# THE AIRLINE CONTRIBUTION TO NOISE REDUCTION

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## 1.0: INTRODUCTION

Airlines, airports and their governing authorities have been responding to mounting pressure for the last 20 years to cut the level of aircraft noise affecting communities near airports. Manufacturers have researched, designed and built quieter aircraft which the airlines have invested in and this strategy has proved very successful to date in reducing noise. With demand for air travel predicted to grow by some 5 to 6% per annum (p.a.) the search for further reductions in aircraft noise generation at source is continuing. However, further improvements are expected to be gradual with no major breakthroughs foreseen in noise reduction technology. This means that alternative solutions to noise exposure at airports must be sought whilst looking for quieter cost effective technologies for new aircraft at the same time. In particular a much greater emphasis will be needed on long term planning of land use around airports so that schemes to reduce the housing and residential population in areas of high noise exposure are implemented.

This paper will outline the current trends in noise reduction and how these have been bought about, with particular reference to British Airways at London Heathrow Airport. It will then look at what is being planned to reduce aircraft noise effects in the future, explain the current technological limits to noise reduction and the relationship of aircraft noise to other environmental considerations. Finally it will look at the alternatives available to deal with this problem and suggest other areas for attention which will become essential if the reduction in the nuisance of aircraft noise at airports is to continue.

## 2.0: NOISE TRENDS TO DATE

No one likes aircraft noise any more than they like noise from road vehicles or railways. Yet an efficient transport system is necessary for economic prosperity, and makes it's own contribution to wealth. For example SRI consultancy working for IATA (International Air Transport Association) in 1990 estimated that Western European economic activity attributable to the provision or use of commercial aviation approached $75 billion annually, while providing 2.5 million jobs. We would argue that the trends in aircraft noise reduction should be considered in the context of the great and growing benefits of air travel.

Air travel in Western Europe has grown by an average 6% p.a. for the last 2 decades with periods of more rapid growth, as in the late 1980s, and slower growth like the one from which we are now emerging. However, there is a broad consensus amongst airlines, airports, aircraft manufacturers, and government agencies such as ICAO (International Civil Aviation Organisation) that long term growth of the order of 5 to 6% p.a. will continue. Growth in the UK is expected to be slightly slower at 4 to 5% p.a..

In addition aircraft are tending to become larger, due to economic pressures on unit costs and runway capacity constraints. The average journey length is also getting longer, by some 2% p.a.. Growth, bigger aircraft and longer flight distances all have implications for aircraft noise. It is against this background that we may examine the specific case for aircraft noise at Londons Heathrow Airport, BA's main base, which exemplifies many of the challenges facing airports and airlines wishing to meet growing customer demand at a large metropolitan airport where noise is a sensitive issue.

Heathrow is the world's busiest international airport, with demand reaching some 42.6 million passengers and 377 thousand aircraft movements (take-offs and landings) in the year to April 1992. Only a handful of US airports, with mainly domestic traffic, are bigger.

The standard method of displaying the area affected by noise around an airport is as a contour. In the UK this has until recently been calculated as a Noise and Number Index (NNI). This is a composite measure of exposure to aircraft noise taking into account the average peak noise level and number of movements of each aircraft type over a specific period. NNI has recently been replaced by the equivalent continuous sound level (Leq) which is comparable to NNI but deals in terms of acoustic energy. We will be looking at NNI as this is what is available historically. The main area we are interested in is the 35 NNI contour, generally considered as the onset of annoyance.

Figure 1 shows the 35 NNI contours for Heathrow in 1974 and 1989. The decrease in area affected is quite clear; the 35 NNI contour area has fallen from 826 to 315 square kilometres, approximately 62%. This reduction is even more significant when considering the increase in throughput at the airport for the same period. Figure 2 shows the trend for passengers in millions and movements in thousands for the same 15 year period. Movements increased 17% to 355 thousand and passengers increased 55% to 38 million, reflecting the use of larger aircraft. British Airways accounts for 38% of movements and 45% of passengers at Heathrow, and therefore has a significant impact due to the particular make up and operation of it's fleet.

Figure 3 shows the number of people living within the 35 NNI contour for the period. It can be seen these have reduced from 2 million to about one quarter of that figure at 500 thousand people. This improvement is still more impressive when looking at the passengers carried per person affected by noise, also shown on figure 3. In 1974 approximately 10 passengers were carried per noise affected person, this has increased 7 fold to 72 in 1989.

## 3.0: REASONS FOR REDUCED NOISE LEVELS

### 3.1: Engine Technology

The major reason for the reduction in noise depicted has been the introduction by the airlines of quieter aircraft. Figure 4 shows the noise produced by a wide range of aircraft at full thrust, standardised to a common thrust level, against date of entry into service. This provides a consistent measure of noise control technology by eliminating aircraft size and performance variables. A ten decibel reduction represents a halving in the noise produced. The downward trend is quite clear and although it can be seen to tail off there has been an overall reduction of some 20 dB or 75% generally. The major part of this noise reduction can be attributed to the engine although some aerodynamic improvements to the airframes have improved the flow of smooth quieter air.(1)

Figure 5 shows a schematic of a modern gas turbine engine and the noise it produces. A gas turbine engine basically consists of a fan and compressors, a combustion source and turbines which power the fan and compressors. Noise is produced by this turbomachinery and from the exhaust jets from both the fan and the core of the engine. Fan noise is also radiated forward. The ratio of air through the fan to air through the engine core is known as the bypass ratio. The technology that has produced the noise reductions seen is the development of higher bypass ratios, which reduce the proportion of faster flowing gases through the core, and thus noise, culminating in the current high bypass engine designs using large single-stage fans with specifically selected blade and vane numbers in combination with advanced sound absorbing materials in the engine and nacelle inlet and exhaust ducts.

Looking in detail at Figure 4 it can be seen that the early jet aircraft powered by turbojet engines are the noisiest. When the first generation of low bypass ratio turbofan engines were introduced into service in the 1960s they brought a marked reduction in noise of some 10 dB. Approximately another 10 dB reduction was achieved in the 70s and 80s with the introduction of the second generation of high bypass engines.

### 3.2: Aircraft Noise Certification

The availability of this technology led to the certification of aircraft types in terms of noise output by regulatory bodies such as the FAA (Federal Aviation Administration) and ICAO. Under ICAO Annex 16, passed in 1971, new "Chapter 2" noise standards were introduced leaving the early turbojet aircraft such as the 707 and Trident as uncertified. By 1976 "Chapter 2" applied to all newly produced aircraft and in 1978 a more stringent "Chapter 3" was passed for all new type designs. Rules were passed to phase out all uncertified types by 1988.

Figure 6 shows equal noise contours or noise footprints at take off for different aircraft operated by BA either now or in the past. They are for 85 dBA and at maximum take off weights where dBA is a frequency weighted noise measure to account for perception by the human ear. The small twin engine shorthaul type Boeing 737 is shown in the 2 variants operated by BA. The significant reduction in the footprint is apparent between the new Chapter 3 -400 series and the older Chapter 2 -200 as shown against the runways of Heathrow. Also shown is an estimate of the noise made by the "uncertified" Trident, which had a passenger capacity similar to that of the 737s. This can be seen to have been far noisier than the aircraft that replaces it. Similarly the four engine longhaul type Boeing 747 is shown in the variants operated by BA. The largest and most modern -400 Chapter 3 footprint is significantly smaller than the -200 which in turn is smaller than the older Chapter 2 -100 footprint.

Further improvements have been made within the Chapter 3 category. For example the latest 747s, the -400 series, are bigger, heavier and are capable of flying further than their predecessors the 747-200s. They are also quieter; the noise certification of an aircraft is related to its maximum take off weight (MTOW) and the 747-400 makes less noise than the 747-200 at it's MTOW. Also an aircraft that is more lightly loaded makes less noise and on routes where the -400s directly replace -200s the extended range capability of the -400 means they are operating well below their MTOW. As a result the 747-400s are quieter still than the 747-200s when comparing noise performance at MTOW. This situation is true for most fleet replacement programmes.

### 3.3: Aircraft Replacement

British Airways phased out aircraft like the Trident by 1986 replacing them with much quieter, and more fuel efficient aircraft like the 737 and 757. With the phase out of uncertified aircraft BA also fitted hush kits to it's fleet of BAC 1-11s for them to meet Chapter 2. The 1-11s are due to be phased out actively in 1993, and throughout the 1990s the noisier 737 and 747 variants are to be replaced by their quieter siblings.

The increase in the number of twin engine aircraft has also made an impact on noise reduction; for safety and airworthiness reasons aircraft are certified in terms of their performance with one engine inoperative so that they can demonstrate safe flight in the event of an engine failure. This means twins are designed to cope with losing half of their power, as opposed to a quarter for a four engine aircraft. The result is that twins have a higher power to weight ratio with all engines operating and therefore climb out higher and faster than a quad. This means they are higher over the local community outside the airport who then hear less noise as they are further away from the source. New four engined aircraft such as the 747-400 also climb out more rapidly than their predecessors, and this trend is likely to continue with the development of higher thrust rated engines.

Of course fleet replacement is an on going process in BA, and is not based on noise alone, but also fuel-efficiency, capacity and operating cost. However the Trident, for example, was phased out with an average age of only 13 years, well before it's "life expectancy", and at considerable cost to the airline in accelerated replacement and reduced resale value.

ICAO and the FAA have now agreed the Chapter 2 phase out plan for non-operation by the year 2002, with a non-addition rule which precludes the sale of these aircraft to any other operators. Figure 7 shows the increasing proportion of Chapter 3 aircraft in the BA fleet from 1982 to 2002. BA is planning to exceed the requirements of the FAA with phase out (ICAO rules are less stringent) by retirement of the 737-200 fleet which at present has an average age of only 10 years.

3.4: Operational Factors

In addition to using engine and airframe technology to reduce aircraft noise at source airlines pay particular attention to the way their aircraft are flown, that is compatible with safe operation, to keep noise to a minimum. Notably BA operates noise abatement procedures on the BAC 1-11, B747-100, B737-200 at some destinations and Concorde. They mainly consist of cutting back power when overflying the local community and accelerating away afterwards. The 747-100 procedure has an extra weight reduction whilst Concordes is unique. Other procedures are considered such as faster rotation speeds or steeper faster approaches but these are limited by pilot workload, ATC (Air Traffic Control) and safety considerations. Also some of these procedures may only move the noise to other communities rather than eliminating it.

Local procedures requiring aircraft to fly particular routes to avoid dense populations are also enacted at many airports. In the UK these are called Standard Instrument Departures (SIDs) or sometimes Preferred Noise Routes (PNRs). The SIDs at Heathrow are indicated on figure 1. SIDs sometimes lengthen routings and add to fuel costs. They also restrict capacity and flexibility as aircraft flying the same SID must fly in a procession at the speed of the slowest whilst maintaining safe separation distances. At the larger UK airports (Manchester and BAA (British Airport Authority) London airports) track monitoring equipment is installed, or is about to be, to monitor adherence to SIDs. Airlines already pay particular attention in their training and flying procedures to following SIDs and are thinking now of how to follow up and act on the results of the monitoring.

Unlike departures, approaches have to be flown in long straight lines in order to make use of Instrument Landing Systems (ILS), essential for landing in anything but excellent visibility, particularly in the UK climate. This means they cannot be routed round high population centres like departure routes. This may change with the introduction of emergent technology. For example Microwave Landing Systems (MLS) are a ground based aid scheduled as a possible replacement for ILS which use microwaves to generate curved paths for aircraft to follow. Other possible alternatives are Global Positioning Satellites (GPS) providing accurate position fix coupled with aircraft Flight Management Computers (FMC) which could allow curved precision approaches by more accurate airborne navigation of the aircraft. BA carefully monitors developments in these technologies so that it can utilise them as soon as is readily possible.

However arguments abound as to the best use of these emergent technologies and how they can integrate with current ATC technology and procedures. For noise abatement purposes it may be possible to adopt curved approaches but this is contentious between environmentalists; on balance it could reduce the total number of people affected by aircraft noise but it would transfer some noise to some communities who are not currently affected.

There are many other specific restrictions to operations at individual airports which reduce capacity. At Heathrow, for example, no take offs are allowed from the northern parallel runway to the east. Also many airports have night flying restrictions; either a curfew or a quota. At Heathrow and Gatwick the night quotas are currently due for review pending results from sleep research carried out by the DoTp (Department of Transport) and part sponsored by BA. Already at Heathrow fewer than 6000 night flights ,roughly between 2330 and 0600 hours, are allowed each year. That is fewer than 2% of total flights. The airlines need this small amount of flexibility to fly at night due to world-wide scheduling constraints, aircraft crossing multiple time zones and for occasional operational delays. There is no great clamour for many more night operations, it is daytime capacity that airlines need because that is when passengers wish to fly.

The most unusual restriction at Heathrow is that one runway has to be used for all landings, the other for all departures. Halfway through the day the runways are switched, so that the runway that has been used for departures is used for arrivals and vice versa. All other UK runways have arrivals and departures mixed, so do other airports with parallel runways. The penalty in lost capacity is considerable, IATA have estimated it to be at least 10 movements per hour, and probably more. This inefficient use of Heathrows existing runways may one day become contentious if the alternative is another runway in the South East of England. Then the noise implications of both options, and their benefits to the passenger, will need to be carefully assessed.

## 4.0: TECHNOLOGICAL AND ENVIRONMENTAL LIMITS TO NOISE REDUCTION

Noise reduction is evolutionary and has to be considered with a number of other factors such as fuel efficiency, performance, weight, cost and of course safety and airworthiness. Whilst noise is a competitive factor with engine manufacturers trying to sell their products, and plays a key role in development of new engines, the best product has to balance all the competing factors.

Figure 8 shows how noise has reduced with increasing bypass ratio and the introduction of modern turbofans. The future is uncertain; whilst current engine technologists look towards making more efficient engines with reduced fuel consumption the only way forwards is by increasing bypass ratios further, and developing ultra high bypass ratio engines (UHBPR). However at present engine noise from the fan and jet are more or less balanced. Whilst increasing bypass ratio will reduce jet noise, larger turbomachinery will be required to power the fan and noise from those sources would therefore increase. Other more radical engine designs such as the contrafan and the propfan present their own particular problems. The contrafan has larger inlet and exhaust "holes" for noise to radiate out. The propfan, which effectively has an infinite bypass ratio, has no ducting at all to incorporate sound absorbing linings, and is free to radiate noise from it's propellers which are likely to have supersonic tip speeds.(2)

This current optimisation and balance of noise and engine performance is indicated by recent predictions from some manufacturers that the approach noise on brand new aircraft types will be no more than 2 or 3 dB higher than airframe noise alone. That is the noise produced by the fuselage, landing gear and flying surfaces without the engine at all. BA is stressing to the manufacturers the need to research noise reductions from there sources.

Fuel efficiency has been achieved alongside noise reduction in the past but, as already described, some conflicts are emerging; super fuel efficient engine designs for the future don't offer good opportunities for noise reduction. In assessing noise control measures care should always be taken to balance other environmental impacts. For example, hush-kitting of aircraft obviously reduces noise but also can significantly increase weight, fuel consumption and thus undesirable emissions to the atmosphere.

## 5.0: WHERE DO WE GO FROM HERE?

We can expect to see noise continue to decrease at airports like Heathrow for the next 10 years due to the continued investment by airlines in Chapter 3 aircraft and the phase out of all remaining Chapter 2 aircraft. However with the absence of any radical new emergent technology to reduce noise at source significantly further, other solutions must be sought to the problem of community noise at airports.

In view of this uncertainty about further technical progress in reducing noise at source, greater attention needs to be payed to regulating land use around airports in such a way that noise sensitive developments in areas affected by aircraft noise are prevented.

In the UK land use around airports has been subject to DoE (Department of Environment) guide-lines in circular 10/73. These guide-lines have been inadequate as, in a number of cases, permission has been granted for new housing around Heathrow airport contrary to the guide-lines. Local councils have in some instances assisted this process, for example when planning permission was granted for new housing on Hounslow Heath, an area over which a main departure routing had been located precisely because there was no housing there. On other occasions, the councils have indicated that they consider 10/73 to be too weak, so that they would only lose on appeal if they tried to oppose planning permission for housing in noise sensitive areas.

Circular 10/73 is currently under review but the airlines have been dismayed that the new Planning Policy Guidance proposed by the DoE could weaken controls on unsuitable residential, school or hospital developments in noise sensitive areas. BA has been encouraged that local authorities around Heathrow are also objecting to the proposed weakening of the already inadequate rules.

In line with IATA policy on the need for more ingenious land use planning around airports BA has suggested that long term land use plans around airports should be drawn up with the objective of reducing the number of noise sensitive properties. Such plans should bring together long term national infrastructure plans with the local planning framework. These plans should allow for less sensitive commercial developments to replace, and contribute to funding, the reduction in noise affected residential property.

Such a land use framework could be structured to give the airlines incentives and targets to achieve improvements in noise performance, in the confident expectation that noise reductions would not be eroded by new housing being located near to airports . At the same time, airlines could have the operational flexibility to meet demand, provided the noise contour affecting the community did not infringe the agreed limits in the long term plan.

THE AIRLINE CONTRIBUTION TO NOISE REDUCTION

British Airways realises that community groups have an important role to play in airport development and is taking the lead with IATA and the AEF (Airports Environment Federation) in developing an approach to assessing the overall environmental impact of airlines and airports, including noise, that will readily allow differing views to be considered.

## 6.0: SUMMARY

Airlines like British Airways have invested heavily in reducing noise for the local community at airports like Heathrow, and will continue to do so; the population affected by noise around Heathrow is approximately one quarter of that in 1974. Whilst this trend will continue over the next 10 years there is uncertainty that current noise reduction technology is able to improve on the plateau it is now approaching. The emphasis will need to be placed increasingly on effective land use planning to reduce the number of people living in the affected areas. This should include schemes which encourage and compensate existing residents to move from the noisiest areas, whilst preventing any new unsuitable noise sensitive development. Both the local community and the travelling public would reap the benefits of such a new approach and British Airways hopes to move towards achieving this mutually beneficial outcome in the future.

## 7.0: REFERENCES

{1} Aircraft Noise
(Cambridge Aerospace Series 1989)

{2} Environmentally Sound
(Rolls Royce Magazine Number 50, September 1991)

Both references by Michael J. T. Smith
Chief of Powerplant Technology (Civil)
Rolls Royce plc

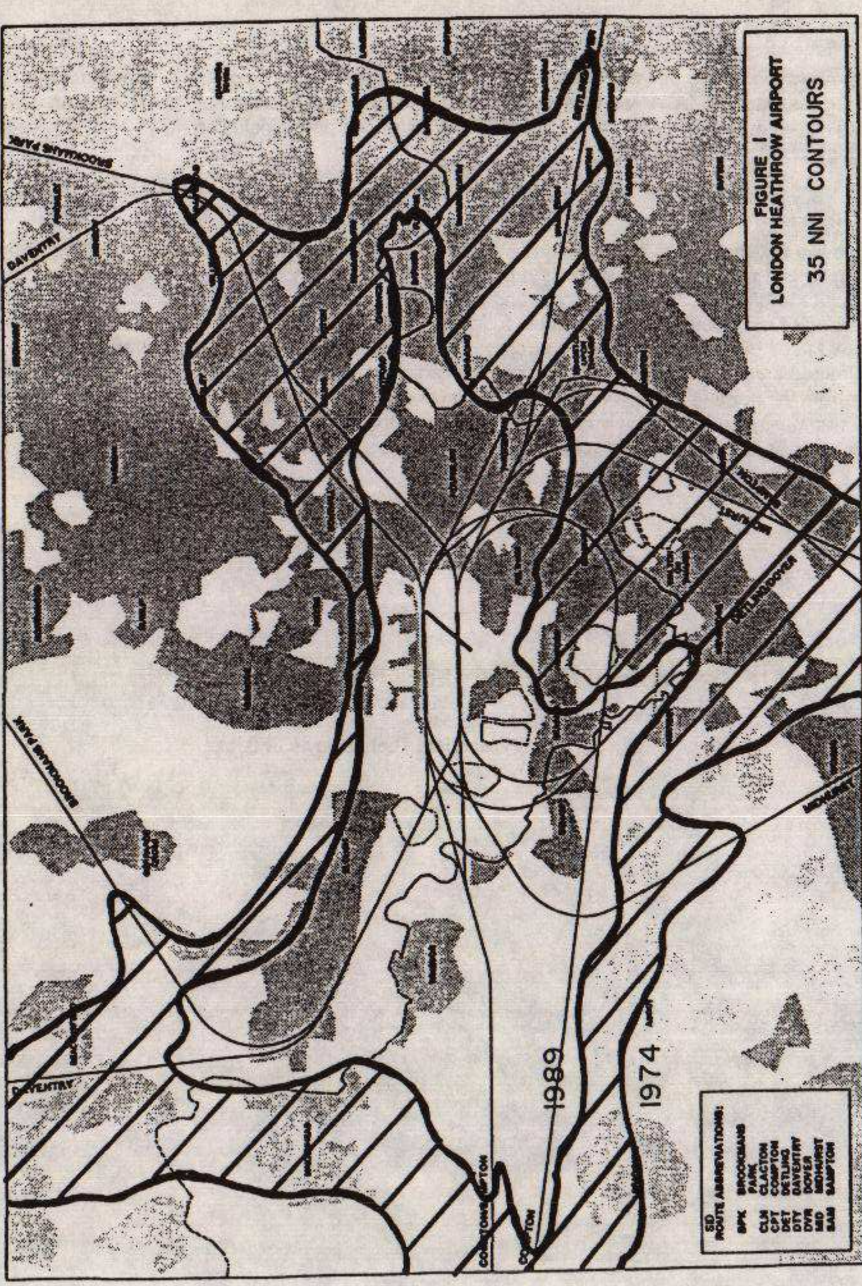
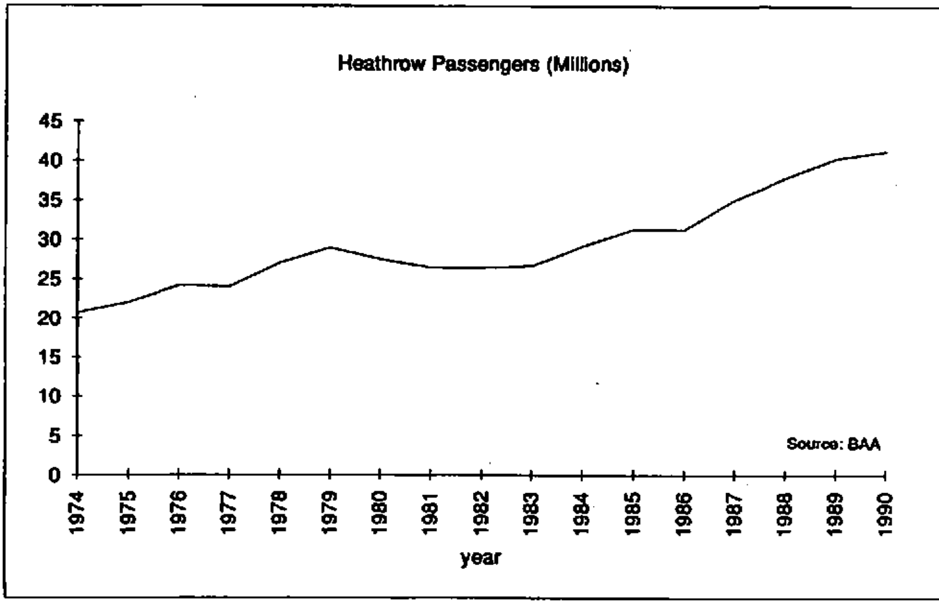



FIGURE 1
LONDON HEATHROW AIRPORT
35 NNI CONTOURS


Heathrow Passengers (Millions)
45
40
35
30
25
20
15
10
5
0
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
year
Source: BAA

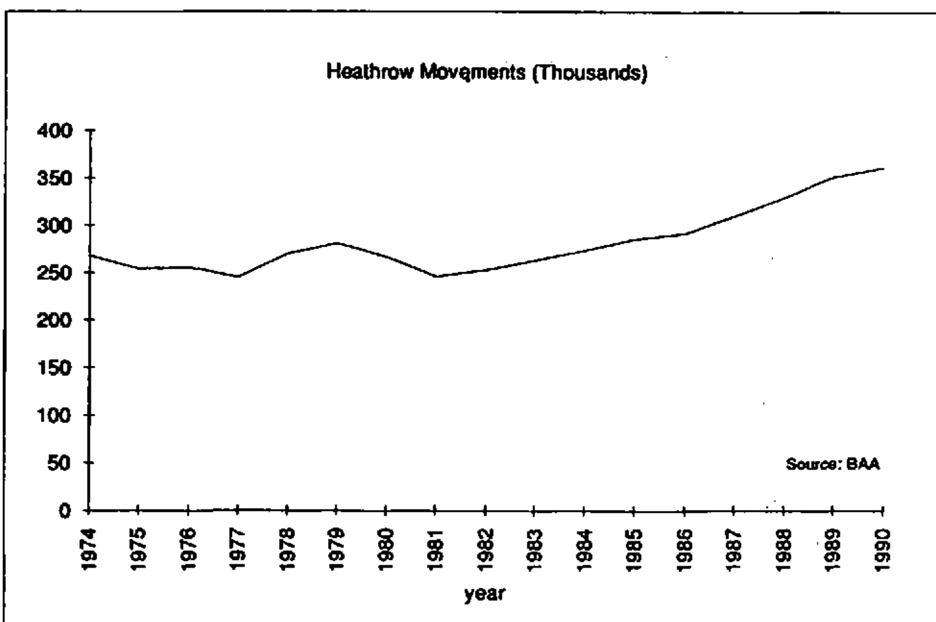
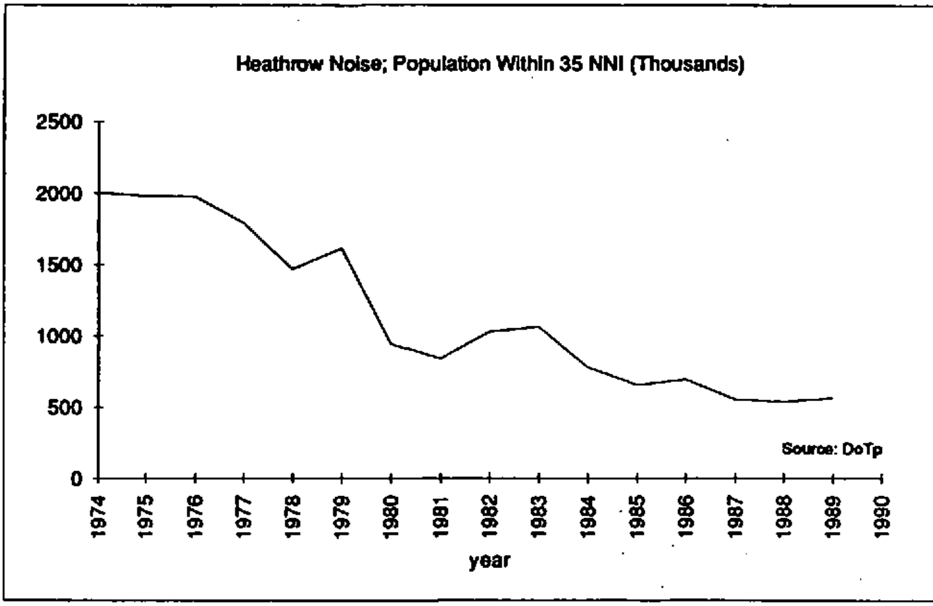

Heathrow Movements (Thousands)
400
350
300
250
200
150
100
50
0
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
year
Source: BAA

FIGURE 2


Heathrow Noise; Population Within 35 NNI (Thousands)
2500
2000
1500
1000
500
0
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
year
Source: DoTp

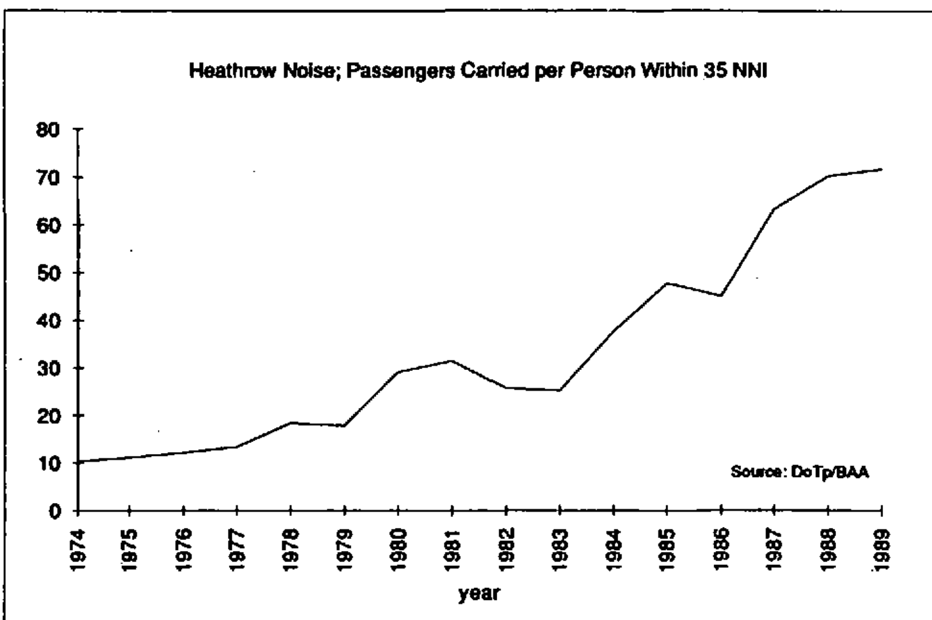

Heathrow Noise; Passengers Carried per Person Within 35 NNI
80
70
60
50
40
30
20
10
0
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
year
Source: DoTp/BAA

FIGURE 3

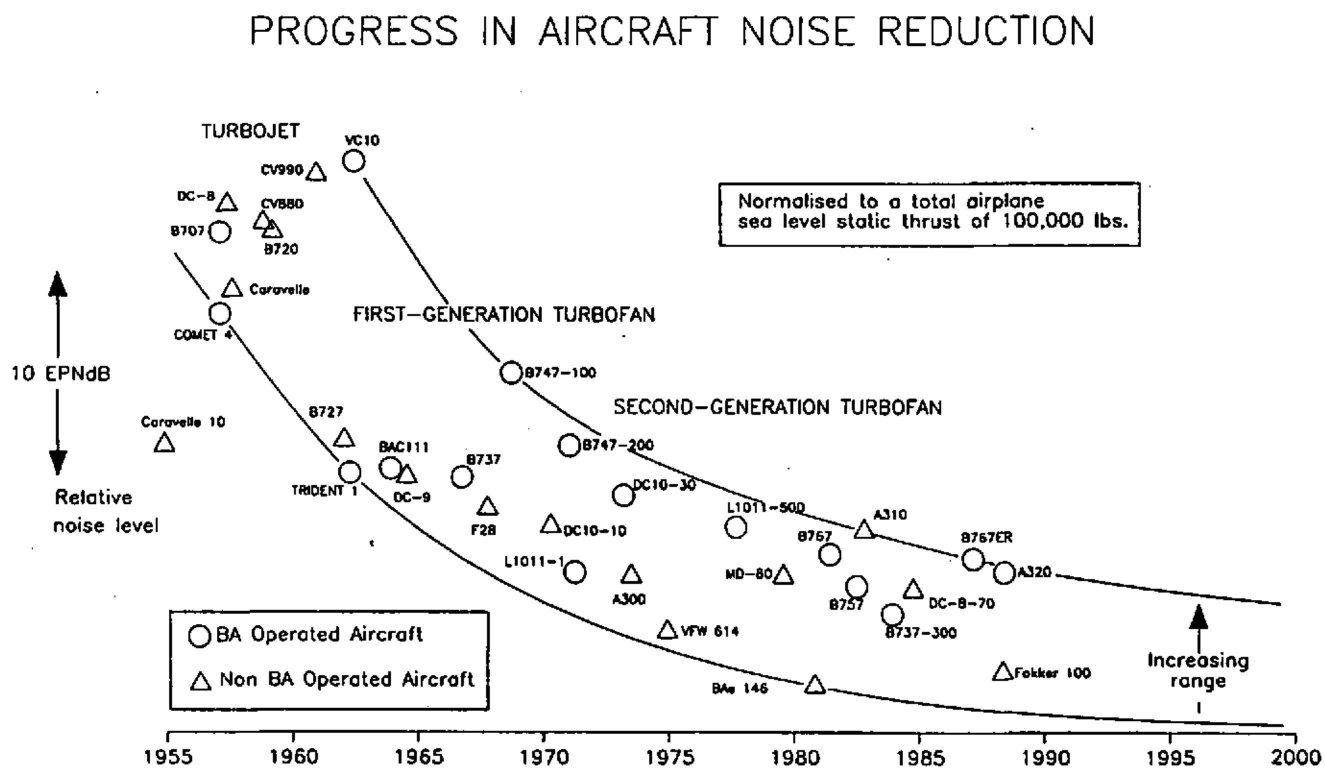

PROGRESS IN AIRCRAFT NOISE REDUCTION
Normalised to a total airplane sea level static thrust of 100,000 lbs.
TURBOJET
FIRST-GENERATION TURBOFAN
SECOND-GENERATION TURBOFAN
10 EPNdB
Relative noise level
Increasing range
BA Operated Aircraft
Non BA Operated Aircraft
VC10
CV990
DC-8
CV880
B707
B720
Caravelle
COMET 4
B747-100
Caravelle 10
B727
BAC111
B737
B747-200
TRIDENT 1
DC-9
DC10-30
F28
DC10-10
L1011-500
A310
B767
B767ER
L1011-1
A300
MD-80
A320
B757
DC-8-70
B737-300
VFW 614
Fokker 100
BAe 146
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000

FIGURE 4.

# TURBOFAN ENGINE NOISE SOURCES

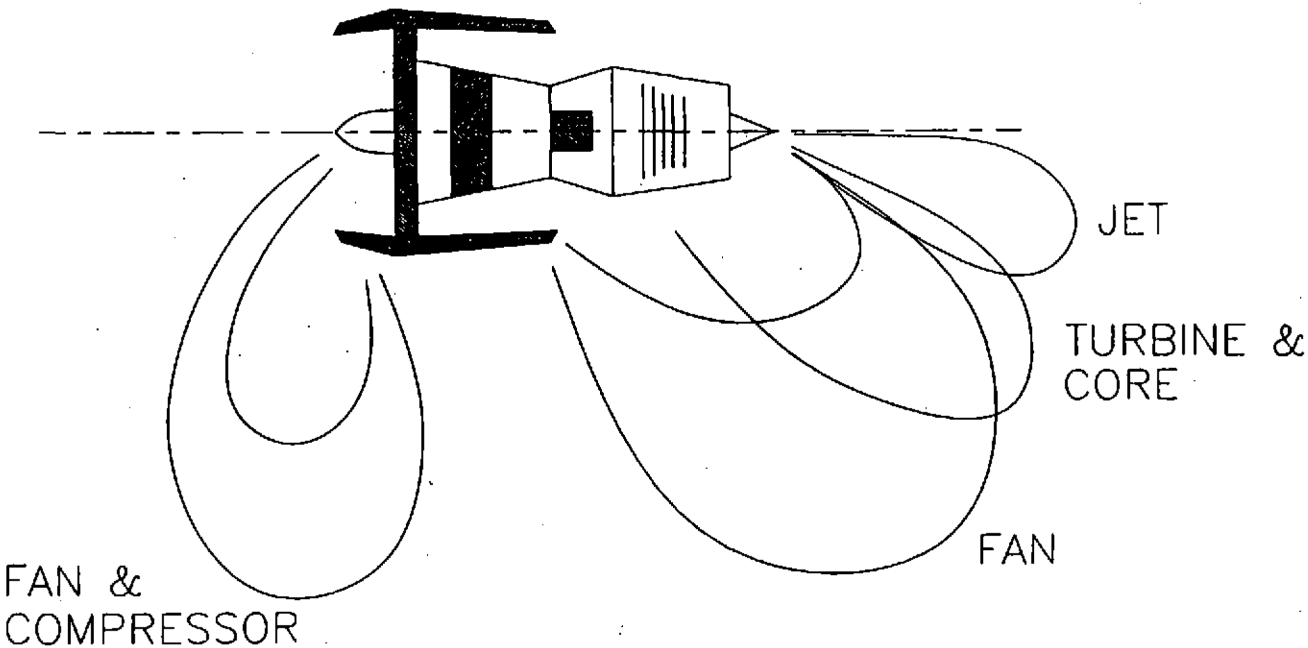
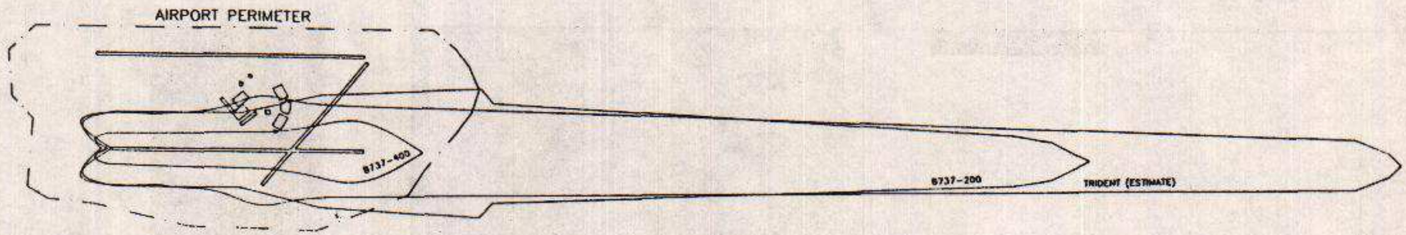


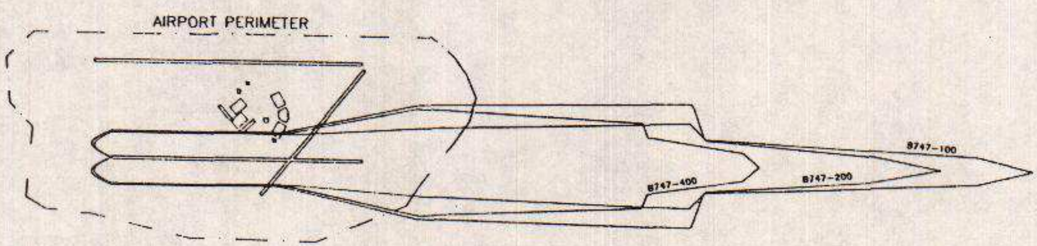

FIGURE 5.

# EFFECT OF FLEET MODERNISATION ON NOISE CONTOURS (85dBA)

## SHORTHAUL



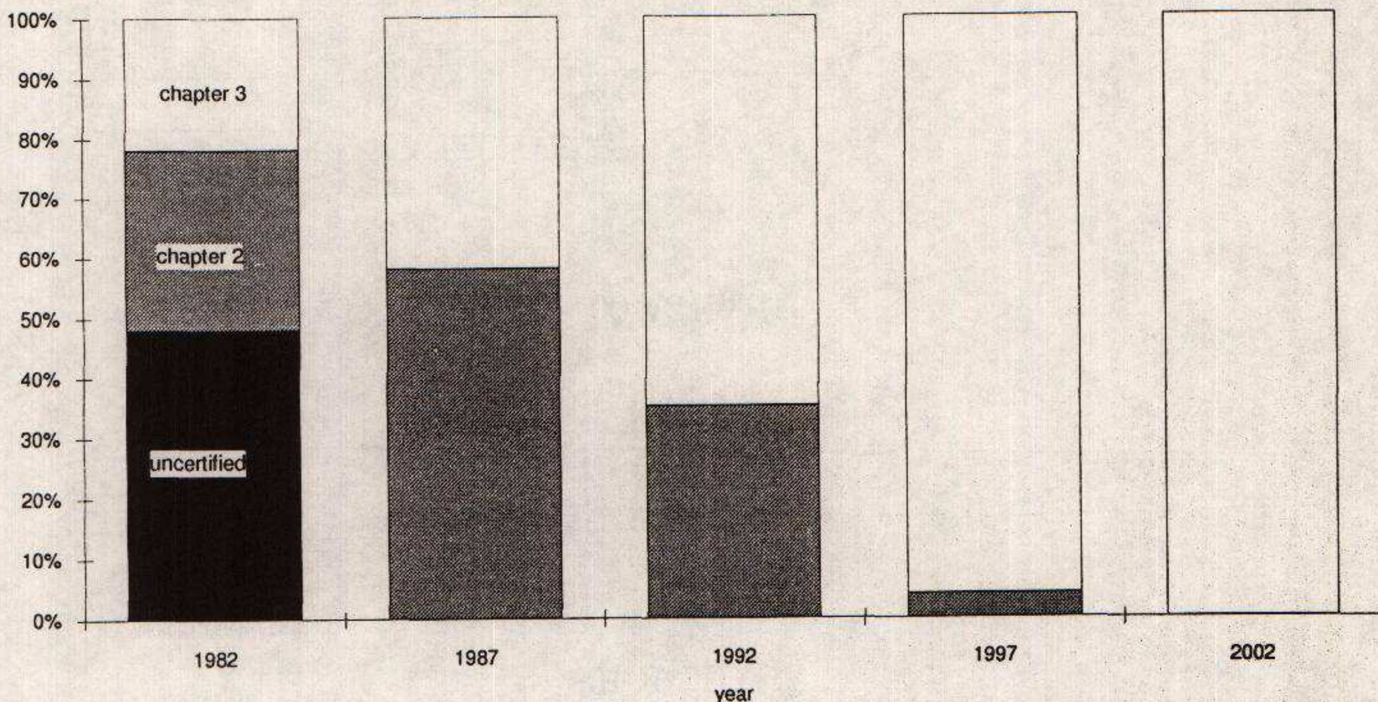

## LONGHAUL




SOURCE: BOEING

FIGURE 6.

British Airways Chapter 3 Fleet




Note: Excludes Concorde and Turboprop Aircraft

FIGURE 7

# NOISE SOURCE VARIATION WITH BYPASS RATIO

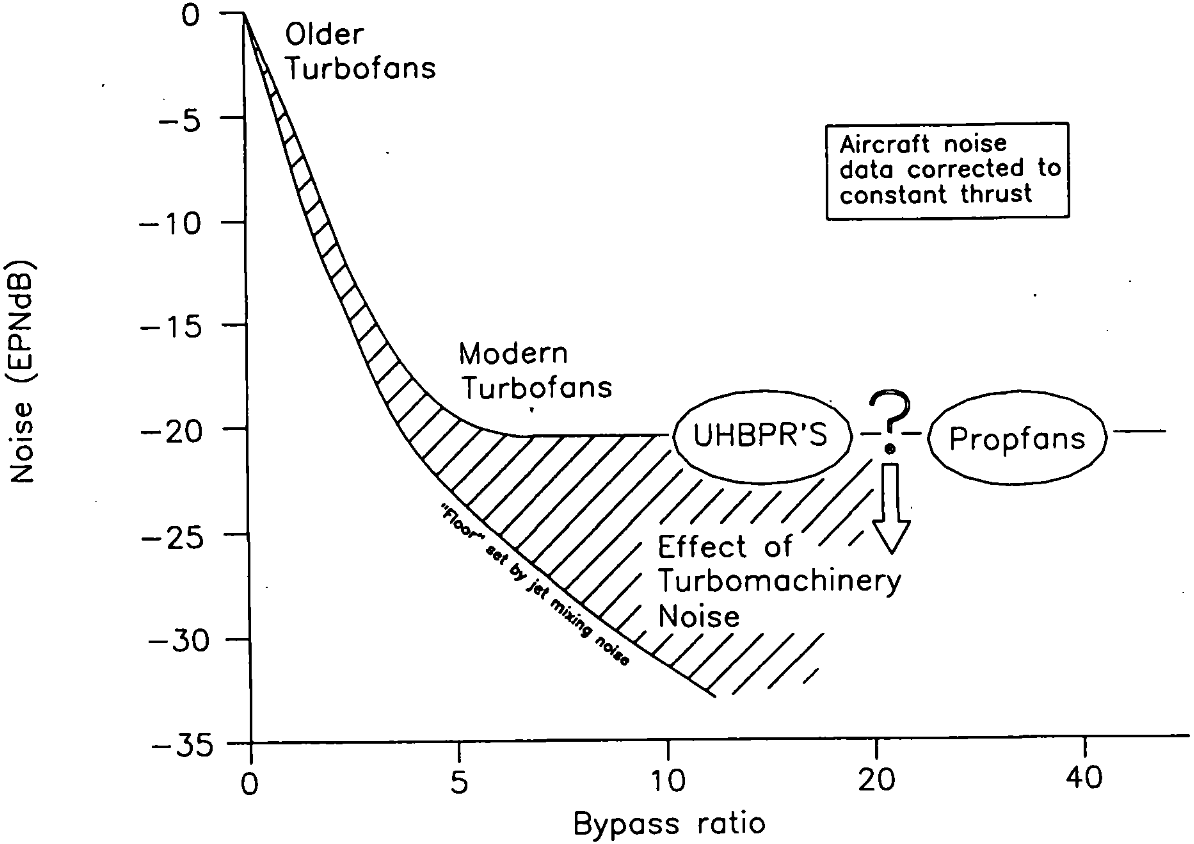



FIGURE 8.