations relating the SST to future Congressional deliberations which strike us as important. The first is economic, inasmuch as conservationists view the SST as a case of misplaced priorities and technology which is out of control. Air and water pollution control should be among our highest priorities in restoring to this country a suitable, acceptable quality of life—which also includes programs to solve social problems of housing, transportation, urban blight and so forth. The Club does not believe that the federal government should be subsidizing a program which will further endanger our environment and threaten public health while these other pressing problems remain unsolved and underfunded. Moreover, the Administration's insistence on reducing federal spending is inconsistent with a commitment to SST development at a time when it is limiting the amounts of federal grants for water pollution control appropriated by Congress.

This Congress should also enact legislation to develop a national energy policy. In terms of energy conservation, which must be included in any discussion of energy resource problems and energy use, the SST seems to be an inappropriate use of these resources. These supersonic planes—not only the United States' prototype, but also the Concorde and the TU-144 as well—are designed to accommodate fewer passengers than our present aircraft fleets, but they will guzzle proportionately more fuel to take off and accelerate to supersonic speeds during cruise operation.

Without exception, objective studies and literature discussing supersonic aircraft find it uneconomical and environmentally hazardous. This documentation simply cannot be ignored. The Sierra Club adds to this volume of opposition its firm objections to SST construction.

Sincerely yours,

MICHAEL MCCLOSKEY, *Executive Director.*

NATURAL RESOURCES COUNCIL OF MAINE,
Augusta, Maine, January 8, 1973.

Senator WILLIAM PROXMIRE,
Joint Economic Committee,
Washington, D.C.

DEAR SENATOR PROXMIRE: The Natural Resources Council of Maine wishes at this time to reiterate its opposition to any federal appropriation for the development of a supersonic transport plane. The Council, which is a non-profit environmental citizens' organization representing almost 100 affiliated organizations and over 2,500 individuals has long been on record as opposed to the development of the supersonic transport plane.

In June 1969, the Board of Directors passed a resolution noting the numerous detrimental aspects of SST development. Among these was the noise factor, method of financing the program, danger to wilderness areas and finally, the obvious lack of priority for more critical programs, including those for the construction of pollution abatement facilities and for the acquisition of land for public purposes. All of these points remain relevant today. (1)

In April 1970, the Council became one of 13 national and state organizations who sponsored the coalition against the SST (620 C St. SE DC 20003) which represents a coordinated citizen effort against the SST.

In June 1970 the Board of Directors of the NRC reaffirmed their position and asked that the SST program be referred to the President's Council on Environmental Quality before any decision was made. (2)

In March 1971 the Third Maine Environmental Congress commended the Maine Congressional Delegation for their part in terminating funds for the SST and urged that measures be adopted to prevent overflights of the U.S. territory by commercial supersonic aircraft. Further they urged that the money be used for the development of efficient mass transit within the U.S. (3)

The Natural Resources Council does not feel that at this time conditions have altered to warrant change in their opposition to further development of this plane, through governmental support.

We would request that this statement be included in the official hearing record of hearings held in Washington on the SST by the Joint Economic Committee December 27–8. Thank you.

Sincerely,

CHARLES G. BOLTE, *Executive Secretary.*

Enclosures.

NRC BOARD OF DIRECTORS, OCTOBER 1969

Whereas to our knowledge. no reliable information exists indicating that the boom created by aircraft flying at supersonic speeds can be brought within tolerable limits, and

Whereas the proposed method of financing the SST program tends to maximize the number of SST's in operation, and

Whereas the presumed policy of the government restricting supersonic flights over populated areas means that any overland flights authorized must be routed over our more remote or wilderness areas in which Maine has an enormous stake, and

Whereas giving precedence to a program with so many apparent drawbacks seems preposterous in view of the many severe cutbacks in desirable environmental programs, including those for the construction of pollution abatement facilities and for the acquisition of land for public purposes,

Now, therefore be it resolved that the Natural Resources Council Board of Directors opposes any further implementation of the SST program, and it urges our congressional delegation to work strongly for a more rational assessment of priorities in funding governmental programs.

NOTE.—See NRC Bulletin October 1969, April 8, 1971—Presented as testimony in support of LD 887—An Act to Regulate Noise Pollution of the Supersonic Transport under the EIC.

NRC BOARD OF DIRECTORS, JUNE 1970

The Natural Resources Council of Maine requests and urges that before additional tax-paid federal funds are committed to the SST program it be referred for appraisal to the President's Council on Environmental Quality.

NOTE.—See NRC Bulletin June 1970—sent to President Nixon April 8, 1971—Presented as testimony in support of LD 887—An Act to Regulate Noise Pollution of the Supersonic Transport Plane under the EIC.

THIRD MAINE ENVIRONMENTAL CONGRESS, MARCH 1971

The Third Maine Environmental Congress regrets any loss of employment or individual income resulting from the rejection of funding for the supersonic transport. We believe, however, that the rejection of this ill-conceived and environmentally unsound project was fully justified. We therefore publically commend Senators Margaret Chase Smith and Edmund S. Muskie, and Representatives William Hathaway and Peter Kyros for their part in terminating funding for the SST. We further urge the Maine Congressional Delegation to sponsor and support measures to prevent over-flight of U.S. Territory by commercial supersonic aircraft. We also urge that the technical facilities and monies diverted from the SST be used for the study and development of efficient mass transport within the United States.

OREGON ENVIRONMENTAL COUNCIL,
Portland, Oreg., January 9, 1973.

Hon. WILLIAM PROXMIRE,
U.S. Senate,
Washington, D.C.

DEAR SENATOR PROXMIRE: We are writing you with regard to the hearings your Committee held on December 27 and 28, 1972 regarding the possible revival of the supersonic transport.

The Oregon Environmental Council joined with the Coalition Against the SST and actively opposed the funding of this project for a number of environmental reasons which are all familiar to your Committee. This letter is to assure your Committee that we have not modified our position and we stand ready to oppose any effort to reinstate the SST program. Of far more concern to us is ground transportation and not supersonic transportation. We desperately need funds for inter-city and intra-city transportation across the nation. We trust that this priority is one which your Committee holds also.

Please include this letter in the hearing record.

Sincerely,

LARRY WILLIAMS, *Executive Director.*

LIFE OF THE LAND,
A GROUP FOR ECOLOGICAL RESEARCH AND ACTION,
Honolulu, Hawaii, January 11, 1973.

Senator WILLIAM PROXMIRE,
Joint Economic Committee,
Washington, D.C.

DEAR SENATOR PROXMIRE: We are informed that your committee has held hearings on the SST recently and that you are accepting additional comments.

We wish to inform you that we are totally opposed to any support of a supersonic transport by federal funds. This includes attempts by groups such as the Aerospace Industries Association to sneak SST funding through Congress under the guise of general support for the aerospace industry.

We also intend to oppose any attempts to allow an SST, whether of U.S. construction or foreign, to land in Hawaii or to fly over the islands.

In addition to the well-known and much publicized problems of air and noise pollution caused by these planes, we must also consider their economic effect. We who live in Hawaii are forced to depend on inexpensive air transportation for travel to other States and for shipment of many crucial materials. With the cost per passenger or ton mile of the SST being much higher than that of the wide-bodied jets, the airlines would have to subsidize these costs through a general increase in rates. The economic effect on Hawaii and on the airlines themselves would be disastrous.

The only conceivable reason for the United States to build an SST is competition with the European powers already doing so. However, this competition is one of prestige only; not building an SST would put the U.S. in a better economic position and make our competitive position on the world travel market more firm.

We ask that you and your committee vote down the U.S. SST, and put an end to this idea for good.

Sincerely,

WILLIAM J. KIMMERER,
TONY HODGES,
Executive Director.

O