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THE ENVIRONMENT:

WHAT IS AVIATION'S IMPACT?

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FEATURES

DEPARTMENTS

COVER

As many of the articles in this issue reflect, we still have much to learn about the environmental impact of aviation, particularly the effect of engine emissions. Studies continue, and a number of measures have been suggested or have been implemented in an effort to minimize possible adverse effects.

Photo by Mark Wagner/Tony Stone Images

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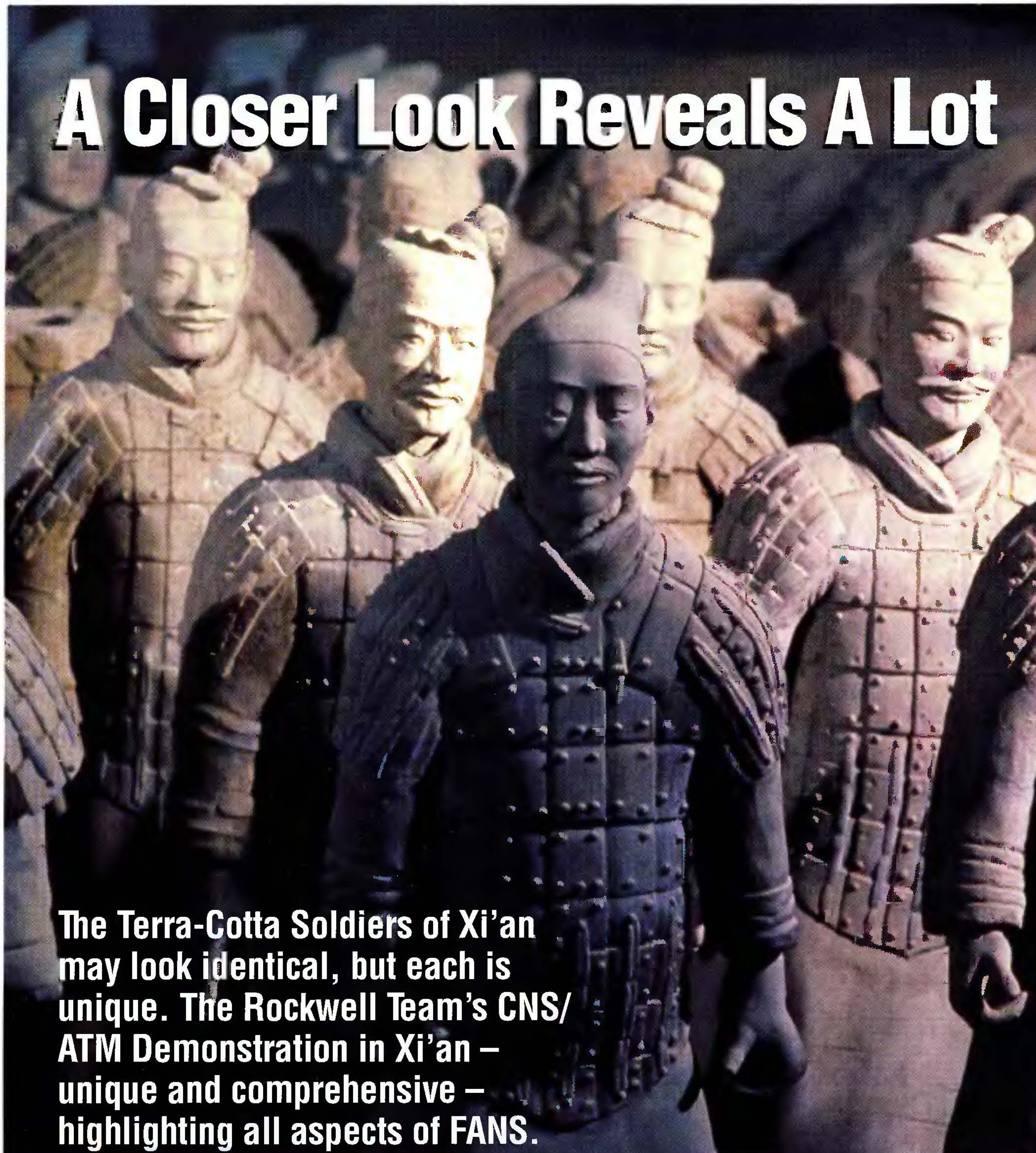

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Standards for aircraft noise, emissions focus of meeting on environmental issues

Members of CAEP gathered at ICAO Headquarters recently to discuss environmental issues, particularly those related to aircraft noise and emissions and the possibility of introducing more stringent standards to protect the environment.

LES MORTIMER
ICAO SECRETARIAT

WHEN the world's experts on aviation environmental protection met at ICAO Headquarters for two weeks last December, a wide range of issues was discussed. In the minds of most participants, however, there was little doubt that the principal challenge was to review aircraft noise and emissions standards and address the question of whether they should be increased.

The members of the Committee on Aviation Environmental Protection (CAEP) introduced more than 100 working documents on such issues as the need for more stringent standards, their technical feasibility and — in something of a departure for CAEP — cost-benefit aspects.

The third meeting to be held by the ICAO committee since it was formed, CAEP/3 examined a number of technical and other matters but it was clear that stringency issues were the centre of attention. Before an increase in stringency can be approved, CAEP requires that three criteria are met: environmental need, technical feasibility and acceptable economic impact.

By the time the meeting concluded on 15 December, CAEP members had not reached an agreement about changes to the permitted noise levels. The committee did, however, adopt noise related recommendations concerning new take-off noise abatement procedures, and the development of guidance material for states on the matter of land-use control near airports. The committee also agreed to recommend that the standards for nitrogen oxides (NO_x) emissions be strengthened, although there was not a consensus on this subject. This matter was referred to the Council of ICAO, which is expected to consider the issue in the second quarter of 1996.

Although there are some common threads, the circumstances surrounding the noise and emissions issues are different, and so these issues can be addressed separately.

The issue of noise

Noise certification standards for jet-powered aeroplanes currently in production are contained in Chapter 3 of Annex 16, Volume I. Annex 16 is the annex of the Chicago Convention that is concerned with environmental protection.

The noise certification standards were developed by the ICAO Committee on Aircraft Noise (CAN — a predecessor of CAEP) in 1973, and have remained essentially unchanged since. However, many aeroplanes which only meet the requirements of the earlier Chapter 2 are still in service, and these are significantly noisier than those meeting Chapter 3 requirements.

In 1990, the ICAO Assembly adopted a resolution which provides for the progressive phase-out of the older, noisier aeroplanes. Before a decision could be made about increasing stringency, it was considered to be essential to ascertain the sort of noise climate likely to surround airports once these older aircraft have been retired.

The future noise climate

A study conducted by CAEP found that at almost all airports examined, a significant decrease in the noise contour area would occur as Chapter 3 aircraft replaced Chapter 2 models, even allowing for expected increases in the size of the aircraft fleet to meet traffic growth. Once the Chapter 2 aircraft had been taken out of service, the contour areas either increased or decreased slightly, depending on the circumstances at the particular airport.

The airports chosen for the study serve airlines with a mix of international and domestic and long- and short-range operations. An essential part of the study involved estimating how the fleets serving these airports would evolve, in terms of both numbers and types of aircraft, as traffic increased and new types were introduced.

The noise climate itself was assessed using the U.S. integrated noise model (INM), which takes into account such factors as aircraft noise, frequency of operation and time of day. It yields results in terms of the areas enclosed within a chosen noise level boundary. If the geographical distribution of people living around the airport is known, the numbers of people living within a chosen noise level contour can also be estimated.

The effect of some potential increases in stringency was also included in the study. The results showed that if the noise limits were to be decreased, and fleet composition eventually changed to include types that meet the new limits, the effect on the contours would be very small. It thus appeared from the study that an increase in stringency was not justified.

Many at the December meeting did not accept this conclusion. To them, the 13 airports included in the study could not be considered representative of airports worldwide. It was inevitable, in their view, that after the Chapter 2 phase-out ended the noise climate would begin to deteriorate again as traffic increased. That this appeared not to happen at some of the airports studied, they stated, was because the airports in question were, or would soon be, capacity constrained.

Possibilities for increasing stringency

The noise limits contained in Chapter 3 have not been amended for more than 20 years because there have been no significant improvement in noise reduction technology in that time. Bearing in mind the criterion of technical feasibility, how can increases in stringency now be considered?

Although there have been no major breakthroughs in noise technology, manufacturers have not been idle; there has been steady, if not dramatic, progress. The more modern designs, therefore, generally meet the requirements with a few decibels to spare, at least at some of the certification measuring points. There therefore appeared to be some scope for a modest increase in the stringency of the limits.

Not everyone at the meeting agreed, for two reasons.

First, noise is a major factor in the design of a new aircraft. The economic implications of failing to meet the noise requirements are so serious that designers have to leave themselves a margin of error. This margin is not always used, and the result is that the aircraft sometimes meets the requirements with apparent ease. Manufacturers will always have to provide themselves with this margin, no matter how stringent the limit, and it is always provided at the expense of weight[1] and performance. The margin by which some of the more modern designs meet the present limits should not therefore be considered as representing a technology bonus that can be absorbed into a stringency increase.

Second, it was contended that most aircraft meeting the limits by a significant margin were new model types at early stages of development. It was well established that developed versions invariably had a higher design take-off weight than the parent aircraft and that noise increased much more rapidly with increasing weight than the Annex 16 noise limits permitted. Since the ability to produce a family of developed models was critical if a manufacturer was to achieve economic success with a design, it followed that the initial model would have to be designed to meet the limits by a comfortable amount — which again should not be mistaken for a technology margin that could be taken up by a stringency increase.

Economic considerations

CAEP addressed the matter of economic feasibility by carrying out a cost-benefit analysis of different possible increases in stringency. Increases in operating costs were assumed to be incurred because new types and developed versions of existing types would need to be designed to meet more severe noise limits at the expense of reduced performance. Restoring that performance would be necessary to increase take-off weight and possibly increase engine thrust, with consequent increases in fuel consumption and operating cost.

Also, costs were thought to be likely to rise because of a decrease in market value of existing non-compliant aircraft if some countries or even airports banned what they perceived as noisier models. Benefits could not be calculated in monetary terms, and could only be expressed as a reduction in noise contour areas, or people affected, at specific airports.

The study showed the costs to be very large; as mentioned above, the reductions in contour areas and people affected were generally small. The results therefore appeared to indicate that the benefits obtained would not justify the costs.

Some CAEP members questioned the study's validity and conclusion. Given that many new aircraft types already meet the proposed new limits, they did not believe that the costs should be so high. Moreover, they were doubtful whether a cost-benefit analysis was an appropriate economic tool to use when benefits could not be assessed in the same units as costs. On the other hand, there was extreme concern among some participants about the potential for reducing the asset value of the existing non-compliant fleet. It was pointed out that although the certification requirements of Annex 16 had never been intended for use as a basis for operational restrictions, this is nevertheless what had occurred in the past. The 1990 resolution by the ICAO Assembly was partially an effort to overcome this problem.

> Fuel-staged combustion has reduced NO_x on an advanced medium-sized engine, but has proved a disappointment on a very large, high-compression ratio engine.

No consensus

Believing that the studies had shown no need for an increase in stringency, some CAEP members felt it was wiser to await the outcome of a major noise research programme under way in the United States before considering any lowering of Annex 16 limits. Others, believing that lower noise limits would not be unduly expensive, felt that ICAO should set more stringent limits immediately; if ICAO failed to do so, they stated, airports and national governments might take matters into their own hands, eroding international standardization and CAEP's credibility.

As a result, the committee ended its third meeting without a consensus on this issue, and was not able to make any recommendation to the ICAO Council on noise limits.

Other noise issues

Two other aspects of the discussions on noise at the CAEP meeting are of particular interest because of their association with the stringency issue. The second CAEP meeting, in 1991, adopted what it called a "balanced programme" for noise reduction around airports. This programme comprised three elements: reduction of noise at source (as controlled through stringency increases), operational noise control measures, and land-use planning. Apart from the stringency aspect, considerable work had been done in preparation for CAEP/3 on the issues of operational noise control measures and land-use planning.

Operationally, the CAEP members agreed on new take-off noise abatement procedures to replace those currently appearing in ICAO Document 8168, which defines procedures for air navigation services related to aircraft operations (PANS-OPS). The new procedures are already in use in one country and are intended to optimize noise reduction at points under the take-off path far from as well as close to the runway end. (For more details on this development, see "Proposed procedures for take-off noise abatement demonstrate potential to mitigate problem," page 19.)

While it was generally agreed the new procedures were an advance on those currently in PANS-OPS, some members doubted that they would have a significant impact. Furthermore, crew training requirements would mean that the procedures could not be optimized for every runway by every airline. It was thought that, in the longer term, more would be gained from the use of noise-avoidance routes and procedures made possible by advanced navigation systems.

There was general agreement that much could be gained by proper land-use planning, and the meeting approved extensive guidance material on that element. The main problem associated with land-use planning was perceived to be aviation authorities' lack of control in most cases over land use around airports. (For more on land-use planning, see "Proposed land-use planning guidance material reviews

1. In ICAO teminology, the term mass is used instead of weight to express a measure of the quantity of matter that an object contains. This is the term recognized by the International System of Units (SI).

A CAEP study of 13 airports found that the noise contour area would decrease significantly as Chapter 3 aircraft replaced Chapter 2 models, even allowing for expected increases in the size of the aircraft fleet. Many CAEP members did not accept this conclusion, and felt it was inevitable that the noise climate would begin to deteriorate again as air traffic increases. *Boeing photo*

possible solutions to problem of noise," page 21.)

Engine emissions

Engine emissions certification standards are contained in ICAO Annex 16, Volume II. Standards limiting the production of carbon monoxide (CO), unburned hydrocarbons(HC) and NO_x were first developed by the ICAO Committee on Aircraft Engine Emissions (the other parent of CAEP) in 1980, and became applicable in 1981. The NO_x standards were made more stringent following the recommendation of the second meeting of CAEP in 1991, with the original limits being reduced by 20 per cent. In considering now whether there should be a further increase in stringency, CAEP/3 applied the same criteria it had used for noise: environmental need, technical feasibility and economic impact.

Environmental aspects

When the original standards were developed in 1980, the over-riding concern was with air quality around airports. Subsequent studies, including one in preparation for CAEP/3, have indicated that the situation around airports has not changed markedly since then and that there is no obvious need for further controls on this account. However, there has been growing concern over pollution of the upper atmosphere leading to such phenomena as global warming and depletion of the ozone layer. Of the emissions currently covered by Annex 16, only NO_x has been mentioned as being possibly implicated. For these reasons, neither CAEP/2 or CAEP/3 has considered it necessary to increase the stringency of the CO or HC standards.

NO_x is a different matter. Some atmospheric scientists have suggested that it may be having two effects. Above the tropopause, where supersonic aircraft cruise and some subsonic aircraft also are beginning to fly, it is thought that NO_x contributes to the destruction of ozone; in the upper troposphere, where the majority of subsonic airliners cruise, it is thought, conversely, to increase the amount of ozone, which at these altitudes is a greenhouse gas. It has not been suggested that aircraft-generated NO_x is a major contributor in these processes, but there is still a great deal of uncertainty about exactly what these processes are and how significant the aircraft component is.

A similar situation was faced by CAEP at its 1991 meeting, which reviewed the state of the art in engine combuster design and decided that it would be possible, without unduly burdening manufacturers, to reduce the Annex 16 NO_x limits by 20 per cent. It was also noted then that some technological developments were being pursued which held the promise of further significant reductions. There was hope too that before CAEP met again in 1995, atmospheric scientific research would be able to provide definitive answers to the questions concerning the effects of aircraft-generated NO_x on the atmosphere. To help promote this work, CAEP outlined the aviation community's needs and concerns to the atmospheric science community, and also offered research assistance to the scientists. Specifically, CAEP decided to develop an inventory of aircraft-generated NO_x emissions worldwide, which scientists could use as a reliable data source. This work did not duplicate similar work already under way in the United States and Europe; CAEP instead carried out an exercise to compare and reconcile the existing programmes.

Unfortunately, by the time of CAEP/3, scientists had still not produced reliable information on the environmental effects of aircraft-generated NO_x. Available data did not suggest the effects were very serious, at least for the time being. Committee members at the 1995 meeting were left in much the same position as those at the meeting four years earlier: if an increase in stringency were to be recommended, it would have to be on the basis of the so-called "precautionary principle." As used by United Nations agencies, this expression means that where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The situation is complicated by the fact that NO_x is not the only atmospheric pollutant arising from aviation; others such as carbon dioxide, water vapour, sulphur oxides and particulates are also of general concern and controlling NO_x may in fact increase the production of some of these other substances.

Combuster technology

As mentioned above, CAEP/2 took advantage of general improvements in technology to increase the stringency of the NO_x standards in 1991, and it also noted that further improvements seemed likely in the foreseeable future, probably by the time the committee met again. The first of these technology developments, fuel-staged combustion, is now in production. It has shown the hoped-for reduction in NO_x on an advanced medium-sized engine, but on a more recently certificated very large, very high compression ratio engine, it has proved a disappointment. The reason appears to be that there is not enough air passing through the engine core to perform all the tasks required of it. Apart from providing oxygen for combustion, the air has to perform several functions, including cooling the combustion gases to reduce the generation of NO_x, and cooling the walls of the combustion chambers to maintain tolerable temperatures. In this case, the need to balance these two requirements has prevented the realization of the anticipated NO_x reduction.

Despite this setback, a review of the performance of recently-certificated engines convinced most CAEP members there was scope for a modest reduction in the NO_x limits. Other members, however, did not believe an increase in stringency was justified given the lack of a clear environmental need. One reason put forward for not recommending an increase in stringency was similar to that used in the case of noise — the need to allow manufacturers scope for development of their engines. In the case of aircraft as a whole, the weight of the aircraft always rises as the design develops, while for engines, it is pressure ratio that tends to rise. NO_x production increases as the temperature in the combuster rises, and this temperature increases as pressure ratio increases. This fact was recognized when the ICAO NO_x limits were developed and was allowed for by establishing a limit which increases with pressure ratio. However, as with noise and weight, it has been found in practice that within an engine family, NO_x emissions rise much more rapidly with increasing pressure ratio than the Annex 16 limits permit. Thus it is claimed that the first models in a new engine family need a comfortable margin over the limits to allow scope for development growth, and such a margin should not be considered as a technology bonus which can be absorbed by a stringency increase.

Another, more fundamental, reason for not recommending a reduction in the NO_x limits was also put forward, reflecting a central dilemma facing engine designers when they try to control NO_x production. Under constant pressure to reduce fuel consumption, designers strive constantly to achieve peak efficiency. The classic way of improving thermal efficiency is to increase pressure ratio, which always leads to increased operating temperatures. High temperatures lead to increased NO_x production and thus the quest for reduced fuel consumption leads to higher NO_x output unless combuster technology can also be improved. From the environmental viewpoint, more fuel burned means more CO_2 and water vapour being released into the atmosphere, and so it may be necessary to make a choice between reducing NO_x and reducing other pollutants. The problem is, however, that in our present state of knowledge we do not know which of the pollutants we should concentrate on reducing. Some CAEP members argued that it would be unwise to force manufacturers to reduce NO_x at the possible risk of increasing CO_2 and water vapour until more work had been done to clarify the situation.

Some CAEP members argued that it would be unwise to force manufacturers to reduce NO_x at the possible risk of increasing CO_2 and water vapour.

Costs and benefits

As it had for noise, CAEP carried out a cost-benefit analysis of some options for reduced NO_x limits. The costs of making the future fleet comply with the new limits were estimated, as was the loss of asset value of non-compliant aircraft. As for noise, benefits could not be estimated in monetary terms; they could only be expressed as the reduction in total NO_x attributable to increased stringency, taking fleet growth into account. Again, as for noise, the results indicated the costs to be high and the benefits minimal, and again some committee members did not find these results convincing.

The conclusion

While accepting that the environmental need for a reduction in the NO_x limits had yet to be proved, most CAEP members felt that there was technical scope for such a reduction, taking into account manufacturers' need for a margin for development. These members did not believe that the costs would, in practice, be significant. Other committee members believed that until the environmental need had been established, especially in view of the possibility of increasing the output of other pollutants, no action was warranted. They also cited the results of the economic study and the technical difficulties that still existed. However, since there was a clear majority — the ratio of those in favour to those against was approximately three to one — the meeting did make a recommendation to the ICAO Council for a reduction of the existing Annex 16 NO_x limits.

The proposal is for a 16 per cent reduction relative to the limits developed at CAEP/2, at a pressure ratio of 30, with the allowance for pressure ratio remaining unchanged. It is proposed that the new limits be applicable to new engine types first certificated after 31 December 1999, and to all engines manufactured after 31 December 2007. An allowance is included for low-thrust engines, which, for reasons of physical size, have difficulty in incorporating the best low-NO_x technology. It remains to be seen whether the ICAO Council, and subsequently ICAO's member States, will accept the proposal. □

Mr. Mortimer, a former Technical Officer in the Operations and Airworthiness Section of the Air Navigation Bureau at ICAO Headquarters, Montreal, is a former Secretary of the Committee on Aviation Environmental Protection. Now a consultant, Mr. Mortimer assisted the ICAO Secretariat at the third meeting of the CAEP.

Experts consider operational measures as means to reduce emissions and their environmental impact

Studies so far indicate that most operational measures have limited potential in reducing aircraft emissions, but further scientific research is necessary before recommendations can be made.

DEPARTMENT OF TRADE AND INDUSTRY (UNITED KINGDOM)

QUESTIONS have been raised for some time about the environmental impact of aircraft emissions, particularly near airports. The emphasis recently has been shifting towards high-altitude emissions, but there remains considerable uncertainty about the role of aircraft in global warming and stratospheric ozone depletion. Nonetheless, the outlook for long-term growth in air travel, coupled with the fact a considerable proportion of the emissions go directly into the lower stratosphere, makes it clear that this high-altitude focus is going to remain at least until scientific understanding has improved.

The ICAO Committee on Aviation Environmental Protection (CAEP) has just completed a four-year study of the issue, in which it addressed the scope for stricter engine emissions standards. It also considered benefits which might accrue from changing the way in which the global fleet is operated.

Aircraft operations are a growing source of emissions into the atmosphere. Assessments of current and future emissions have been reported to CAEP by the National Aeronautics and Space Administration (NASA) and the European Civil Aviation Conference (ECAC) group of experts on the abatement of nuisances caused by air transport (ANCAT). In broad terms, these two studies show that the global civil aircraft fleet consumed about 120 million tonnes of fuel in 1992, and generated approximately 1.3 million tonnes of nitrogen oxides (NO_x), 380 million tonnes of carbon dioxide (CO_2) and 150 million tonnes of water vapour (H_2O). Assuming a traffic growth rate of 3.6, it is estimated that the more efficient aircraft fleet operating by 2015 will consume 2.5 times more fuel, producing 2.3 times more nitrogen oxides and 2.5 times more carbon dioxide and water vapour (see *Table 1*).

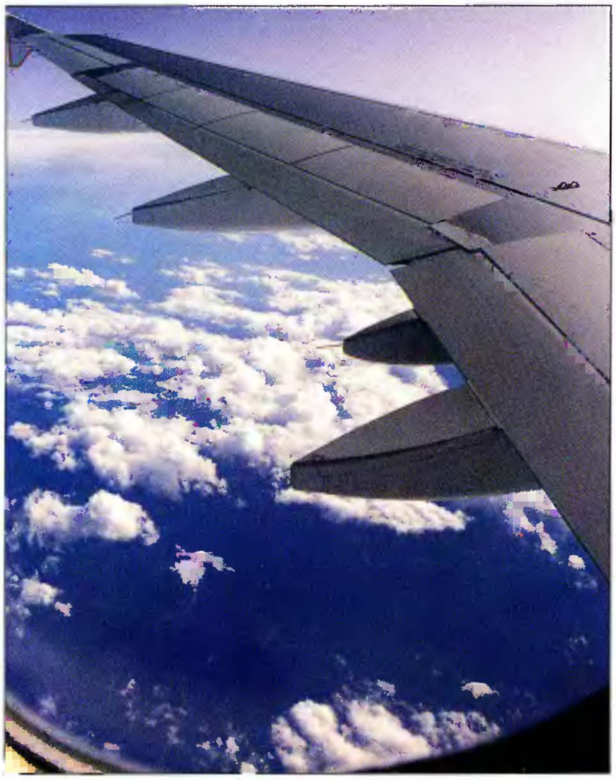
Table 1. Aircraft fuel consumption and emissions
(million tonnes)

Year	1992	2015	2040
Fuel	120	302	420
NO_x	1.3	3.0	2.4-4.4*
CO_2	380	953	1 326
H_2O	150	372	517

Note: Forecast assumes traffic growth factor of 1.0 in 1992, 3.6 in 2015 and 6.5 in 2040.

** A forecast range is given to reflect uncertainty about ability of new technology to control NO_x emissions. For other pollutants, the mid-case estimate is shown.*

Also reported to CAEP were the results of the U.K. Department of Trade and Industry long-term emissions burden studies based on forecast traffic growth rates, fleet growth, and a range of options for technology improvement, regulatory changes and operational efficiencies to the year 2040. This produced a range of emissions burdens with typical base case values for the above pollutants showing growth factors (compared with 1990) of 3.5 for fuel consumption and emissions of nitrogen oxides, carbon dioxide and water vapour.



Aircraft emissions of primary concern are injected mostly into the relatively clean upper troposphere and lower stratosphere during the cruise segment of flight.

The emissions of primary concern — carbon dioxide, nitrogen oxides and water — are injected mostly into the relatively clean upper troposphere and lower stratosphere during the cruise segment of flight. NO_x emissions are of particular concern because of their ability to increase ozone levels through catalytic action with oxygen. The effects of subsonic aircraft on climate change have yet to be fully understood, and the stratospheric emissions of a potential supersonic transport fleet also need to be considered.

These emissions could affect climate through several mechanisms. These include changes in the distribution and concentration of greenhouse gases such as water vapour, carbon dioxide and increased tropospheric ozone through NO_x emissions. Also of concern are increases to contrail and cirrus clouds through emitted water vapour and particulates and changes to aerosol concentrations through emissions of sulphur dioxide and soot. The first two effects are thought to increase global warming, while the effect of increases in aerosol concentrations may have an opposite effect. The relative magnitudes of these effects are currently under scientific scrutiny.

The industry's response has been positive. Manufacturers are meeting the envi-

Table 2. Possible operational measures

Measures to reduce fuel consumption (and hence emissions)

- ATC improvements
- Direct flights to reduce total air distance per passenger
- Optimization of climb/descent profiles in terms of fuel, NO_x or other pollutants
- Reduction of cruise speed
- Harmonization of fuel prices to prevent "tankering"
- Prohibiting short-distance sectors
- Improvement of load factors
- Airport related measures (reduced engine taxi, towing of aircraft etc.)

Measures aimed at reducing the effects of emissions

- Reducing cruise altitude
- Restrictions on flight routes
- Reducing flights in daylight
- Widening (or narrowing) of flight corridors
- Respositioning of flight corridors (to use or avoid extreme weather systems)

ronmental pressures by producing efficient aircraft with improved fuel consumption and lower emissions per seat-mile. This will slow the predicted growth of emissions but probably not be able to fully compensate for the expected growth in air travel.

Operational measures that could contribute to environmental protection fall into two distinct categories: those designed to reduce fuel consumption and emissions and those designed to reduce the effects of these emissions. However, it is most important to recognize that the two categories are strongly linked. For example, an alteration to cruise altitude may be beneficial to the atmospheric processes but is likely to result in an overall increase in fuel consumption. Similarly, re-routing away from sensitive areas of the atmosphere is likely to lead to increased fuel consumption.

Measures CAEP had considered under these two categories are shown in *Table 2.* The committee consulted widely with manufacturers, airlines and other bodies, quickly concluding that such measures had limited potential to effect a reduction in the total aircraft emissions burden.

Following is a review of the committee's findings with respect to the measures to reduce fuel consumption and, hence, emissions.

Reducing fuel consumption

Air traffic control (ATC) improvements to reduce distance flown between cities and to minimize stacking and diversions clearly would be beneficial, but the extent to which this might be achieved would depend upon harmonization of ATC systems globally.

Direct flights that bypass airline hubs, generally using smaller regional aircraft, are more common now than in the past. The environmental benefits of this practice have yet to be evaluated and, considering the loss of economies of scale offered by large aircraft, may actually be negative.

Optimizing climb emissions would have a limited impact on emissions but might have a significant noise impact around airports.

Reducing cruise speed seems an attractive option but aircraft are designed to operate at optimum speed and altitude. Altering speed or altitude could introduce serious fuel consumption and emissions increases. Flight time and scheduling implications are obvious.

Fuel price harmonization and short sector prohibition require international regulatory action, which might be difficult to achieve in a global, market-driven culture, and any benefits would be difficult to quantify.

Load-factor improvement — a popular option with environmental groups — has shown a steady increase with the advent of improved yield management techniques, but will be difficult to take beyond the 75 or 80 per cent mark (yearly average) without losing the service flexibility required by the majority of the air travelling public.

> The committee consulted widely with manufacturers, airlines and other bodies, quickly concluding that such measures had limited potential.

Airport-related measures, while offering some real environmental benefits within an airport boundary, will have no effect on the problem of emissions at cruise.

Reducing effects of emissions

Another list in Table 2 shows those measures that it is felt could reduce the effect of emissions on the atmosphere. The study included a preliminary examination of the sensitivity to moving all emissions to lower altitudes and to more northerly and southerly flight tracks. The results confirmed a link with ozone production to flight altitude and a less significant sensitivity to latitude. However, it should be noted that current data are not adequate to permit definitive conclusions.

Reducing cruise levels for contemporary aircraft is expected to increase fuel consumption and emissions, as such aircraft are designed for specific flight regimes.

Route restrictions to avoid sensitive atmospheric regions is likely to extend flight times and therefore increase emissions.

Reducing daylight flights, which could reduce ultraviolet catalysis of some emissions, has severe practical difficulties and is unlikely to yield real benefits.

The effects of widening or repositioning flight corridors to reduce emissions concentrations could not be assessed with the models available.

Next steps

Further work is clearly necessary before definitive recommendations can be made, and much of this work needs close cooperation with the scientific community. In particular, there is a need to quantify fuel consumption and engine emissions reductions along with estimates of environmental benefit and cost. And for measures implying an increase in fuel consumption and mass emissions, careful assessment of the trade-offs will be required.

It is clear that these kinds of operational measures will not offset the impact of the forecast growth in air travel. Many have limited practical appeal, but others are worthy of further study.

For those measures designed to reduce fuel burn and emissions, more detailed quantification is required, along with estimates of associated environmental benefits and cost. For those designed to reduce the environmental impact of emissions, quantification of benefits and costs also is yet to be completed. Environmental benefits will require fine judgements which are best offered by the scientific community. The development of appropriate computer models to adequately solve such problems is still in its infancy and some years from producing results. The CAEP process within ICAO is likely to be best placed to coordinate this area of work. □

This article was co-written by Malcolm O. Ralph and Peter J. Newton of the Aerospace Division of the U.K. Department of Trade and Industry. Mr. Ralph led the group of experts within CAEP that has been exploring this issue.

Lingering uncertainty about aviation's impact addressed by growing body of scientific data

A number of research efforts are under way to determine current and future levels of emissions and to gain a better understanding of the chemical and physical processes in the atmosphere that could be adversely affected by aviation.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
(UNITED STATES)

GERMAN AEROSPACE RESEARCH ESTABLISHMENT
(GERMANY)

SCIENTIFIC studies undertaken in recent years continue to suggest that aviation may contribute to detrimental chemical changes in the global atmosphere, particularly ozone (O_3) content, as well as possible climate modification. In response, the work programme of the ICAO Committee on Aviation Environmental Protection (CAEP) continues to give a high priority to consideration of standards and other measures for the control of emissions at altitudes above those associated with existing airport community regulations. And aviation is also being taken into account in the development of broad international agreements to protect the environment, particularly the Montreal Protocol on Substances that Deplete the Ozone Layer and the UN Framework Convention on Climate Change.

However, there is considerable uncertainty about the actual global effects of aircraft emissions, and much related research is being sponsored by governments and other organizations throughout the world. A database prepared by CAEP indicates that a number of ICAO member states have sponsored related investigations.[1]

Besides computer modelling of the atmosphere, these efforts include direct measurements and laboratory characterization of relevant atmospheric processes and engine exhaust chemistry, studies of wake phenomena, and development of current and forecasted emission inventories. Results of this research will serve as the basis for guidance to policy makers seeking to further protect the earth's well-being.

1. The States which have undertaken investigations are Australia, Canada, France, Germany, Japan, the Netherlands, Norway, the Russian Federation, Sweden, Switzerland, the United Kingdom, and the United States.

A complex system

An earlier concept of the atmosphere was a somewhat independent and relatively uniform entity. Today we have accepted a rapidly growing body of new scientific knowledge supporting a much more realistic concept of the atmosphere as an element of a complex system that can be affected by anthropogenic (i.e. human) activities. For example, it is important to remember that ozone is constantly being destroyed and replenished in the natural atmosphere; it is, indeed, a renewable resource like water. And before the effect of anthropogenic pollutants, an equilibrium level of ozone existed which absorbed much ultraviolet sunlight at wavelengths that can now possibly reach the surface of the earth and affect the biosphere. This system analogy can also be used to indicate the possible effects of most aircraft engine exhaust constituents or other pollutants that contribute to the chemical composition of the atmosphere.

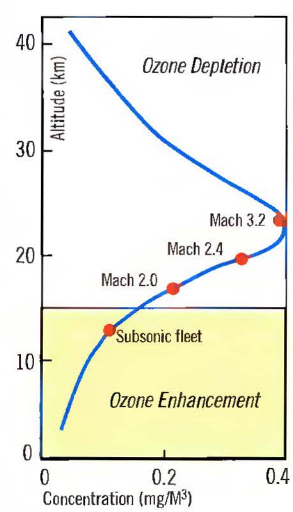


Figure 1. Typical distribution of ozone in the atmosphere and effects of aviation. The actual relationships depend on many parameters. Ozone concentration is shown for a mid-latitude.

What allows humans to have an effect on the vast atmosphere is that ozone and other important chemicals only exist naturally in trace quantities. For example, ozone occurs in quantities of one to 10 parts per million by volume (ppmv) in the stratosphere. How little actually exists in the atmosphere is demonstrated by its column abundance. If all ozone could be collected at the surface of the earth at sea level pressure, it would only be about three millimetres thick.

Therefore, the early hypothesis which predicted dire effects of oxides of nitrogen ($NO_x = NO + NO_2$) from supersonic transport (SST) aircraft on stratospheric ozone was taken very seriously and contributed to a decrease of interest in commercial supersonic technology for many years. Since more has been learned about atmospheric chemistry, it has been accepted that NO_x would likely destroy ozone generally as first predicted, but that the same emittant from subsonic aircraft would also produce ozone. The crossover point between production and destruction is generally in the lower stratosphere (*Figure 1*), near the altitude where long-range subsonic aircraft cruise.

Anthropogenic effects on climate are similarly the result of trace changes in the atmosphere. For example, all the concern about the greenhouse effect of carbon dioxide (CO_2) is the result of an increase from a level of about 280 ppmv before the industrial revolution to about 350 ppmv in 1990. Aviation today contributes about three per cent of the CO_2 produced by the burning of fossil fuels, an amount that will likely grow. In addition, aircraft engines also produce other emissions that may contribute to climate change. Water vapour is an important greenhouse gas, as is the ozone that is controlled by NO_x emissions. Because aircraft NO_x is deposited near the tropopause, many scientists believe aircraft have greater leverage on climate change than equivalent ground-level emissions. And, finally, of possible equivalent importance is particulate matter or aerosols in aircraft exhaust which may contribute to the formation of clouds that directly affect radiative processes and climate.

These, therefore, are the atmospheric processes to which aircraft contribute, and which serve as the focus of the related research. The scientific issues can be succinctly stated as:
- •What are current and future emissions from aircraft?
- •What chemical and physical processes in the atmosphere could be perturbed by aircraft emissions?
- •Are atmospheric observations consistent with the current understanding of aircraft emissions-related chemistry and physics?
- •What are the predicted ozone changes and climatic impact associated with aviation?
- •What are the uncertainties in these predictions?

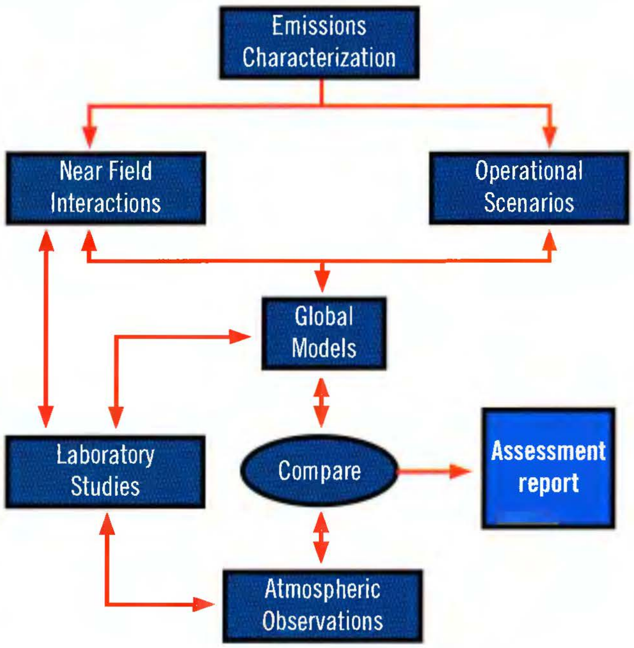


Figure 2. Interrelationship of assessment research topics.

Atmospheric research

To demonstrate how these questions are being addressed, it's helpful to review the very broad research efforts being implemented in Europe and the United States.

In Europe, many of the projects have been coordinated by the Environment and Climate Research Programme of the European Commission. The completed first phase of that effort, conducted between 1992 and 1994, was the Aeronox Project. In the United States, the major effort is the Atmospheric Effects of Aviation Project (AEAP), co-sponsored by the U.S. National Aeronautics and Space Administration (NASA) and the U.S. Federal Aviation Administration (FAA).

Although organized and managed somewhat differently, both the U.S. and European efforts include the following topics and activities, which are inter-related (*Figure 2*) for the purpose of overall scientific assessment:
- •*Emissions characterization*. Characterization of current and advanced engine emission constituents at all flight conditions.
- •*Near-field interactions*. Study of fluid dynamics and/or chemical processes in an aircraft wake which can alter properties of engine exhaust products or their deposition altitude in any way that might significantly influence their ultimate effect on the background atmosphere.
- •*Operational scenarios*. Development and maintenance of a three-dimensional (3-D) database representing all aircraft emissions along realistic flight paths for current and future operations.
- •*Atmospheric observations*. Measurement of chemical and physical characteristics of the atmosphere relevant to possible effects on ozone and climate.
- •*Laboratory studies*. Ground-based simulation and measurement of chemical and physical processes relevant to aviation.
- •*Global modelling*. Computational models of the atmosphere to evaluate chemical and physical effects.

Subsonic aircraft

Typical of research results associated with the current primarily subsonic fleets are those from the Aeronox Project, which had the specific objective of determining the impact of NO_x emissions from aircraft on the atmosphere at altitudes of 8 to 15 kilometres. To characterize emissions, altitude test chamber measurements of emissions were made at cruise conditions for modern aircraft engines, the Rolls-Royce RB211 and Pratt & Whitney Canada PW305. From these and other available data, predictive equations for NO_x emissions at cruise conditions were developed.

Studies of wake processes found that only minor chemical changes occur in the vortex regime of the emission plume. The speciation of NO_x emissions was shown to remain essentially unchanged for about one kilometre beyond aircraft engine exits, at least when the ambient air is not saturated with ice and contrails do not persist. However, related processes are very complex, and the behaviour of aged plumes has not yet been investigated. In addition, the current results do not exclude the possibility of further changes in the dispersion phase.

A global inventory of aircraft emissions, developed jointly by the European Civil Aviation Conference (ECAC) and the European Commission, was used in 3-D atmospheric models employing a variety of global simulations to investigate changes in NO_x concentration and photo chemistry. Although aviation contributes only a small amount to the global NO_x from all sources, its calculated contribution to the concentration of NO_x in the upper troposphere was shown to be large, in particular above 30 degrees north latitude. During winter months, aircraft were predicted to be the dominant upper tropospheric source for NO_x in the northern hemisphere mid-latitudes. In summer, because of stronger upward transport and lightning sources, the contribution from aviation was smaller.

The resulting atmospheric ozone change depends in a strongly non-linear manner on the NO_x concentration level. It was confirmed that, on average, NO_x emissions from subsonic aviation cause ozone increases of a few percent in the troposphere and lower stratosphere, with a maximum in the summer months. Locally, 3-D ozone concentration changes at global model grid scales showed increases of up to 10 per cent. The impact per unit of NO_x emission of these disturbances on ozone is strongest in relatively clean air. A doubling of aviation emissions in the northern hemisphere would cause less than the doubling of present aviation's contribution to tropospheric ozone increase. Results were very sensitive to the background values of nitrogen oxides, and to details of the models.

Another productive collaboration of the European Commission and member states has involved studying pollution from aircraft emissions in the North Atlantic flight corridor, a programme known as Polinat, which looks at whether model predictions can be verified. Measurement campaigns west of Ireland, using a Dassault Falcon research aircraft, were performed in November 1994 and July 1995. Another winter campaign is being prepared for early 1997, with simultaneous measurements on board a Swissair Boeing 747 flying within the corridor. Interim results from this research effort are reviewed below.

Emissions from air traffic in terms of NO_x, nitric acid (HNO_3), sulfur dioxide (SO_2), water (H_2O) and particles are clearly measurable. Some plumes exhibit peak concentrations of nitrogen oxides that are more than a factor of 10 above normal background values. Other instruments, in particular for aerosols composed of soot or sulfuric acid particles, show similar peaks reflecting various products from aircraft emissions.

Air traffic emissions cause very spotty distributions of the concentration field, especially for NO_x. Often, the corridor traffic produces accumulations in narrow "pipes" due to multiple aircraft plumes superimposing each other.

Measured concentration levels of SO_2, acetone, and particles were much higher than can be expected from air traffic emissions. Backward trajectory analyses for a particular case indicated that the pollution originated from the North American continent, south of the Great Lakes, and was brought to these altitudes by strong upward motion occurring days before the measurements.

Tropopause variability is very high. A considerable fraction, more than 70 per cent, of the emissions west of Ireland in November 1994 occurred above the tropopause in the lower stratosphere.

It was possible to measure water vapour at a high accuracy level to clearly identify the relative saturation of air with respect to ice. Large-scale persistent contrails were observed under these conditions.

Meteorological data from the European Centre for Medium Range Weather Forecasts (ECMWF) model were found to describe very accurately the structure of the weather systems encountered by the Falcon during the measurement campaign.

The Aeronox Project has raised a number of questions related to emissions, transport and chemistry, climate, and validation. These include the following:

- What are the emission rates for NO_x from sources other than aviation, in particular from lightning?
- What are the effects of emission conversions in exhaust plumes from the end of the vortex regime to scales resolvable by global models?
- What are the effects of exchange between the troposphere and stratosphere?
- How do aircraft emissions affect climate?
- Can the computed changes in air chemistry resulting from aviation be validated by comparison to observed concentration?
- Are climate models adequate for chemistry coupled studies?

Several other projects (*Table 1*) which address these questions are currently sponsored by the European Commission, or have been proposed within other programmes. The same questions are being addressed in the subsonic assessment (SASS) element of the American AEAP effort and other worldwide research. For example, a series of atmospheric measurements are planned in April and May 1996 to study the effects of aircraft emissions on radiative processes. Utilizing Douglas DC-8 and Lockeed ER-2 aircraft as instrument platforms, the SASS-sponsored measurements will seek to determine the effect of contrails on the earth's radiation budget; the effect, if any, of aircraft exhaust on ambient cirrus cloud; and whether aircraft emit enough soot or sulfate to be radiatively significant.

Other SASS observational efforts will seek to define the natural budget for NO_x, a major underlying question of tropospheric science.

Supersonic aircraft

The major results of AEAP have been associated with its study of atmospheric effects of stratospheric aircraft (AESA), an element of the programme that began in 1990, whereas SASS was initiated several years later in 1994. AESA is studying the effects of a proposed fleet of advanced supersonic transport aircraft (see "Design of next-generation supersonic transport must address a number of environmental concerns," page 15) on stratospheric ozone and climate change. Results of a recent AESA assessment reported in 1995 indicate that the amount of stratospheric ozone is determined by photochemical production and loss processes (as noted above), and by the transport of air throughout the atmosphere. Atmospheric measurements show that photochemical loss of ozone is dominated by catalytic reactions involving NO_x, hydrogen oxides (HO_x), and halogen radicals, specifically chlorine oxides (ClO_x) and bromine oxides (BrO_x). Heterogeneous (i.e. multiphase) reactions which occur on or in stratospheric aerosol particles play an important role by reducing the ozone loss resulting from NO_x and increasing that due to HO_x and halogens. Atmospheric circulation determines the time spent by air in regions of photochemical loss and the distribution of exhaust gases emitted by a fleet of aircraft. Most recently, it has been conceptualized from some observations that transport of air between mid-latitudes and the tropics is restricted, especially between altitudes of 20 to 28 kilometres. Without such a restriction, transport of air from the primary flight corridors at mid-latitudes into the tropics may result in a more rapid spread of exhaust

Table 1. Various European projects

AEROCHEM
Assess 3-D chemical impact of past, present and future subsonic/supersonic aircraft on the atmosphere by means of global chemical transport models.

AEROCONTRAIL
Formation, growth, and evaporation of contrails; microphysics, interaction with aerosols and cirrus clouds, effects on radiation budget and climate.

AEROJET
Non-intrusive measurements of aircraft engine exhaust emissions. Exhaust gas measurements in the jet regime of an Airbus A340 by on-board FTIR-Mirror, FIR-Heterodyne, imaging IR radiometer.

AEROTRACE
Measurement of trace species in the exhaust from aero-engines. Provide quantitative data on the emissions of trace species from aircraft engines over the entire flight cycle, using available and established on-line and off-line analytical techniques in combination with gas sampling; measure particulates, nitrogen species, speciated hydrocarbons; assess fuel quality.

MOZAIC
Measurement of ozone and water vapour on Airbus in-service aircraft. Evaluation of aircraft impact on the atmosphere by improving scientific basic knowledge through *in-situ* measurements on five A340 aircraft.

STREAM
Stratosphere-troposphere experiments by aircraft measurements. Future activities will include modification of an Airbus A340 to serve as global atmospheric research platform.

from the lower to upper stratosphere, where the catalytic destruction of ozone by NO_x is more efficient.

Five two-dimensional (2-D) photochemical models were used to calculate the impact of a supersonic fleet for a variety of cases, including sensitivity tests for the emission index (EI) of NO_x — expressed as grams of equivalent nitrogen dioxide (NO_2) per kilogram of fuel burned. Other factors involved in the calculation were cruise altitude, background atmospheric chlorine amount and fleet size. Individual models were used to test sensitivity to a variety of effects not included in these basic predictive calculations. The range of model results is shown in *Table 2*. Conditions include a baseline fleet of 500 aircraft capable of operation at Mach 2.4 and consuming 8.2 x 10^{10} kilograms of fuel per year in an atmosphere with a background stratospheric aerosol amount equivalent to a relatively clean period between major volcanic eruptions. The calculated changes in ozone result from a decrease in the middle and upper stratosphere and an increase in the lower stratosphere and troposphere.

Table 2. Calculated steady-state total column ozone change

Scenario				2-D model results
Mach number	Cl_y (ppbv)	EI_{NO_x} (g NO_2/kg fuel)	Fleet size	Ozone change (%)[a]
2.4	3	0	500	-0.3 to -0.1
2.4	3	5	500	-0.3 to +0.1
2.4	3	5	1000	-0.7 to +0.03
2.4	3	10	500	-0.5 to 0.0
2.4	3	15	500	-1.0 to -0.02
2.4	3	15	1000	-2.7 to -0.6
2.4[c]	3	5	500	-0.5 to +0.02
2.4[d]	3	5	500	-0.06 to +0.1
2.4	2[b]	5	500	-0.4 to +0.02

Northern hemisphere, averaged over one year for several supersonic fleet scenarios
(a) Range of average values obtained from the five 2-D models used in this assessment
(b) Expected in a 2050 atmosphere. (c) Cruise + 1 km (d) Cruise -2 km

The significant time required for photochemistry and transport to effect these ozone changes precludes large ozone changes near the assumed flight corridors. The emission index of NO_x (EI_{NO_x}) values in Table 2 reflect those expected for future combustors (five grams of NO_2 per kilogram of fuel) and those closer to current engines (15 g/kg).

To improve simulation of the aircraft in the computer models, ***in situ*** aircraft exhaust sampling experiments and modelling of engine processes, including dilution of exhaust gases in the atmosphere, are being used to define the important chemical and dynamical features of exhaust plumes. In particular, measurements of reactive nitrogen (NO_y) species, condensation nuclei (CN) and CO_2 were made recently in the exhaust of a Concorde SST and a NASA ER-2 subsonic aircraft while in flight. The emission indices were calculated independently of plume dynamics because measurements of CO_2 provide a measure of fuel consumption. The measured NO_x is very close to results deduced earlier from altitude chamber measurements of exhaust from the Concorde Olympus engine. These results suggest that the methodology developed to calculate the emission index of NO_x at cruise using altitude chamber data will be appropriate for evaluating new aircraft engines.

Observations show that NO_x is the most abundant reactive nitrogen (NO_y) species in both supersonic and subsonic aircraft plumes. The presence of only a small percentage of nitric acid (HNO_3) and nitrous acid (HONO) is in agreement with observations of HO_x in the plume and theoretical model calculations. However, the large number of detectable particles in the Concorde plume conflict with the results of plume models that predict a small fractional conversion of SO_x to condensed sulfate in the form of extremely small particles that ultimately coagulate with larger background sulfates. These results indicate that the current understanding of plume chemistry and particle formation processes is not complete. If new supersonic aircraft produce particles at a rate comparable to the Concorde measurement, significant increases in particle number and surface area could occur in the lower stratosphere of the northern hemisphere. Including these increases in predictive models could change calculated ozone and climate impacts from a fleet.

Sulfur emitted by a fleet of supersonic aircraft could especially increase the aerosol surface area throughout the lower stratosphere. And although the increase in surface area is predicted to decrease the impact of NO_x emissions (i.e. through catalytic conversion to HNO_3), it also could increase ozone loss because of the existing chlorine and hydrogen radicals in the stratosphere. If the emitted sulfur immediately formed small, long-lived particles in the plume, the global increase in sulfate surface area would be maximized. A model that included aerosol processes was used to calculate ozone changes when all of the sulfur was emitted as small particles into a volcanically unperturbed stratosphere. The change in total column ozone from the injection of small particles depends in a complex way on the emission index of NO_x and the amount of background chlorine. For EI_{NO_x} equal to five grams per kilogram of fuel, the calculated ozone depletion increased when small particles were formed, the overall perturbation becoming as large or larger than that for the EI_{NO_x} of 15 grams/kilogram fuel case, without the consideration of sulfur. Thus, further study of the effects of fuel sulfur are planned.

> If all ozone could be collected at the surface of the earth at sea level pressure, it would only be about three millimetres thick.

Major investigation of climatic effects has been deferred in the stratospheric element of the U.S. project until the controlling ozone chemistry is better understood. But a general circulation model was first used in the recent assessment to calculate the global surface air temperature and stratospheric temperature responses to predicted changes in ozone and water vapour from a fleet of supersonic aircraft with the emission index of NO_x at 15 grams of NO_2 per kilogram of fuel. Since the resulting changes in temperature are smaller than the climatic fluctuations in the model, they likely would not be detectable in the atmosphere. Climate effects due to sulfur and soot emissions, while likely to be small, have yet to be evaluated. Formation of persistent contrails from supersonic aircraft is expected to be infrequent, but additional particles in the exhaust might subside into the troposphere and contribute to cloud formation.

Several classes of uncertainty are associated with predictions of the possible impacts of future supersonic transports made with 2-D models, as shown in Table 2. Uncertainties in some model parameters can be readily quantified and evaluated directly with the models. Other sources of uncertainty have been identified but not yet quantified. Finally, uncertainty from the possibility of missing processes or major errors in our understanding cannot be quantified, but only discussed in terms of the overall confidence in the assessment. However, the probability that important processes have been overlooked decreases as we continue to explore perturbations with models and continue to challenge these models with atmospheric measurements. The primary methodology for improving predictive capability will continue to involve testing model representations of the atmosphere through comparison with observational data. Substantial progress in that direction will be realized in the near term by systematic comparisons with recent data from satellite-based measurements as well as ***in situ*** and remote sensing from the ER-2 aircraft and balloon platforms.

International scientific assessments and ICAO's role

As reported to the third meeting of the CAEP in December 1995, ongoing research indicates that although progress is being made in understanding the environmental

continued on page 25

This article was co-written by Howard L. Wesoky of the Office of Aeronautics at the National Aeronautics and Space Administration, Washington, D.C., and Ulrich Schumann and Dietmar Wurzel of the German Aerospace Research Establishment (DLR). Mr. Schumann is based at Oberpfaffenhofen, Germany and Mr. Wurzel at Washington, D.C.

Design of next-generation supersonic transport must address a number of environmental concerns

Since its inception in 1990, the High-Speed Research Programme has gathered data on the potential impact of a future fleet of supersonic aircraft. It has also sought technological solutions to three major environmental challenges: emissions, noise and sonic boom.

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MARKET studies indicate that growth on long-haul routes will provide a large potential market for a new supersonic airliner. Technology holds the key to successful introduction of a cost-effective aircraft that will capture a large share of that market. A research programme launched by the U.S. National Aeronautics and Space Administration (NASA) and U.S. aerospace industry envisions a Mach 2.4 aircraft which will accommodate 250 to 300 passengers on long-haul oceanic flights with a range of at least 5,000 nautical miles (9,260 km).

However, before any next-generation supersonic airliner can near take-off status, assurances of environmental compatibility will be required. Success in environmental areas will be necessary to achieve social acceptance and certification, and each area requires substantial dedicated work before achieving success. This is where NASA has focused considerable effort. Since its inception in 1990, NASA's High-Speed Research (HSR) Programme has worked to develop a better understanding of the potential impact of a future fleet of supersonic aircraft and also to develop the technological solutions to ensure environmental compatibility.

The High-Speed Research Programme environmental goals have been focused on three major issues: airport community noise, atmospheric effects, and sonic boom. Recently, research and studies on radiation characterization and prediction have been initiated.

The primary environmental concern relative to a large supersonic transport (SST) fleet operating in the stratosphere is the possibility that engine exhaust products could change the chemical balance and cause appreciable ozone depletion. This issue has been given highest priority in the HSR Programme and, as a result, the Atmospheric Effects of Aviation Programme (AEAP) was created to establish a scientific basis to assess the atmospheric effects (i.e. both chemical and climatic) of aviation, particularly emissions from commercial aircraft engines. (For more on this programme, see "Lingering uncertainty about aviation's impact addressed by growing body of scientific data," page 11.)

The assessment of the atmosphere is being accomplished by conducting *in situ* measurements of atmospheric contaminants and ozone using high-altitude research aircraft and remotely piloted vehicles and by developing high-fidelity atmospheric simulation models based on those measurements. Operational scenarios regarding projected fleet size and routes have been developed and, in conjunction with enhanced atmospheric models, are used to predict the impact of future aircraft fleets on the atmosphere. In consonance with the AEAP activities, the HSR Programme is developing combustor technology with an established goal of reducing engine exhaust to an emissions index of five grams of oxides of nitrogen (NO_x) per kilogram of fuel burned.

With respect to airport community noise, the HSR Programme goal is the achievement of noise levels as quiet as new subsonic transport aircraft compliant with noise limits contained in ICAO Annex 16, Chapter 3. To meet these noise standards, a future high speed civil transport (HSCT) needs a near 20-decibel improvement relative to first-generation Concorde technology — in effect, a 75 per cent decrease in perceived loudness. The objectives of HSR Programme noise research and studies has been to determine the feasibility of technological compliance with the existing subsonic limits in Annex 16.

Airport community noise studies have been completed which reflect the operation of generic HSCT aircraft using standard subsonic aircraft procedures as well as proposed advanced operational procedures to evaluate the HSCT aircraft community noise impact. Information concerning projected aircraft operations as well as current subsonic aircraft traffic patterns and day-night loudness contours have been estimated at several major international and noise-sensitive airports. These airports reflect easy over-water access, such as at Los Angeles, as well as airports which require considerable flight over a populated area, such as London Heathrow.

To meet Chapter 3 noise limits, a future supersonic airliner would need a near 20-decibel improvement relative to the Concorde — in effect, a 75 per cent decrease in perceived loudness.

A series of wind tunnel tests was conducted recently at NASA's Ames Research Center to assess the noise and thrust performance of an integrated airframe and engine/nozzle configuration. The objectives of these high-lift engine aero-acoustic technology tests were to measure the change in jet noise reduction effectiveness for an HSCT noise suppression nozzle mounted in close proximity to a high-lift wing and also the engine/nozzle power effects on the high-lift system.

Progress in noise reduction has been encouraging. Multidisciplinary research efforts have shown that the Chapter 3 noise limits may be achievable with a combination of advanced engine cycle and nozzle designs, advanced acoustic liner materials, aircraft high-lift devices and specialized operational procedures. Each of these specific technologies has drawbacks as well as advantages which must be assessed individually and as an integrated configuration.

Achieving the Chapter 3 limits poses a significant challenge for future supersonic airliners. Based on wind tunnel testing and analytical methods, the effects of meeting the Chapter 3 limits still result in a substantial increase in take-off gross weight — on the order of seven to 14 per cent. This weight increase, of course, directly translates into increased acquisition and operating costs. It becomes evident that any reduction in sideline noise beyond Chapter 3 would exact an increasingly larger penalty in vehicle weight and cost.

Sonic boom alleviation has been addressed in the HSR Programme. Research has shown that the intensity of the sonic boom signature can be reduced by altering the distribution of aircraft volume and cross-sectional area. Although proposed methods to eliminate the boom entirely have been investigated, obtaining a viable solution is very elusive. Emphasis in HSR sonic boom research has shifted to determining the magnitude of sonic boom softening possible without incurring unacceptably large performance penalties. Also, research has been conducted to determine the atmospheric propagation of the sonic boom to determine operational corridors and procedures and the potential impact on marine mammals. The present programme view is that an HSCT will operate supersonically only over water and subsonically over land.

The substantial uncertainties in the knowledge of the radiation environment at the projected HSCT flight altitudes and the biological response to that environment are being addressed as part of the HSR commitment to assessing the impact of environmental concerns. NASA is working with the National Council on Radiation Protection and Measurements (NCRP) to identify critical scientific research that must be accomplished in order to provide a sound scientific basis for determining atmospheric radiation exposure. The HSR Programme is implementing a dedicated flight test programme, using high-altitude research aircraft, to conduct *in situ* measurements to quantify the ionizing particle field components in the atmosphere as a function of latitude and longitude and at altitudes between 50,000 feet (15,240 m) and 70,000 feet (21,340 m), which will provide a database for refining and validating environmental radiation models.

The HSR Programme embodies an environmental research effort which addresses the four major environmental concerns for future supersonic airliners. The data produced will enable a knowledgeable decision by industry regarding production of a high-speed civil transport that is both economically viable and environmentally compatible. □

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Aggressive and proactive campaign has resulted in improvement in environmental performance

Qantas Airways is in the process of implementing an environment management system that is proving effective at addressing an array of environmental challenges and regulatory requirements.

VINCE CHAPLIN
QANTAS AIRWAYS LTD.
(AUSTRALIA)

SIGNIFICANT technological improvement in aircraft engine noise and emissions performance seem unlikely in the near future, but there is at least one way that airlines today can reduce their adverse impact on the environment. In Qantas' experience, considerable improvement is possible through a systems approach to managing environmental issues on the ground.

Qantas first adopted an environment policy in 1991. The policy was designed to challenge various departments at the airline to consider their activities in terms of newly implemented environmental regulations. There was still the question, however, of how to change the culture of the company to incorporate a new responsibility for environmental protection into everyday operations. The answer was to raise the profile of the environment by identifying corporate opportunities that would also be of benefit to the environment (an example is the financial saving that could accrue from conserving resources and reducing waste disposal costs), and by analysing the company's strengths and weaknesses from an environmental perspective. The airline was able to capitalize on a groundswell of environmental consciousness pervading Australian society, but a weakness was the lack of an appropriate model to pull all of its efforts together into a cohesive and proactive system.

Which standard to use?

In 1992, the British Standards Institution (BSI) released its BS7750 specification for environmental management systems, following the development of a draft European Community environmental regulation the previous December. Various compliance-based models were also available from the United States. For Qantas, it was a matter of evaluating and adopting one of these models.

The BSI specification was criticised for its prescriptiveness, the European scheme for its dissimilarity with the problems in Australia, and the U.S. model for what was perceived as too narrow a focus, given that country's predilection for litigation. So Qantas based its initial development of an environmental management system on early drafts of the U.K. specification, on the understanding that it would be similar to what was being developed by the International Organization for Standardization (ISO).

The airline compiled a draft environmental manual, and established a committee with representation from key departments. A series of environmental audits of hangars and workshops was undertaken to identify infrastructure projects that needed capital improvements, and these environmental "hot spots" were monitored by the Environment Committee through to completion.

One of the first projects to be identified was the requirement for a separate drainage system for the capture of liquid wastes from undercarriage cleaning, paint stripping and aircraft washing. Many new hangars had these drains built in, but older ones required retrofitting, which mandated more underground collection tanks and upgraded waste treatment facilities to accommodate the larger volumes.

A liquid recycling centre was established for segregating chemicals that had been used in the process of aircraft maintenance. This centre, itself a recycled shipping container, was adapted to form a safe repository for solvents, paint strippers, hydraulic fluids, fuel and oil. Personnel (quickly nicknamed "Toxic Avengers") were seconded from Engineering to facilitate the process of hazardous waste disposal. A significant benefit from this process was the decrease of monthly liquid waste disposal costs to U.S. $20,000 from close to $100,000.

Chemicals storage also posed a significant problem. To provide secondary containment in areas where fluids were stored, modified shipping containers with sealed floors were placed at strategic locations around the maintenance base to satisfy the basic tenet of any successful environmental management system — ease of use.

Recycling of inflight waste items such as aluminium cans, glass bottles and plastic is under way on many flights within Australia, and the system is now being expanded to international routes with the implementation of glass bottle recycling.

In addition, there are numerous other recycling projects around the company, including recycling of office paper and cardboard, laser printer toner cartridges, aluminium cans, glass bottles and shrink wrap plastic from freight areas.

Also, Qantas is using recycled products in office paper, toner cartridges and typewriter ribbons, and recycled paper in baggage tags, passenger boarding passes, packaging material and a host of other end uses.

Employees back effort

The Environment Committee also helped establish a regular column in the staff newspaper dealing with environmental matters. The paper's Environment Corner quickly proved to be a popular way of providing information on how employees were improving environmental performance in different departments. It recognized people genuinely trying to reduce environmental impact.

Presentations on subjects as diverse as energy-efficient design, waste management and total life-cycle analysis were given to numerous departments to further improve their performance and cut costs.

A brochure was developed in 1994 to provide bite-sized amounts of information to staff and passengers about the company's environmental performance. The brochure proved exceedingly popular. The airline is now considering publication of a more detailed annual environment report to further promote its performance in this area.

Flight attendants undergoing initial training are briefed on environmental matters associated with airline operations. This allows them to answer questions about engine emissions and inflight waste recycling

Last year Qantas Airways implemented an environmental management system. The company's entire fleet complies with ICAO Chapter 3 noise and emissions levels, another achievement reached in 1995. *Boeing photo*

which are sometimes asked by concerned passengers. Crew training also covers measures in other areas of the company's operations as well as details of sponsorships or cooperation agreements with environmental groups. Line management receives training in occupational health, safety and environment management, and the response overall has been enthusiastic and supportive.

The strategy behind Qantas' approach to managing its environmental impact is to strive for continuous improvement. It is a familiar approach in areas of Qantas' operations that are already in conformance with ISO 9001 — a model for quality assurance in design, development, production. installation and servicing.

With the identification and rectification of many potentially polluting activities, the challenge remains to improve on the existing documented procedures to embrace all of the elements of ISO 14001, which addresses environmental management systems (but has not yet been published as an international standard). The Catering Department already has auditable safety and environmental elements within its quality accreditation to ISO 9000. Engineering procedures are also being updated to reflect what actually is being done to prevent pollution.

Review process comprehensive

The first of several core elements to Qantas' environmental management system approach is a review of environmental aspects and impacts, further enhanced by an external environmental audit of 16 major sites that was completed prior to the airline's privatization. This led to the identification of issues to be addressed in various areas such as engineering, maintenance, catering and freight operations.

Other core elements of the environmental management system address legal requirements, objectives, and the establishment of environmental management programmes.

The primary objective of the environmental management system is compliance with government regulations, but there are also potential savings to be achieved in the reduction of waste and in reducing water and energy consumption.

A programme is being developed for achieving these objectives in airline operations that could affect the environment. It consists of the following elements:

- raising general environmental awareness;
- establishing a monitoring regimen for pollution control equipment, underground storage tanks, stormwater quality and other environmental aspects, including maintenance of records of steps taken to rectify deficiencies;
- developing a computerized accident/incident reporting system; and
- adopting strategies to reduce waste, as well as conserve energy and water.

Last year a special committee of the board of directors was established which meets quarterly to review progress in managing environmental aspects of the airline's operations. The environment section of the committee's report typically covers developments in aircraft noise and emissions certification standards, noise issues at various airports, implementation of the environmental management system standard, environmental audit follow-up, management of contaminated sites and incidents, and efforts to minimize waste.

Environmental awards

Regardless of the achievements to date, the challenge remains to continue down the path of implementation towards possible ISO 14001 accreditation, a specification for environmental management systems.

In 1995, Qantas won an award from Flight International magazine for its efforts in the environmental area, a development testifying to our efforts in not only implementing the environmental management system but also for having reached an entirely Chapter 3 compliant fleet in the same year. Local recognition came in the form of an award from the Botany Business Enterprise Centre for our environmental measures at the site of Qantas' head office and major maintenance base.

On another front, Qantas was instrumental in securing a 1995 environmental tourism award for an Australian travel agency which, having operated a series of Antarctic charters with Qantas as the carrier, prepared a rigorous series of pre- and post-activity reports on the potential and actual environmental impact of the charter flights. □

Mr. Chaplin is Environment Operations Controller in the Safety and Environment Department of Qantas Airways Ltd., Sydney.

Proposed take-off noise abatement procedures demonstrate potential to mitigate problem

New noise abatement procedures developed by CAEP specify boundaries that give operators the flexibility to tailor procedures to meet the requirements of different airports, thereby providing maximum noise alleviation at all sites.

THOMAS L. CONNOR
FEDERAL AVIATION ADMINISTRATION
(UNITED STATES)

NEW take-off noise abatement procedures were proposed in a recommendation arising from the third meeting of the ICAO Committee on Aviation Environmental Protection (CAEP).

These new procedures, already in use in one country, comprise a "close-in" procedure intended to alleviate noise close to the runway, and a second procedure which is intended to be used when a noise sensitive area exists further from the runway.

The current operating procedures for take-off, which were designed to ensure that the necessary safety of flight operations is maintained while minimizing noise exposure, were approved by ICAO in 1982 and can be found in Volume I of ICAO Document 8168 (PANS-OPS), which describes procedures for air navigation services related to aircraft operations. The document defines two procedures: Procedure A is intended to provide noise relief during the latter portion of the take-off, and Procedure B is for noise relief close to the airport.

The proposed new procedures define boundaries for thrust and speed profiles after lift-off that, in common with existing procedures, are aimed at achieving noise reduction either close to, or more distant from, the runway end. Specifying boundaries allows operators the flexibility to design procedures appropriate for maximum noise alleviation at different airports. The present PANS-OPS procedures prescribe specific flight profiles that do not allow such flexibility, but which nevertheless fall within the limits of the proposed procedures and could continue to be used where appropriate. The consistent use of the new procedures has been shown to provide significant mitigation of the noise problem in comparison with consistent use of the present PANS-OPS procedures.

The recommendation arising from the December 1995 meeting of CAEP came as the result of a three-year effort by a group of technical experts representing the aircraft manufacturers (the International Coordinating Council of Aerospace Industry Associations), airlines (International Air Transport Association), pilots (International Federation of Air Line Pilots' Associations), airport authorities (Airports Council International) and from CAEP-member states. The objective of this technical group was to identify operational strategies that could effectively mitigate aircraft noise as part of an overall plan to prevent the increase of noise around airports. In this work, all aspects of safety were considered, examined and reported.

An initial activity was to collect information on existing noise abatement procedures. Several sources of pertinent information were contacted. Questionnaires were constructed with the intent to obtain the information on current and prospective noise abatement procedures, including costs and benefits. The survey findings, along with the analyses, presentations and discussions, focused the deliberations of the technical group toward achieving the objective. A wide variety of ideas on noise abatement approach and departure procedure schemes were addressed including two-segment approach, steeper glide slopes, manoeuvring, and variations in flap and engine-thrust management. The role of automation on the flight deck and its relationship to noise abatement were thoroughly examined. Through it all, the technical group tried to assess the potential benefits of these schemes along with the safety, operational and workload implications. The expertise of the industry representatives was invaluable in this effort.

The recommended new procedures for close-in and distant noise abatement prescribe the minimum operating conditions of flaps, thrust and speed management to achieve optimum noise abatement. The procedure for noise abatement close to the end of the runway consists of the following general operating segments (see *Figure 1*):

1. Lift off and climb to at least 240 metres (800 ft) above the aerodrome elevation.
2. Reduce engine thrust to no less than the level to maintain the final take-off engine-out climb gradient.
3. Retract flaps or slats on schedule.
4. At 900 metres (3,000 ft) above the aerodrome elevation, accelerate to en-route climb speed and transition to normal en-route climb procedures.

The procedure for noise abatement at some distance from the runway consists of the following general operating segments (see *Figure 2*):

1. Lift off and climb to at least 240 metres (800 ft) above the aerodrome elevation.
2. Initiate flap or slat retraction.
3. Reduce engine thrust to no less than the level to maintain the final take-off engine-out climb gradient.
4. At 900 metres (3,000 ft) above the aerodrome elevation, accelerate to en-route

Figure 1

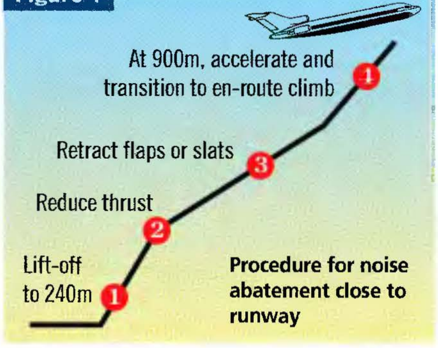


Figure 2

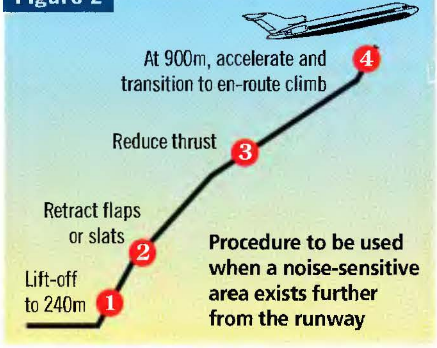
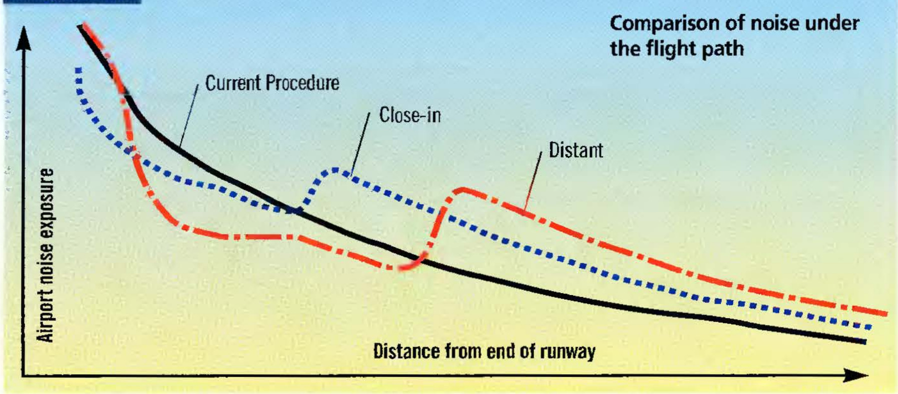


Figure 3



climb speed and transition to normal en-route climb procedures.

Under both procedures, if the aeroplane is equipped with an operational automatic thrust restoration system (ATRS) the thrust reduction may be that which would maintain, without any intervention, a minimum climb gradient of 0 per cent in case of the loss of power in an engine. An automatic thrust restoration system is a certified device which, in the event of an engine failure, directly increases the thrust of the remaining engine(s), or is a combination of warning, guidance and automatic control intended to provide an equivalent level of safety to the aircraft. The use of the automatic thrust restoration system is possible in this context on the condition that the system will, at a minimum, restore sufficient thrust to maintain the final take-off engine-out climb gradient.

ATRS was a special focus of the technical group's work. The issues included viability, airworthiness and the extent of noise benefits. Presentations by some manufacturers clarified the various thrust restoration technologies and strategies. The manufacturers' data, along with noise studies, helped in the decision to include ATRS in the proposal.

To encourage safe, standardized procedures, the technical proposal was modified at the CAEP meeting to incorporate operational guidelines. The guidelines include the following:
(1) For each procedure, the aircraft operator should specify the altitude above field elevation at which thrust reduction from take-off thrust or aircraft configuration change, excluding gear retraction, is initiated; (2) Each aeroplane operator should limit the number of noise abatement procedures for any aircraft type to no more than two; (3) Each operator is encouraged to use the appropriate noise abatement procedure when an airport operator requests its use to abate noise for either a close-in or distant community; (4) The noise abatement procedures should not be construed to affect the responsibilities and authority of the pilot-in-command for the safe operation of the aircraft.

Noise abatement through aircraft flap and engine-thrust management schedules effectively shifts noise away from one area to another. Substantially reducing engine thrust and therefore noise over a sensitive area will almost always entail increasing noise over other areas as a result of the reapplication of engine power to the climb condition. *Figure 3* demonstrates this shifting of noise in a hypothetical example. The close-in and distant procedures are most effective at airports with distinct population centres and abundant noise-compatible land areas. These procedures are least effective at airports in heavily urbanized settings with a uniformly distributed population.

The take-off noise abatement procedures offer potential noise benefits not fully realized when only examining airport noise contour maps. For some aeroplane types that conform with the noise levels in Chapter 3 of ICAO Annex 16, the use of the procedures provides the opportunity for negotiations between the airport authorities and the airlines to substantially reduce single event noise levels at critical noise-monitoring locations. The lower noise level could open access to airports and allow for reduced landing fee penalties where restrictions or penalties are imposed because of the local-use criteria.

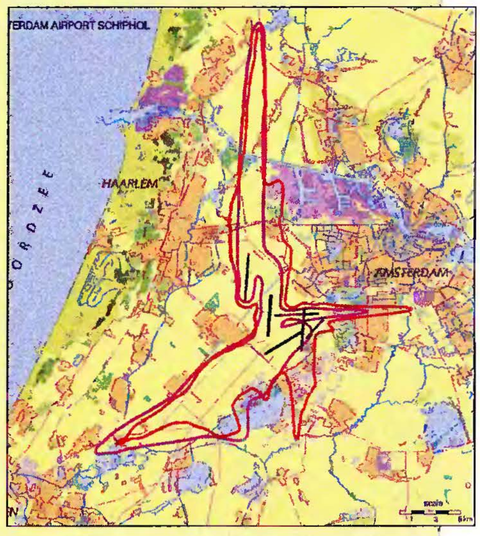
While demonstrating significant noise reductions for the current production Chapter 3 aircraft, the effectiveness of flap and engine-thrust management is expected to diminish with future generations of higher bypass jet aircraft. Noise can also be shifted from populated areas by preferred routing, with the benefits maximized through advances in air navigation technologies. Future technological advances in satellite navigation, flight management and air traffic management, along with analytical tools to determine minimum noise routes, offer excellent potential to reduce the impact of airport noise. Even without the new navigation technologies, the prospect for benefits is good through the dissemination of effective practices. □

Mr. Connor is the Manager of the Technology Division in the Office of Environment and Energy at the U.S. Federal Aviation Administration, Washington, D.C, and is also a rapporteur on noise issues for the ICAO Committee on Aviation Environmental Protection.

New land-use planning guidance material would review possible solutions to problem of noise

A.J. KOPPERT
DIRECTORATE-GENERAL OF CIVIL AVIATION (KINGDOM OF THE NETHERLANDS)

NOISE ZONES AT SCHIPHOL AIRPORT



The contour areas shown in this illustration of noise zones at Amsterdam's Schiphol Airport represent the contours for 35 Kosten units (Ke), indicated in red, and for a special night noise index of LAeq 26 decibels (indoors), to apply after the new fifth runway comes into operation in 2003.

In the Netherlands, different types of noise indices apply to various categories of aerodromes. For smaller airports, noise zones are calculated for the noise index known as Bkl, with a limit value of 50 decibels (dB), to be adjusted to 47 dB in 2000. For larger airports and military air bases, noise zoning is based on the Kosten method. The legal outer boundary for land-use planning purposes is 35 Ke.

The Bkl method includes weighting factors for day, night and weekend operations, which are calculated over the busiest six-month period. The Kosten formula was derived as the relationship between the average amount of annoyance and the number of aircraft movements in a year, the corresponding maximum sound pressure level and a weighting factor for the time of day.

A special night noise index was implemented at Schiphol in 1994 because the Kosten method of designating noise zones was not considered appropriate for predicting the effect on people's health in relation to nighttime operations. The LAeq noise index is also in effect at other airports in the Netherlands with night operations.

LAND-USE planning is considered an essential element in any strategy to control noise around airports, even though there is an accelerating trend toward quieter aircraft.

Although the noise exposure around airports will generally decrease with the phase-out of noisier aircraft, many experts anticipate that this development will eventually be offset at many airports by growth in air traffic. Since there is little prospect of a further significant reduction in aircraft noise, it would be difficult to maintain the status quo, particularly at airports without noise constraints.

The expected rise in traffic volumes, with consequent pressure on airports to expand capacity, has raised concerns about the impact on areas surrounding airports. Some governments and airport authorities as well as international aviation organizations have already drawn attention to the problem and have been urging preventive measures.

This concern is behind a decision by the ICAO Committee on Aviation Environmental Protection (CAEP) to review the usefulness of ICAO guidance material related to noise exposure around airports. Where necessary, CAEP has been updating this documentation in an endeavour to assist authorities in choosing appropriate responses to the problem.

At its third meeting, last December, the CAEP adopted a recommendation to the ICAO Council to amend guidance on land use and environmental control found in Part 2 of the ICAO Airport Planning Manual. It also recommended that ICAO promote awareness of the need for land-use control among contracting states.

Not a new challenge

The Airport Planning Manual first addressed the role of land-use planning more than two decades ago. "The compatibility of an airport with its environs is an ideal which can be pursued by proper planning of the airport, control of pollution-generating sources and land-use planning of the area surrounding the airport," the manual states. "The aim is to provide the best possible conditions for the needs of the airport, the community in the surrounding area and the ecology of the environment."

This ideal situation has still to be realized in many cases.

A CAEP survey of land-use measures and policies in various countries has found that no specific strategy prevails. This being the case, three key measures are recommended:

- surveys of areas around airports;
- definition of the zones associated with different noise levels, with criteria for the appropriate use of land;
- implementation of legislation or regulations and policies to ensure that all new developments comply with these criteria.

The amendment to the planning manual would provide guidance on various means for controlling the use of land around airports. The effectiveness of such controls for existing and new airports, or those under development, should be considered separately for each application.

Land-use control systems may be categorized as (a) planning instruments; (b) mitigating instruments; or (c) financial instruments. If endorsed, the amendment would provide authorities with guidance on the effectiveness of the instruments in these three categories.

A detailed plan

One particularly effective approach would be a detailed, comprehensive plan which could serve as a guide to local land-use decisions and the development of controls such as noise zoning, capital improvements planning, subdivision regulations and environmental reviews.

continued on page 25

Mr. Koppert is in the Airport Planning and Environment Section of the Directorate-General of Civil Aviation in the Kingdom of the Netherlands.

ICAO UPDATE

ICAO to investigate shooting down of civil aircraft

ICAO has initiated an investigation into the shooting down of two U.S.-registered civil aircraft by Cuban military aircraft on 24 February 1996. The investigation is being undertaken at the request of Cuba, the United States and the United Nations Security Council.

The ICAO Council adopted a resolution on 6 March strongly deploring the shooting down of the two civil aircraft, and directing the Secretary General to immediately investigate the incident in its entirety. The resolution reaffirmed the principle that States must refrain from the use of weapons against civil aircraft and must refrain from endangering an aircraft or its occupants when carrying out an interception.

The resolution also urges all States which have not yet done so to ratify Article 3 bis of the Convention on International Civil Aviation, which recognizes that every State must refrain from resorting to the use of weapons against civil aircraft in flight.

The Secretary General is expected to report on the investigation to the Council by early May. □

Airline accidents, fatalities decline

The number of fatal accidents and passenger fatalities declined in 1995, according to an analysis of preliminary safety data by ICAO. The scheduled air carriers of 184 contracting states experienced 26 fatal accidents and 710 passenger deaths in 1995, down from 28 accidents and 941 fatalities in the previous year. The statistics also show an improvement in non-scheduled services, which accounted for 40 fatal accidents in 1995, down from 54 in 1994. The number of passenger fatalities, however, rose to 391 from 251 in 1994.

The number of acts of unlawful interference diminished significantly, falling to 13 incidents from 37 in 1994. The 13 incidents of 1995 resulted in injuries to three (including one perpetrator). In 1994, 31 people were killed and another 52 were injured. Five perpetrators were also killed, and one injured.

ICAO Council President Dr. Assad Kotaite has urged ICAO's Air Navigation Commission to "go to the root" of the problem of safety oversight.

"In spite of the implementation of strong regulatory programmes, many preventable accidents continue to occur," Dr. Kotaite told the commission.

"The limitations of regulatory safety measures are widely recognized," he stated. "It is not surprising that a number of states have placed increased emphasis on non-punitive accident prevention activities to complement their regulatory safety programmes. It is therefore essential to incorporate additional non-regulatory accident prevention measures if we are to continue to improve aviation safety." □

Next month in the Journal

The April 1996 issue of the Journal will focus on aviation training developments and will include a description of how simulators can be used for providing emergency training for tower controllers.

Council President holds discussions in Washington, Cairo and New York

ICAO Council President Dr. Assad Kotaite was in Washington, D.C. on 22 January for meetings with the Administrator of the Federal Aviation Administration (FAA) and other FAA officials responsible for a wide range of aviation matters. Dr. Kotaite also visited the State Department, where he met with the Acting Assistant Secretary and the Deputy Assistant for International Organization Affairs, the Deputy Assistant Secretary for Transportation Affairs, and other officials dealing with economic affairs. During his meetings, he was accompanied by the Representative of the United States on the Council of ICAO.

Earlier, from 5 to 12 January, the President was in Cairo for the Limited Middle East Regional Air Navigation Meeting. (For a report on the outcome of this meeting, see p. 22, January/February 1996.)

While in Cairo, Dr. Kotaite was received by the Secretary General of the League of Arab States, the Minister of Transport, Communications and Civil Aviation of Egypt, and the Chairman of the Board of the Civil Aviation Authority of Egypt. He visited the National Civil Aviation Training Organization (NCATO) and also visited the new premises for the ICAO Regional Office.

On 6 February, the President of the Council was in New York where he met with the United Nations Secretary-General and discussed with him matters of mutual interest to the UN and ICAO.

Donation supports technical cooperation programme

The Government of the Kingdom of the Netherlands recently gave ICAO a donation of 40,000 guilders (approx. U.S. $23,000) in support of the organization's technical cooperation programme. The Netherlands has been a regular contributor to the voluntary fund for nearly 30 years.

The fund is used by ICAO to provide civil aviation administrations in the least developed countries with essential office equipment such as personal computers. □

ICAO Council appointment

H. Preza (Angola)

Helder da Dilva Gonçalves de Moura e Preza has been appointed Representative of Angola on the Council of ICAO. His appointment took effect in November 1995.

A graduate of Luanda University, where he specialized in electronic engineering, Mr. Preza has also pursued studies in Brazil, Canada and Norway. He served in a number of progressively responsible positions in the civil aviation administration of his country, and was Angola's Director of Civil Aviation from 1993 to 1995. Mr. Preza is proficient in Portuguese, French, English and Spanish, and was a part-time lecturer at Angola University's Faculty of Engineering from 1985 to 1993. As a delegate of Angola, Mr. Preza has participated a number of international and regional meetings organized by ICAO as well as in various other civil aviation international meetings. □

Secretary General visits Mexico, Cuba and the Philippines

ICAO Secretary General Dr. Philippe Rochat made several trips in late January to discuss aviation matters with civil aviation leaders and with staff at two ICAO regional offices.

During a visit to Mexico, the Secretary General met with the Director General of Civil Aviation. Their discussion included various subjects but focused mainly on the restructuring of the air transport industry in that country.

Dr. Rochat visited the ICAO Regional Office in Mexico City. The office, to be relocated within the region in the near future, is accredited to the Contracting States in North America, Central America and the Caribbean.

The Secretary General was in Cuba on 25 and 26 January, where he met with the Minister of Foreign Affairs and the President of the Cuban Civil Aviation Institute (IACC) for a broad overview of civil aviation issues. He also attended, together with the ministers of transport of Spain and Cuba, the opening of a meeting of Ibero-American aeronautical authorities and airport and air navigation agencies.

During his stay in Havana, Dr. Rochat signed two agreements with the Spanish authorities. One agreement provides for the introduction of the ICAO Trainair Programme in Latin America and the Caribbean. The Trainair Programme was developed by ICAO to improve the effectiveness and cost efficiency of civil aviation training in the developing world. Under a separate agreement, Spain is to provide two technical cooperation officers to ICAO regional offices in Lima and in Mexico. The signing ceremony took place at the Spanish Embassy before a number of dignitaries, including the Representative of Spain on the Council of ICAO.

On 30 and 31 January the Secretary General was in the Philippines, where he was received by the President of the Republic, and met with the Secretary of Foreign Affairs and the Secretary of Transport.

During his stay in Manila, Dr. Rochat opened a meeting of the Directors General of Civil Aviation of South-East Asian States. The Secretary General also held discussions with the Asian Development Bank about financial support for civil aviation projects in the region.

On his way to Manila, the Secretary General stopped in Bangkok to visit the ICAO Asia and Pacific Office and to meet with government officials. □

New manual addresses de-icing and anti-icing operations

ICAO recently published the first edition of a manual on de-icing and anti-icing operations for aircraft on the ground.

The document, which provides operators with guidance on the standardization of operational procedures, resulted from a meeting of various experts at a forum on de-icing and anti-icing operations organized by the International Air Transport Association (IATA) in September 1992.

The manual (Document 9640) is currently available in English, and is expected to be printed in the French, Russian and Spanish languages by mid-year.

The IATA forum that led to publication of the manual is held periodically with the objective of standardizing and monitoring the safety and efficiency of ground de-icing and anti-icing procedures.

ATBriefs

Air Transport Bureau

New ICAO manual . . . The ICAO Manual on the Regulation of International Air Transport is now available. The comprehensive reference document, which has been several years in the making, is of value to regulators, the airline industry, training institutions and students, commentators and others interested in how and why international air transport is regulated. A copy of the manual, Document 9626, can be obtained from ICAO at a cost of U.S. $40. Contact Document Sales Unit, International Civil Aviation Organization, 1000 Sherbrooke St. W., Montreal, Quebec, Canada H3A 2R2; telephone (514) 285-8022; facsimile (514) 288-4772.

Airport signs and displays . . . A publication on international signage for use at airports and marine terminals has been produced jointly by ICAO and the International Maritime Organization (IMO). The publication, Document 9636, can be obtained from the ICAO Document Sales Unit at a cost of U.S. $28, or from the IMO.

Planning workshops . . . A regional workshop on forecasting and economics was held in Warsaw last autumn. Another workshop — on statistics and forecasting for systems planning — was held in Lima. Both workshops included topics such as ICAO's statistics programme, forecasting methodology, the outlook for traffic growth in the regions, and the application of cost-benefit analysis in the planning process. Key issues affecting the development of airlines, airport and air navigation systems in the region were also discussed.

Asia/Pacific traffic forecast . . . The release of the report of the last meeting of the Asia/Pacific Area Traffic Forecasting Group is imminent. It will contain details of the group's assessment of long-term growth trends in passenger traffic and aircraft movements for the region as a whole and for important route groups. The report, being published for ICAO by the Australian Government, will be used in the planning of air navigation systems but is expected to be in wide demand by all those interested in the outlook for the world's most dynamic aviation market.

Large-scale technical cooperation projects receive go-ahead

Large-scale technical cooperation projects were recently approved and are being implemented by ICAO in Lao People's Democratic Republic and in the Latin American region. Large-scale revisions to ongoing projects in Argentina, Bolivia, Colombia, Myanmar and Paraguay were also approved.

Following is a brief description of the two new projects (financial figures are in U.S. dollars):

- *Lao People's Democratic Republic.* A planned two-year project commenced in January 1996 and will develop the country's capability in providing safe and efficient air transportation domestically. Other objectives are to strengthen the service and regulatory components of the national aviation system, and to support ongoing efforts in the Indo-China subregion to harmonize international civil aviation operations between neighbouring countries.

The project, which is funded by the United Nations Development Programme (UNDP), will cost $500,000.

- *Latin American subregion.* A four-year project valued at over $2.15 million is supporting the development of continuing airworthiness and operational safety of aircraft in 19 countries of Latin America. The cost of the project is shared by the UNDP, the United States and 19 Latin American states. □

Upper atmospheric research

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effects of aircraft emissions, considerable uncertainty remains about the degree of the actual impact. The most authoritative related international scientific assessment of atmospheric ozone is conducted by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), in support of the Montreal Protocol. In WMO's most recent report, in 1994, the chapter on aviation noted:

> *Preliminary model results indicate that the current subsonic fleet produces upper tropospheric ozone increases as much as several percent, maximizing at the latitudes of the North Atlantic flight corridor. . . . Little confidence should be put in these quantitative model results of subsonic aircraft effects on the atmosphere. . . . There are important uncertainties in supersonic assessments. . . . Models may not be properly including mechanisms that are important in this crucial altitude range.*

The comparable assessment of climate change is prepared by the Intergovernmental Panel on Climate Change, which recently reported that:

> *Our current best estimate is that the positive radiative forcing due to the release of NO_x from aircraft could be of similar magnitude or smaller than the effect of CO_2 released from aircraft. These estimates are preliminary and may well change in future assessments. . . . Aircraft also emit carbon monoxide, water vapour, soot and other particles, sulfur gases and other trace constituents which have the potential to cause radiative forcing. The impact of such emissions has not yet been properly assessed.*

ICAO has developed emission standards which, although formally associated with aircraft take-off and landing operations, have also indirectly served to reduce emissions at altitude. These precautionary approaches will, however, become increasingly complex and expensive as emissions stringency is increased.

Seeking a scientific basis for future standards is important, and the ICAO Assembly has expressed support for the CAEP work programme in this area, noting in particular the need for ICAO to maintain its leadership role in environmental issues. In recognition of other UN policy-making bodies in the environmental field, it has also asked CAEP to continue to maintain and develop liaisons with such organizations.

This is an ongoing task that will be advanced in April 1996 by ICAO co-sponsorship of a symposium on the global atmospheric effects of aviation. The objective of this symposium, to be held in Virginia Beach, Virginia, is to bring scientific, technology and policy leaders together to review the status of all relevant atmospheric research, discuss potential mitigation measures and consider what policy-relevant information may be available to decision makers in the next few years.

As noted at the beginning of this article, future international environmental assessments are likely to devote more attention to the role of aviation. Thus it is now timely for decision makers to begin consideration of those assessments, related research programmes and appropriate expectations. To foster a continuing productive relationship between the responsible communities, a report of the symposium proceedings will be prepared by the participants and published before the end of 1996.

Other organizers for the forthcoming symposium, to be hosted by NASA, are the Association of European Research Establishments in Aeronautics, the European Commission, the Intergovernmental Panel on Climate Change, the U.S. National Oceanic and Atmospheric Administration, UNEP and WMO. Together, these other major organizations have a common interest with ICAO in minimizing aviation's detrimental effects on the atmosphere, and each plays an important role in sponsoring research or in the ongoing international scientific assessment process. From this growing relationship, a clear direction should be developed for CAEP's continuing consideration of aviation's impact on our atmosphere. □

Land-use planning

continued from page 21

Zoning, together with a programme to incorporate sound insulation in noise sensitive buildings located within the airport noise contours, serves a two-fold purpose: the protection of the airport from urban development and, conversely, the protection of nearby residents from noise. By making use of noise contours around airports that delineate areas affected by different levels of noise, zoning enables areas to be identified where no land use should be permitted because of unacceptable noise levels.

The amendment to the planning manual would also provide for a review of various noise zoning and land-use planning systems that have been implemented by a number of ICAO contracting states. There are various approaches to the development of compatible land use, and differences may arise as a result of variations in building construction techniques, climatic conditions and the attitudes of local residents.

It should be kept in mind that the authority to implement and enforce land-use regulations usually rests not with the national aviation authorities, but with national or local planning authorities. Nevertheless, aviation authorities, airports and airlines are able to influence the process and can defend their interests adequately when such regulations are to be imposed. □

Council appoints ANC President

V.M. Aguado

The ICAO Council has appointed Victor M. Aguado (Spain) as President of the ICAO Air Navigation Commission (ANC) for a one-year period commencing 1 January 1996.

Mr. Aguado served as an air navigation commissioner from 1993 to 1995, and during that period also served as a member of Spanish delegations to several ICAO meetings, including the 31st ICAO Assembly in autumn, 1995.

Mr. Aguado has acquired extensive experience in several aviation disciplines. Before his appointment to ICAO, he served for a few years as Executive Vice-President of ISDEFE, an electronics systems engineering company. A member of the Special Corps of Aeronautical Engineers of the Civil Aviation Administration, Mr. Aguado's career began with Lufthansa Airlines in 1975. In 1978 he joined the Civil Aviation Administration of Spain, and was initially posted to U.S.-based Mitre Corp. as a systems engineer responsible for the specification and procurement of semi-automated air traffic control (ATC) systems. Later, he oversaw implementation of several projects in Spain as the Manager of the ATC Modernization Programme.

From 1984 to 1990, he served as Executive Technical Adviser on aviation and aerospace related matters in the Dept. of Defense.

Mr. Aguado, a private pilot, acquired a master's degree from Massachusetts Institute of Technology (MIT) in 1982. Fluent in Spanish, English and French, he has also taken post-graduate studies in business and financial management at schools in Spain. □

POSTS VACANT

Principal Legal Officer, Legal Bureau, Headquarters, Montreal. Ref. PC 96/05/PO or P-5.

A principal officer or senior-level post at Headquarters, Montreal. *Essential* qualifications and experience: advanced university degree in law, with specialization in international law, air law or commercial law, or bar membership with specialization in these areas; at least 15 years' experience, of which at least 10 years at the international level, in co-ordinating or directing activities in areas of major importance to the Organization; ability to draft clearly and concisely, and to present articulate verbal reports; experience in legal work and in the drafting of international instruments; ability to maintain harmonious working relationships in a multinational team. *Desirable* qualifications and experience: experience in high level negotiations with governmental and other authorities; knowledge/ exposure to legal/institutional aspects of new technologies in civil aviation (e.g. CNS/ATM); knowledge of the legal rules and procedures of the United Nations common system; ability to use office automation equipment and contemporary software.

Command of one of the languages of the Organization (Arabic, Chinese, English, French, Russian, Spanish) is essential and a good working knowledge of one of the others is desirable.

The PO level carries a starting net base salary per annum of U.S. $59,645 (without dependents) and U.S. $64,544 (with dependents). Post adjustment on initial salary step is U.S. $7,276 (without dependents) and U.S. $7,874 (with dependents) per annum and is subject to change.

The P-5 level carries a starting net base salary per annum of U.S. $53,611 (without dependents) and U.S. $57,806 (with dependents). Post adjustment on initial salary step is U.S. $6,540 (without dependents) and U.S. $7,052 (with dependents) per annum and is subject to change.

Initial appointment will be on a three-year, fixed-term basis (for an external candidate, first year is probationary). *Deadline for applications: 17 June 1996.*

Supervisor, Aeronautical Data Base, Aeronautical Information and Charts Section, Air Navigation Bureau, Headquarters, Montreal. Ref. PC 96/06/P-3.

An intermediate post at Headquarters, Montreal. *Essential* qualifications and experience: university degree, preferably in one of the technical or scientific fields or equivalent qualifications and experience; at least five years of practical experience in system development and computer programming, specializing in PC based data base application software is essential; ability to write clearly and concisely and to present articulate verbal reports; initiative, judgement and ability to maintain harmonious working relationships in a multinational team. *Desirable* qualifications and experience: knowledge of Banyan Vines, Foxpro and/or other base applications software as well as of the functioning and organization of aeronautical information services and aviation terminology is highly desirable.

Command of one of the languages of the Organization (Arabic, Chinese, English, French, Russian, Spanish) is essential and a good working knowledge of one of the others is desirable.

This level carries a starting net base salary per annum of U.S. $38,291 (without dependents) and U.S. $40,997 (with dependents). Post adjustment on initial salary step is U.S. $4,671 (without dependents) and U.S. $5,001 (with dependents) per annum and is subject to change.

Initial appointment will be on a three-year, fixed-term basis (for an external candidate, first year is probationary). *Deadline for applications: 17 June 1996.*

Chief, Aeronautical Information Unit, Aeronautical Information and Charts Section, Air Navigation Bureau, Headquarters, Montreal. Ref. PC 96/07/P-4.

An advanced post at Headquarters, Montreal. *Essential* qualifications and experience: university degree, preferably in one of the technical or scientific fields or equivalent qualifications and experience; at least 10 years' experience in the provision of aeronautical information services, including extensive experience in automated services and some flight or airline dispatching experience; ability to write clearly and concisely and to present articulate verbal reports; initiative, judgement and ability to maintain harmonious working relationships in a multinational team. *Desirable* qualifications and experience: experience in the inter-relationships of associated aviation fields, such as the provision of ground services; ability to use office automation equipment and contemporary software.

Command of one of the languages of the Organization (Arabic, Chinese, English, French, Russian, Spanish) is essential and a good working knowledge of one of the others is desirable.

This level carries a starting net base salary per annum of U.S. $45,413 (without dependents) and U.S. $48,824 (with dependents). Post adjustment on initial salary step is U.S. $5,540 (without dependents) and U.S. $5,956 (with dependents) per annum and is subject to change.

Initial appointment will be on a three-year, fixed-term basis (for an external candidate, first year is probationary). *Deadline for applications: 17 June 1996.*

Regarding the posts announced above, please note:

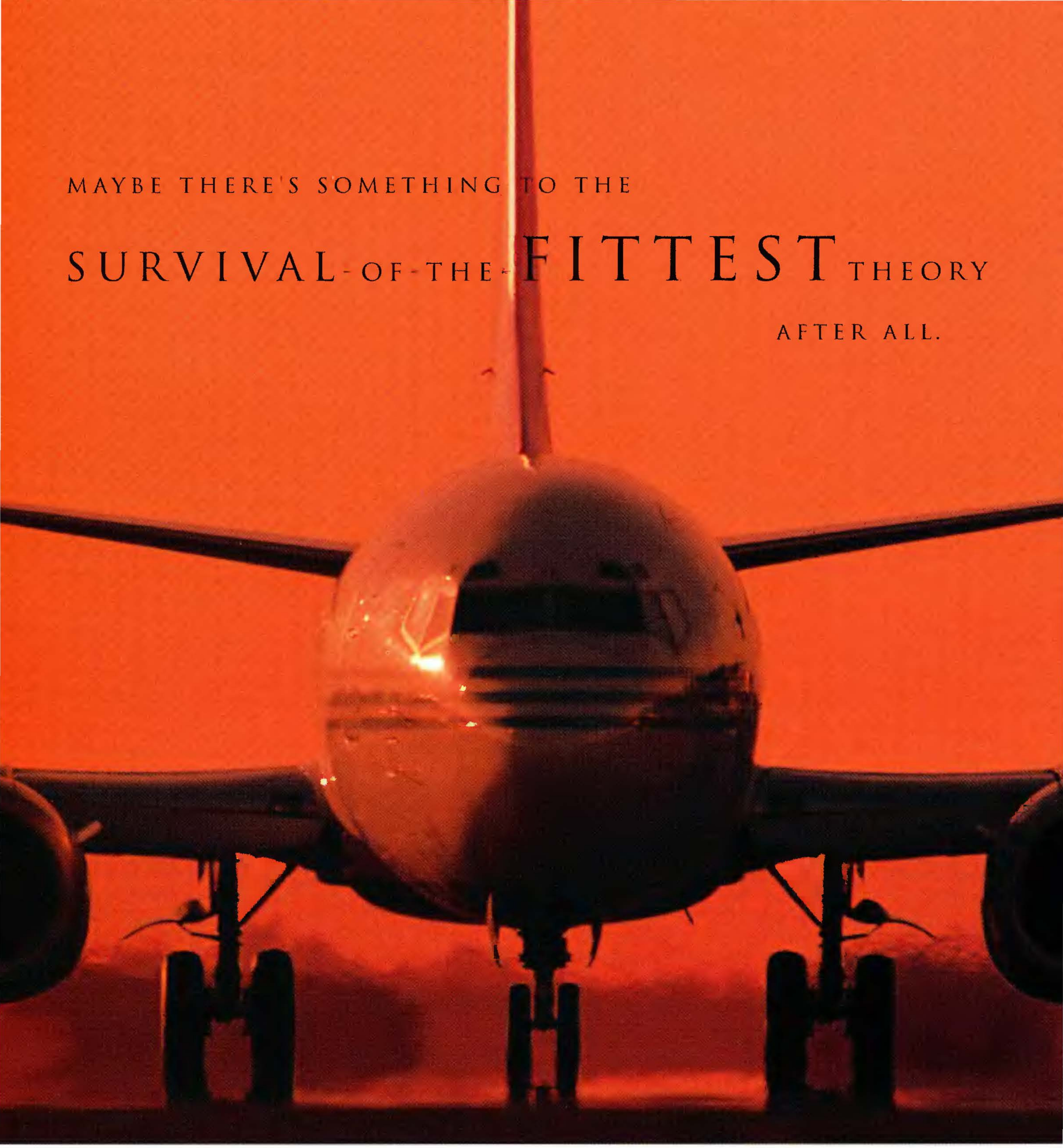
1. That there is, in addition to the salary stated, an allowance for dependents, an education grant for children, provision for adequate annual and sick leave and appropriate social security protection. Travel to and from duty station for the officer and recognized dependents is paid and there is a provision for certain initial and terminal expenses.

2. Appointments from outside the United Nations Common System will be made at the minimum of the salary range indicated. Applications should indicate Vacancy Notice No. and full title of post and must be made on the ICAO Application-for-Employment form in strict accordance with all instructions on the form.

3. Please note that ICAO staff members are international civil servants subject to the authority of the Secretary General and may be assigned to any activities or offices of the Organization.

4. The International Civil Aviation Organization is an equal-opportunity employer and wishes to increase the number of women at all levels. It therefore invites applications from women for specific vacant posts as well as for roster evaluation for future vacancies. The statutory retirement age for the ICAO Secretariat staff is 62. Only applicants who are expected to complete a term of appointment will normally be considered.

Further information about the vacant posts and conditions of service as well as application forms may be obtained by writing to the appropriate departments of the governments of the member States of the Organization, or to the Chief, Personnel Branch, International Civil Aviation Organization, 1000 Sherbrooke Street West, Suite 400, Montreal, Quebec, Canada H3A 2R2.



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