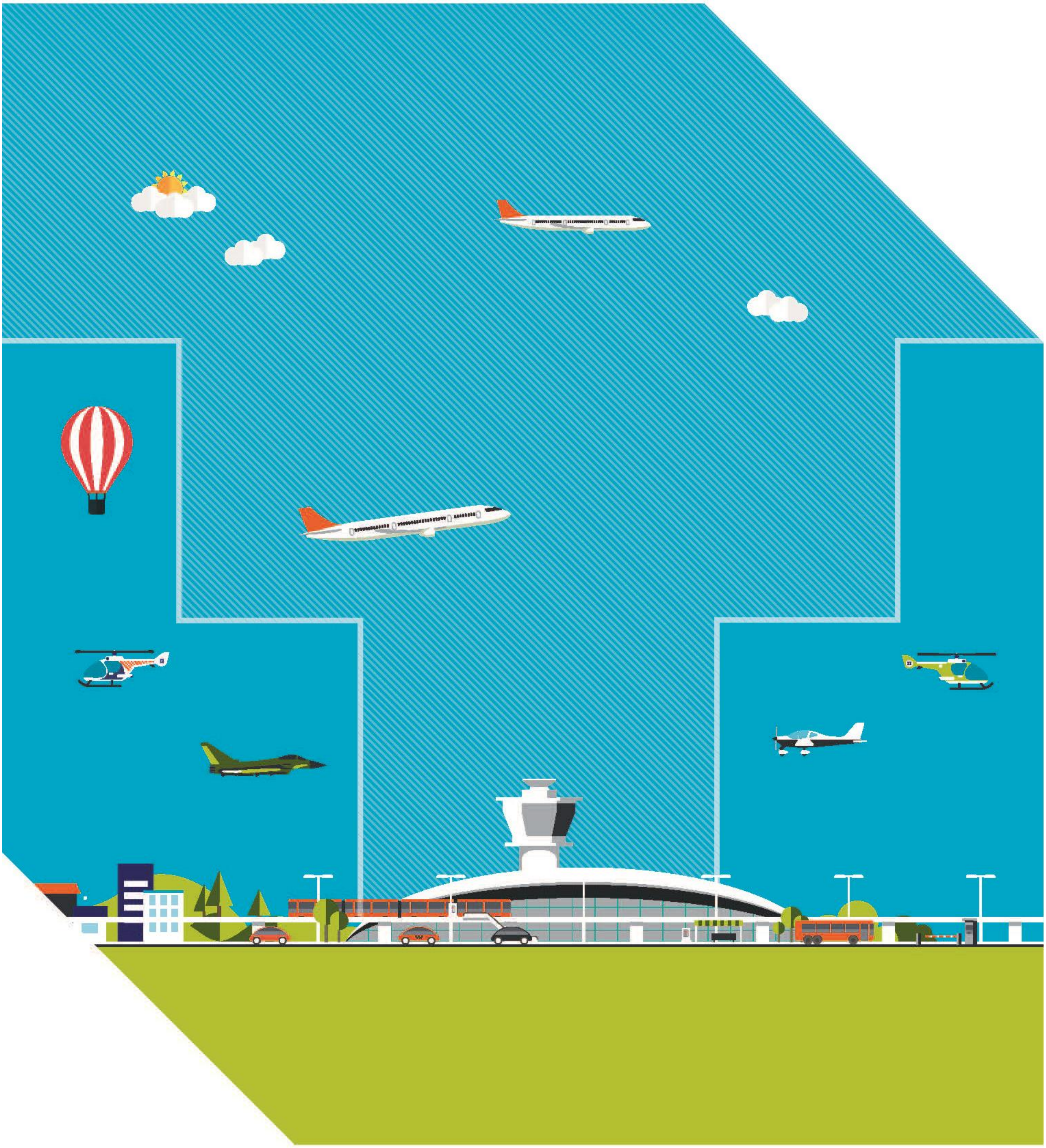
Draft airspace design guidance – consultation

Annex 1: Draft environmental requirements technical annex

CAP 1521



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The latest version of this document is available in electronic format at www.caa.co.uk, where you may also register for e-mail notification of amendments.

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Introduction

The text in this document refers to the policy proposals and draft guidance on which the Department for Transport is currently consulting (click here for details). Should Government Directions, policy and guidance change after the consultation, this document will be updated accordingly.

1. The Civil Aviation Authority (Air Navigation) Directions 2001 (incorporating Variation Direction 2004) (HMG, 2001) require the CAA to take into account 'the need to reduce, control and mitigate as far as possible the environmental impacts of civil aircraft operations, and in particular the annoyance and disturbance caused to the general public arising from aircraft noise and vibration, and emissions from aircraft engines'. In order to achieve this, the CAA requires sponsors to provide an environmental assessment. Every airspace change will be different and the extent of environmental assessment will vary from case to case. It is the function of this document to assist those preparing airspace change proposals in providing sufficient environmental information for both consultation and to inform the decision-making process.

2. This document, to be read alongside the CAA's guidance on airspace change, gives an outline of relevant methodologies for use in environmental assessment. It is not a complete instruction manual on all aspects of the topic. Readers should seek expert assistance where relevant.

3. Environmental science is continually evolving and this document describes assessment methods applicable at the date of publication. New methodologies based on sound principles may well be developed. This document will therefore be subject to review and updating in order to ensure that it reflects 'best practice'.

Airspace design

4. The environmental assessment must include a high quality diagram of the airspace change in its entirety as well as supplementary diagrams illustrating different parts of the change, as necessary. These diagrams must show the extent of the airspace change in relation to known geographical features and centres of population.

5. The change sponsor must provide the CAA with a complete set of coordinates describing the proposed change in electronic format using World Geodetic System 1984 (WGS 84). In addition, the change sponsor must supply these locations in the form of Ordnance Survey (OS) national grid coordinates. This will give non-aviation stakeholders an accurate geographical description of the proposed arrangements. This electronic version must provide a full description of the horizontal and vertical extent of the zones and areas contained within the airspace change. It must also include coordinates in both WGS 84 and OS national grid formats that define the centre lines of routes including airways, standard instrument departures (SID), standard arrival routes (STAR), noise preferential routes (NPR) or any other arrangement that has the effect of positioning traffic over a particular geographical area. Coordinates for current airspace and airport arrangements can be found in the UK Integrated Aeronautical Information Package (UK IAIP)[1]. Details of WGS 84 latitude/longitude and the OS national grid coordinate system can be found on the Ordnance Survey website – this contains software that will facilitate conversion between latitude/longitude and OS national grid.

6. Change sponsors should provide indications of the likely lateral dispersion of traffic about the centre line of each route. This should take the form of a statistical measure of variation such as the standard deviation of lateral distance from the centre line for given distances along track in circumstances where the dispersion is variable. Change sponsors may

[1] http://www.nats-uk.ead-it.com/public/index.php.html

supply the outputs from simulation or trials to demonstrate the lateral dispersion of traffic within the proposed airspace change or bring forward evidence based on actual performance on a similar kind of route. Change sponsors must explain different aspects of dispersion, for example, dispersion when following a departure routeing and when vectoring – where the aircraft will go and their likely frequency.

7. Change sponsors must provide a description of the vertical distribution of traffic in airways, SIDs, STARs, NPRs and other arrangements that have the effect of positioning traffic over a particular geographical area. For departing traffic, change sponsors should produce profiles of the most frequent type(s) of aircraft operating within the airspace. They should show vertical profiles for the maximum, typical and minimum climb rates achievable by those aircraft. A vertical profile for the slowest climbing aircraft likely to use the airspace should also be produced. All profiles should be shown graphically and the underlying data provided in a spreadsheet with all planning assumptions clearly documented.

Traffic forecasts

8. The amount of air traffic is an important consideration in the assessment of airspace changes and their environmental impact. Change sponsors will have made an assessment of traffic forecasts before reaching the conclusion that an airspace change should be considered. Forecasting is not an exact science and no one pretends that the future will turn out exactly as predicted. There are many factors outside the control of the change sponsor and it would not be reasonable to hold the change sponsor to account for deviating from forecasts unless traffic levels breach binding constraints (for example, planning agreements, environmental legislation or limits imposed by Government policy). Nonetheless, forecasts are essential to the airspace change process, not only providing justification for changes, but also enabling the impact of changes to be properly considered. In planning changes to airspace arrangements,

change sponsors may have conducted real and/or fast time simulations of air traffic for a number of options. Such simulations will help to establish whether options will provide the required airspace capacity.

9. Change sponsors must include traffic forecasts in their environmental assessment. Information on air traffic must include the current level of traffic using the present airspace arrangement and a forecast. The forecast will need to indicate the traffic growth on the different routes contained within the airspace change volume. The sources used for the forecast must be documented.

10. Forecasts must be for at least 10 years from the planned implementation date of the airspace change. There may be good reasons for varying this – for example, to use data that has already been made available to the general public at planning inquiries, in airport master plans or other business plans. It may also be necessary to provide forecasts further into the future than 10 years; for example, extensive airspace changes.

11. There are considerable uncertainties in forecasting growth in air traffic. Traffic forecasts will be affected by consumer demand, industry confidence and a range of social, technological and environmental considerations. It may be appropriate for change sponsors to outline the key factors and their likely impact. In these circumstances, change sponsors should consider generating a range of forecasts based on several scenarios that reflect those uncertainties. For some change proposals it may be necessary for traffic forecasts to contain not only numbers but also types of aircraft.

Noise: standard metrics

L_{Aeq} contours

12. The most commonly used method of portraying aircraft noise impact in the UK is the L_{Aeq} noise exposure contour. Noise exposure contours show a

set of closed curves on a map. Each contour shows places where people get the same amounts of noise from aircraft, measured as L_{Aeq}. L_{Aeq} is measured in a unit called dB which stands for 'decibel'. The 'A' subscript means A-weighted (which matches the frequency response of the human ear) and the 'eq' subscript is an abbreviation of the word equivalent, i.e. L_{Aeq} is the equivalent continuous sound level. They are analogous to the contours on an ordinary map showing places at the same height. Noise exposure is generally used to indicate the noise environment averaged over a time interval. Research indicates that L_{Aeq} is a good predictor of a community's disturbance from aircraft noise.

13. Conventional noise exposure contours, which are produced regularly for major airports, are calculated for an average summer day over the period from 16 June to 15 September inclusive, for traffic in the busiest 16 hours of the day, between 0700 and 2300 local time. These are known as $L_{Aeq,\ 16\ hours}$ contours. This calculation produces a cautious estimate of (i.e. tends to over-estimate) noise exposure. This is mainly because airports are generally busier during the summer and a higher number of movements is likely to produce higher L_{Aeq} values. Aircraft tend to climb less well in higher temperatures so, because they are closer to the ground, L_{Aeq} values will tend to be higher than in colder weather.

14. Where changes to airspace are proposed during night time, aircraft noise must be calculated for an average summer night over the period from 16 June to 15 September inclusive, for traffic in the busiest 8 hours of the night, between 2300 and 0700 local time. These are known as $L_{Aeq,\ 8\ hours}$ contours.

15. Runway usage can vary considerably from year to year due to variations in wind direction. It is therefore recommended that average summer day contours be produced using long term average runway usage. Where sufficient data is available this should be based on the last 20 years'

runway usage. If less than 20 years' data is available, it should be based on available data.

16. Change sponsors must produce $L_{Aeq, 16 hours}$ noise exposure contours for airports where the proposed option is likely to result in a change in traffic patterns or traffic volumes or fleet mix below 4,000 feet, or else provide a rationale why the proposed change will not result in a change to L_{Aeq} contours. That rationale must be approved by the CAA. If L_{Aeq} contours are to be produced, at least four sets of contours must be produced:

- current situation (baseline) – these may already be available as part of the airport's regular environmental reporting or as part of the airport master plan
- situation immediately following the airspace change; this may be achieved by re-producing the current situation contours (i.e. using the same traffic volumes and fleet mix, but revising for any changes to routes and/or traffic patterns
- situation after traffic has increased but assuming the proposed change had not been implemented (10 years after intended implementation)
- situation after traffic has increased under the new arrangements (10 years after intended implementation).

17. The height of 4,000 feet was selected as the criterion for L_{Aeq} contours because aircraft operating above this altitude are unlikely to affect the size or shape of L_{Aeq} contours.

18. The contours must be produced using a recognised and validated noise model such as the UK Aircraft Noise Contour Model (ANCON) or the US Aviation Environmental Design Tool (AEDT). For consistency and comparison purposes, if a noise model is already in use at an airport, the same model should be used for the assessment of any airspace change proposal related to that airport.

19. Terrain adjustments must be included in the calculation process (i.e. the height of the aircraft relative to the ground is accounted for). These corrections are limited to geometrical corrections for aircraft-receiver distances and elevation angles. It is not necessary to include consideration of other more complex effects, such as absorption of sound over uneven ground surfaces or noise screening or reflections from topographical features or buildings.

20. Contours must be portrayed from 51 dB $L_{Aeq,\ 16\ hours}$ (for day-time) and 45 dB $L_{Aeq,\ 8\ hours}$ (for night-time) at 3 dB intervals. Department for Transport policy is that these values represent the Lowest Observed Adverse Effect (LOAEL), the point at which it regards adverse effects begin to be seen on a community basis. A table should be produced showing the following data for each 3 dB contour interval:

- area (km^2)
- population (thousands) – rounded to the nearest hundred.

21. It is sometimes useful to include the number of households within each contour, especially if issues of mitigation and compensation are relevant.

22. Note:

- this table should show cumulative totals for areas/populations/ households; for example, the population for 51 dB L_{Aeq} will include residents living in all higher contours
- the source and date of population data used must be noted; population data should be based on the latest available national census as a minimum, but more recent updated population data is preferred
- the areas calculated should be cumulative and specify total area within each contour, including that within the airport perimeter
- where change sponsors wish to exclude parts of the area within contours – for example, excluding the portion of a contour falling

over sea – this may be shown additionally and separately from the main table of data

- change sponsors may include a count of the number of schools, hospitals and other special buildings within the noise exposure contours.

23. Contours for assessment should be provided to the CAA in both of the following formats:

- electronic files in the form of a comma delimited ASCII text file containing three fields as an ordered set (i.e. coordinates should be in the order that describes the closed curve) defining the contours in Ordnance Survey national grid in metres:

Field	Field name	Units
1	Level	dB
2	Easting	six figure easting OS national grid reference (metres)
3	Northing	six figure northing OS national grid reference (metres)

- paper version overlaid on a good quality 1:50 000 Ordnance Survey map; however, it may be more appropriate to present contours on 1:25 000 or 1:10 000 Ordnance Survey maps.

24. Ordnance Survey national grid coordinates are required because they are the common standard for noise exposure contours population/household databases in the UK. Change sponsors should ensure that they are familiar with conversion from latitude and longitude to Ordnance Survey national grid coordinates.

25. An additional portrayal of contours for a general audience may be provided overlaid on a more convenient map (for example, an ordinary road map with a more suitable scale for publication in documents). The underlying map and contours must be sufficiently clear for an affected

resident to be able to identify the extent of the contours in relation to their home and other geographical features. As such, the underlying map must show key geographical features, for example, streets, rail lines and rivers.

100% mode noise contours

26. Average summer day contours reflect the direction of usage of an airports runway(s) during the summer period. For safety reasons aircraft take-off and land into wind, and therefore the runway direction in use will change depending on wind direction. While summer average day noise contours reflect noise exposure for an average summer day, because they represent an average of the two runway directions available, they do not represent the noise associated with a single runway direction. 100% mode noise contours address this by depicting the summer average day flight operations for a single operating mode. Since a runway can be used in one of two directions, there will be two 100% mode noise contours, one for each runway direction. Taking the example of London Stansted, whose runway is orientated north-east (runway 04) and south-west (runway 22), the long-term average summer day runway use is 72% runway 04 and 28% runway 22. 100% mode contours would depict 100% of the average summer day operations on runway 04 and 22 respectively.

Nx contours

27. Nx contours show the locations where the number of events (i.e. flights) exceeds a pre-determined noise level, expressed in dB L_{Amax}. For example N65 contours show the number of events where the noise level from those flights exceeds 65 dB L_{Amax}. The levels of 65 dB L_{Amax} for day-time flights and N60 for night-time flights were selected because they are specified in the Department for Transport's Air Navigation Guidance as supplementary metrics. Typically, contours ranging from 10 events to 500 events are plotted.

28. As with L_{Aeq} contours, the N65 contours must reflect a long-term average summer day (16 hours, from 0700 to 2300) and the N60 contours must

reflect a long-term average summer night (8 hours, 2300 to 0700), using actual runway usage and including all air traffic movements. The other requirments set out earlier in this document for L_{Aeq} contours are also relevent for Nx contours.

29. By showing the distribution of noise events under different circumstances, Nx contours may also be used to address the common criticism that L_{Aeq} contours only show the impact on an average day. Nx contours could be used to demonstrate different methods of runway usage or show how movements vary at different times of day. Nx contours can be a useful aid to the public because if the number of movements doubles, then the Nx doubles, all other things being equal. L_{Aeq} type metrics are logarithmic in nature, which translates to an increase by 3 dB for a doubling of traffic.

Difference contours

30. Indicators such as those described so far are important in measuring and portraying the total noise impact, but can be complemented by showing how an airspace change redistributes noise burdens. In effect, other indicators can be used to show the changes in noise exposure over an area.

31. One way of portraying changes in noise exposure is the difference contour. These contours show the relative increase or decrease in noise exposure, typically in L_{Aeq}, on a base scenario, which is normally chosen to be the current situation. The increases/decreases are shown in bands:

- increase/decrease (±) of 1 – 2 dB
- ± 2 – 3 dB
- ± 3 – 6 dB
- ± 6 – 9 dB
- ± > 9dB.

32. Because the contours show increases and decreases, some form of colour shading is required to show whether a particular area will

experience an increase or decrease in noise exposure. It is recommended that red is used for increases in noise exposure and blue is used for decreases in noise exposure.

33. Population/household counts can be used to compare the numbers of people that may experience increased noise exposure with those who will gain from the proposal.

34. Difference contours are particularly applicable where the degree of redistribution of noise impact may be large, for example, revising arrival and departure routes or in adapting the mode of runway operation. Change sponsors may use difference contours if it is considered that redistribution of noise impact is a potentially important issue. One caveat is that where aircraft noise is relatively low, aircraft noise may well not be the dominant noise source. As such, the benefits and disbenefits shown by difference contours may or may not be realised in practice.

Operational diagrams

35. Operational diagrams portray a representation of how the airspace is to be used. They do not use or contain any information about noise levels. This can be advantageous when it is difficult or impossible to measure aircraft noise accurately and reliably, for example, when aircraft noise levels are relatively low. It is a disadvantage when aircraft noise levels can be accurately determined, in which case the omission of noise information might be misleading. For each route, a box with information about the distribution of air traffic is shown on a diagram of the airspace overlaid on a map showing recognisable geographical features. Each box can include the following information (change sponsors may vary the information displayed providing that the diagram is a fair and accurate representation of the situation portrayed):

- average number of daily movements
- percentage of all aircraft movements at the airport using that route
- daily range of movements – minimum and maximum
- percentage of days with no movements.

36. Operational diagrams are typically used to show daily traffic movements but can be used to portray other time periods where air traffic varies considerably over time.

37. Change sponsors should always bear in mind that the production of a large number of operational diagrams covering every eventuality in great detail has the potential for confusion. The challenge is to present information on aircraft noise in ways that are clear and accurate, without omitting essential detail, but which can be readily understood by a non-technical audience. Nx contours and operational diagrams should be considered as communication tools with limited applicability in the assessment process. There is a proportionate balance to be struck between the amount of data produced and the degree to which this information actually helps the audience to understand the key issues. Thus, Nx contours and operational diagrams should only be considered as supplementary communication tools.

Overflight

38. CAP 1498 (Definition of Overflight)[2] presented a definition of 'overflight' based on the angle of elevation between a person on the ground and an aircraft in the sky (Figure 1). The report suggested two elevation angles, 60° and 48.5° (Figure 2). There are pros and cons for both angles. The boundary of a 60° 'V' represents a reduction in noise level of 1.6dB relative to directly overhead, which may not be perceptible and thus may not represent all those overflown, particularly in cases for a completely new flight path. Conversely, a 48.5° angle may be less sensitive to

[2] www.caa.co.uk/CAP1498

changes in flight concentration within the ‘overflight area’, since it would encompass a greater area and number of flights.

39. On balance the CAA recommends the use of a 48.5° angle for representation of overflight. If airspace change sponsors choose to use 60° instead, this fact plus the rationale must be made clear in any representations of overflight used for the proposal.

40. One method of portraying the anticipated change of aircraft traffic patterns is a simple portrayal of areas likely to be overflown. This can be achieved by using the distances presented in Figure 2, to extend a track-keeping swathe to represent an overflight area – the key difference being that the overflight area would widen with increasing altitude whereas as a track-keeping swathe would not.

41. If sufficient information is available to estimate the distribution of flights within a track-keeping swathe, the distribution of overflights can also be estimated and combining this with numbers of flights, a count of the population beneath the proposed overflown airspace, namely the population that experiences ‘overflight’ can be estimated. The attraction for both airspace change sponsors and residents alike is that this concept is easy to understand.

42. There are methodological limitations of population counts and the calculation of residential areas overflown. For example <u>not all individuals within an overflight swathe are affected to the same extent</u>. A resident living 28 km along a track from an airport with aircraft operating at 5,000 feet will experience less impact than a resident at 9 km with aircraft at 1,500 feet. However, the population count method for overflight considers both residents to be equivalent.

Figure 1: Overflight elevation angle

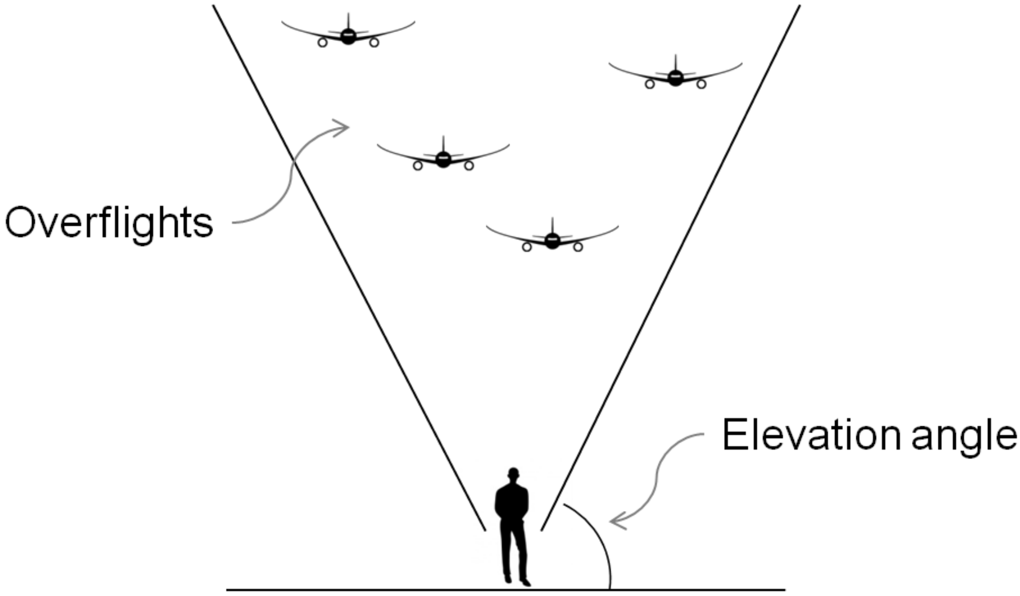
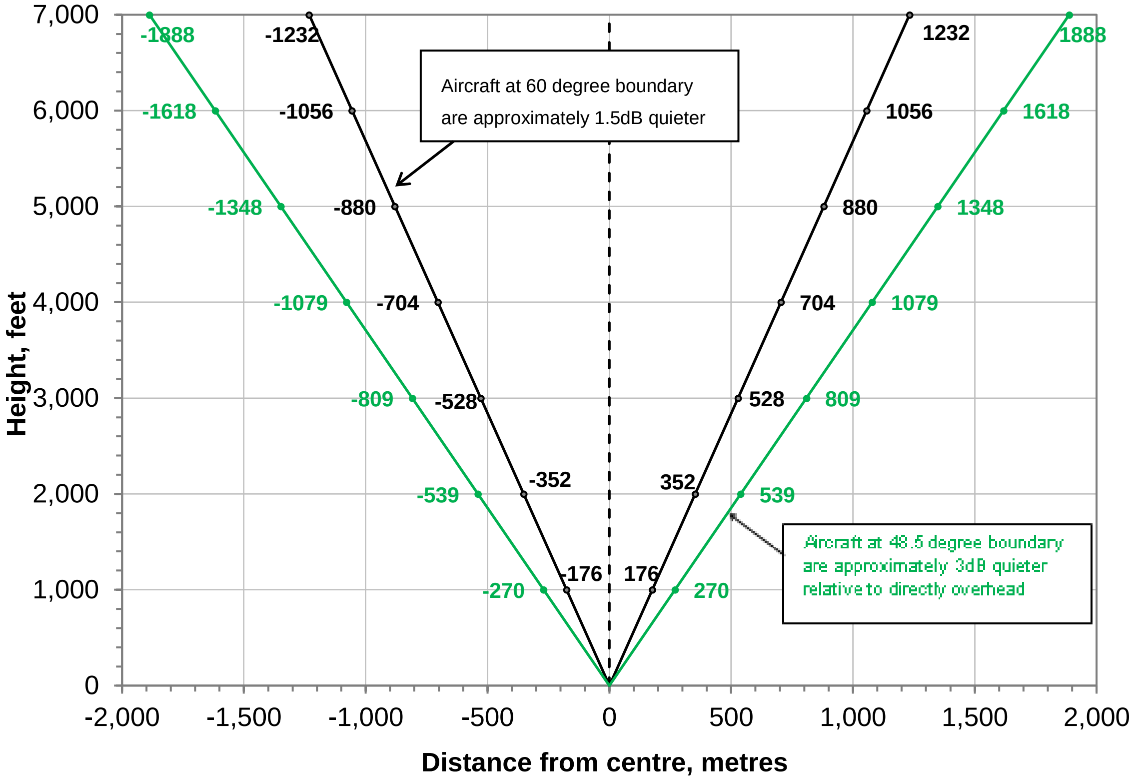


Figure 2: Lateral distance of aircraft from overhead at the boundary of 60 and 48.5 degree "V"



L_{max} spot point levels

43. Change sponsors may produce diagrams portraying maximum sound event levels (L_{max}) for specific aircraft types at a number of locations at ground level beneath the airspace under consideration. This may be helpful in describing the impact on individuals. It is usual to include an accompanying table showing the sound levels of typical phenomena, for example, a motor vehicle travelling at 30 mph at a distance of 50 metres.

Noise measurement

Sound

44. Sound is energy propagating through the air by the mechanism of the wave motion of its particles. It causes small fluctuations in air pressure, which are detected by the ear or other receiving instrument such as a noise monitor. The audible quality and quantity of the sound depends upon the amplitude and frequency of these fluctuations. Most sounds consist of a mix of different frequencies. Frequency refers to the number of vibrations per second of the wave motion and is measured in Hertz (Hz). 'Noise' is generally used to denote unwanted sound.

Sound power and intensity

45. The strength of a noise source is usually quantified in decibels (dB). Sound quantities described in decibels are referred to as sound levels. Decibels are used because sound powers and intensities cover a wide range of values. Using the decibel, which is a logarithmic unit, avoids the problems caused by having to manipulate numbers with many digits. Decibels relate one quantity to another. In effect, they are ratio measures. In sound measurement, the reference level is taken to be the threshold of human audibility – this is 20 μPa (micro Pascals) or 2×10^{-5} Pascals (where one Pascal equals 1 Newton per square metre). Decibels are subject to the usual rules applying to the manipulation of logarithms. This

means that increasing the sound energy by a factor of k, i.e. k times as much, increases the dB value by 10 $\log_{10}$ k. Thus, doubling the sound energy results in an increase of 3 dB. Similarly, halving the sound energy results in a decrease of 3 dB.

Loudness and intensity

46. The extent of the unacceptability of sound depends at least on three physical characteristics:

- intensity
- duration
- frequency.

47. Intensity is the rate of flow of sound energy through a unit area normal to the direction of propagation. It is a physical quantity measured in Watts per square metre ($W.m^{-2}$). Loudness is the perceived or subjective magnitude of sound. Other things being equal, the approximate relationship between intensity and loudness is that a tenfold change in intensity produces a twofold change in loudness. It must be stressed that this is an approximate relationship; it varies between individuals and with the characteristics of the sound. It is not the same as the relationship between sound energy and sound level. Loudness is a subjective measure which varies between individuals and is, therefore, not easy to measure.

Noise measurement scales

48. Noise is inherently complex. A number of different noise measurement scales have been devised. Each of them captures some, but not all, of the different aspects of this complexity.

A-weighted sound level – L_A

49. Frequency affects how sound is perceived. The normal human ear responds to sound over a wide range of frequencies but with different

sensitivities. A variety of frequency weightings have been developed to match these response characteristics – the most common being A-weighting. This broadly matches the frequency response of the human ear. It is widely used for the measurement of noise from all modes of transport. Decibel levels measured on this scale, abbreviated as LA, are written as dB(A) or dBA. References to sound levels within this document imply the use of A-weighting unless stated otherwise.

Maximum sound level – L_{max}

50. The simplest measure of a noise event such as the overflight of an aircraft is L_{max}, the maximum sound level recorded. It is usual to measure L_{max} using the sound level meter's slow response, which damps down the very rapid, largely random fluctuations of level.

Long-term noise exposure and equivalent continuous sound level – L_{Aeq}

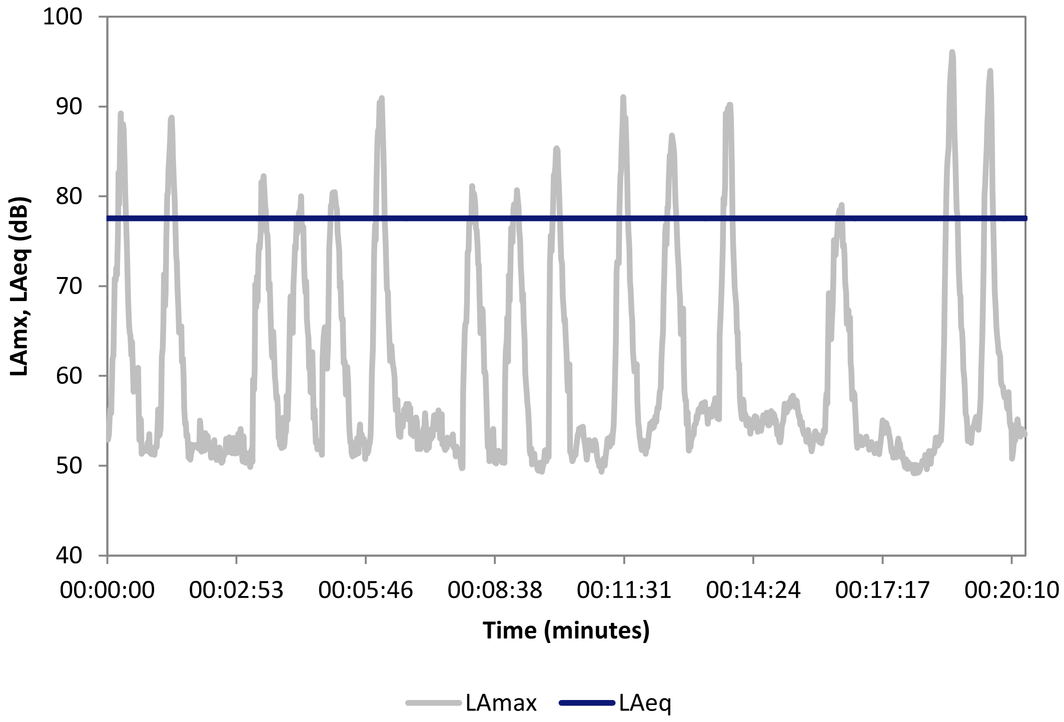
51. The levels of individual noise events are useful for many purposes including aircraft certification. However, in order to assess environmental noise exposure, it is necessary to consider and take into account the impact of many events over longer periods – days, months, years – living near an airport. These events will generally differ in magnitude; there will be different numbers in each hour or day; and they will occur at different times of day. Most indices for these assessments are L_{Aeq}-based.

52. Equivalent continuous sound level or L_{Aeq} is defined as the level of hypothetical steady sound which, over the measurement period, would contain the same (frequency-weighted) sound energy as the actual variable sound (Figure 3). L_{Aeq} can be measured over any scale in practice, but L_A is the most widely used. The corresponding L_{Aeq} is sometimes abbreviated L_{eq}.

53. L_{Aeq} can be measured or calculated in several ways. The total noise exposure can be measured if the sound meter runs continuously during the measurement period. If the requirement is to monitor the contribution

of aircraft noise only to the total, the meter can be programmed to calculate the exposure due to noise events above a pre-determined threshold. Additional information on aircraft operations can subsequently be used to identify those noise events likely to have been caused by aircraft.

Figure 3: Illustration of the L_{Aeq} for a location exposed to aircraft noise events over 20 minutes



Noise modelling

Levels, footprints and contours

54. Event levels such as L_{max} describe the noise of individual aircraft flights observed at particular points. To describe the noise impact over an area, footprints and contours are used. These are lines on a map or diagram joining points with the same value of the noise metric. The area inside this line shows all places where the noise impact is equal to or greater than some value. A footprint is for a single event; a contour is for noise exposure from many events.

55. Footprints are used to compare the noise characteristics of different aircraft. They help to illustrate the effects of different operating procedures. Thus, they show how these modify footprint shapes and areas. They are also helpful in depicting the relative contributions of different aircraft types to noise exposure.

56. Long-term noise exposure is usually measured by an index, such as equivalent continuous sound level or L_{Aeq}, spanning a suitable period of time (such as an average day or night). The extent of total noise exposure is illustrated by noise exposure contours. Contours (lines of equal L_{Aeq}) are effectively aggregations of noise footprints of all the individual aircraft movements. Contours help to quantify the extent of aircraft noise exposure. As a start, they serve to illustrate its geographical distribution. The total impact is normally summarised in terms of the areas and numbers of people/households enclosed by the contours. Contours can be used to compare situations at different times, different places and under different circumstances.

57. Event levels, footprints and contours are relatively simple concepts, but their determination is complicated. They are subject to both measurement and statistical uncertainty. The areas of both contours and footprints are very sensitive to changes in noise emissions. Typically, the total area increases by approximately 20% for a 1 dB increase in average source levels.

Noise monitoring

58. For particular locations, noise event levels and exposure levels can be readily measured using sound level meters. These meters may be portable (used for research studies) or fixed (used by airport operators). Modern noise monitors are robust and reliable. They function for long periods, in most weather conditions and with minimal attention – they are also increasingly sophisticated, and can be linked together to form noise monitoring systems. They can be further enhanced with radar data and

flight operations data to provide noise and track keeping systems such as those installed at major airports.

59. The analysis and interpretation of noise measurements is complicated by inherent variability. A particular aircraft type can produce a wide range of noise levels at any particular location on the ground. This occurs even when the aircraft's ground tracks are very similar. The principal causes are differences in aircraft weights, flight operating procedures and atmospheric conditions. The weather affects the performance of aircraft, especially their climb rates. This is especially important for departures, as the climb rate affects the distance the sound travels through the air. The meteorological conditions also affect the way in which sound propagates between aircraft and the ground. Atmospheric variation – of wind speed, temperature, humidity and turbulence – can itself cause significant differences in event levels, of up to 10 dB or more. Noise data must therefore be expressed in statistical terms as averages – which are susceptible to a degree of uncertainty.

60. A further complication for the automated monitoring of aircraft noise is how to distinguish the noise of aircraft from background noise, mainly from road vehicles and other human activity. This is an increasingly difficult problem. Levels of aircraft noise generally continue to diminish in relation to noise from other sources, thus accurate aircraft noise exposure level estimation requires considerable scrutiny of environmental data. This is essential to ensure both reliable identification of aircraft events and exclusion of non-aircraft sources of noise.

61. Noise exposure patterns around airports are normally determined, in large part, by computer modelling. The methods used need to be theoretically sound, but they must incorporate real measured data on aircraft performance and noise characteristics. To ensure public confidence, the results of this modelling must be regularly validated, hence there must be regular checking through exposure measurement programmes.

Noise modelling

62. The requirements to determine noise exposure levels have led to the development of various aircraft noise exposure models. These are computer programs that calculate noise contours as functions of information describing the aircraft traffic and the way in which aircraft are operated.

63. Modelling means calculating noise exposure rather than measuring it. Calculating some aircraft noise characteristics from purely theoretical scientific principles is feasible, but it would be far too complex and computationally intensive for application in the production of noise contours. Instead, relatively simple mathematical tools combined with data about the generation and propagation of aircraft noise from a large body of measured data are used. The first step is to gather a large body of representative measured noise data for a range of aircraft types under different flight conditions. The next step is to create robust mathematical tools to estimate how noise will propagate from these noise sources. Modelling aircraft noise involves combining the noise from many individual aircraft movements. All the different types of aircraft and operations have to be taken fully into account, including their specific noise and performance characteristics following different flight paths during both arrivals and departures. It is essential to have reliable ways of estimating how sound attenuates with distance along the propagation path.

64. Models must sum the diverse sound energy inputs from the individual events over a time period that is sufficiently long (usually months rather than days). This ensures that the results are statistically reliable enough to identify differences between one situation and another. Most models calculate noise exposure levels over an array of grid points around the airports. Contours are then fitted to these point levels by mathematical interpolation.

65. These models need input information on aircraft performance and noise characteristics. Direct measurements of noise and flight paths are made. An important source of data is that collected by manufacturers as part of the certification process. Sufficient data are required to allow the model to represent all operations of importance. The data on aircraft flight paths must adequately represent actual operational air traffic patterns. This includes the way aircraft adhere to Noise Preferential Routes (NPRs) and Standard Instrument Departures (SIDs). But it must also cover the way that traffic is dispersed by air traffic control intervention (known as radar vectoring) and is sequenced on arrival.

Guidance on the use of the Aviation Environmental Design Tool (AEDT) for noise modelling

Introduction

66. This section offers guidance on the use of the Aviation Environmental Design Tool (AEDT). AEDT is produced by the US Federal Aviation Administration (FAA) and replaced the Integrated Noise Model (INM) as of May 2015. The INM was widely used for the calculation of aircraft noise in the vicinity of airports. As of March 2017, AEDT 2c gives similar if not identical results to INM 7.0d. However, the FAA now considers INM a legacy tool with no plans to update the model or its associated databases.

67. As well as replacing INM, AEDT also replaced earlier FAA models for calculating airport local air quality emissions and greenhouse gas emissions, facilitating integrated environmental analysis and assessment.

68. AEDT is one of the few models commercially available for the calculation of aircraft noise to airports and their noise consultants. Other models in common use have been developed by governments and aviation authorities and are not normally available to external agencies. AEDT is a very comprehensive aircraft noise model but the accuracy of its outputs is dependent on the quality of input data and the way in which the model is

used. The default settings for the model may not be appropriate under particular circumstances and therefore use of those default settings may generate inaccurate results.

Aircraft

69. AEDT contains data on the aerodynamic performance and noise characteristics of a large number of aircraft types. However, data for some important aircraft types are not included. A substitution list is provided for those aircraft types that do not feature within the AEDT database. Noise data used by AEDT are based on measurements carried out during the certification process for each aircraft and these may not be representative of aircraft noise measurements taken under normal operational conditions.

70. For nearly all aircraft types, the AEDT default departure profile uses maximum thrust generating the maximum climb rate. Use of maximum thrust on take-off is not a typical mode of operation for most civil jet aircraft. Engine maintenance considerations dictate a lower thrust setting on take-off than that typically assumed by AEDT. Thus the default profile can alter the modelled distribution of noise exposure on the ground compared to normal operation – i.e. in some locations it may overestimate noise exposure, while underestimating in other locations.

71. AEDT includes provision for noise modellers to provide their own aircraft performance data. Where this is not possible, for whatever reason, an alternative is to adjust the take-off mass of the aircraft by increasing the input stage length of the profile, increasing fuel load and take-off mass. Stage length defines the distance between departure airport and destination. Increased take-off mass has the effect of reducing the climb gradient calculated, making it more representative of normal operations. The noise modeller needs to use judgement in order to assess whether this approach is appropriate and, if so, the relevant stage length to apply.

72. Aircraft in flight are subject to variability in their navigational performance. This should be taken into account during noise modelling using the dispersed track function available within AEDT. This enables the noise model to account for the lateral dispersion of aircraft tracks about the mean track. This can be achieved by using data from a noise and track keeping system or radar data. If neither of these is available, a noise modeller can use guidance provided in ECAC Document 29 4th Edition Vol. 2 section 3.4.2, or use subjective judgement combined with knowledge of operations by aircraft at similar airports as an input to the AEDT dispersed track function.

Contour calculation

73. Unlike INM, AEDT does not offer the facility for rotating the axis of the calculation grid to align with the runway axis in order to avoid spurious asymmetry in the calculated contour. As a consequence, AEDT generally requires a finer grid of more closely spaced points than was necessary for INM.

74. How grid spacing is defined is dependent on the grid type chosen. AEDT gives the noise modeller the ability to choose and/or alter the type of calculation grid used, from which noise contours are calculated. How the calculation grid is defined affects the accuracy and validity of contours produced. AEDT permits two types of calculation grid, 'Dynamic Grid', and 'Grid'. Dynamic Grid is an irregular grid, where AEDT subdivides grid cells according to a user input parameter 'Refine Tolerance for LinearINMLegacy'. This is a decibel threshold value at which point the grid subdivides into smaller cells to increase grid resolution. The recommended value for Refine Tolerance is 0.1dB.

75. Alternatively 'Grid' defines a regular structure with equally spaced grid points. For this setting a grid spacing of 50 to 100m for both X and Y directions is recommended.

Climate change and CO_2 emissions

76. The Department for Transport's Aviation Policy Framework[3] sets out the priorities for action on climate change at global, EU and national levels in the aviation context.

77. In addition, the Department for Transport's guidance to the CAA on airspace and noise management and environmental objectives[4] recognises that aviation is a contributor to greenhouse gas emissions that cause climate change. It states that:

"the CAA has the opportunity to contribute to the Government's aim of reducing CO_2 emissions by seeking to promote the most efficient use of airspace including procedures that enable aircraft to climb efficiently, allow direct routings, reduce holding times and facilitate the consistent use of continuous descent and low power/low drag procedures. This is referred to as flight efficiency and has the potential to reduce CO_2 emissions. The potential to maximise flight efficiency is primarily above 7,000 feet where local community impacts are not a priority. Flight efficiency is also possible below 7,000 feet, although between 4,000–7,000 feet it should be balanced with noise environmental impacts."

78. Change sponsors must demonstrate how the design and operation of airspace will impact on emissions. The kinds of questions that need to be answered by the change sponsor are:

- are there options which reduce fuel burn in the vertical dimension, particularly when fuel burn is high for example, initial climb?
- are there options that produce more direct routeing of aircraft, so that fuel burn is minimised?

3 Aviation Policy Framework, Department for Transport, March 2015. This is expected to be replaced by a new aviation strategy in 2018.

4 As noted at the start of this document, the text in this document refers to the policy proposals and draft guidance on which the Department for Transport is currently consulting.

- are there arrangements that ensure that aircraft in cruise operate at their most fuel-efficient altitude, possibly varying altitude during this phase of flight?

79. It must of course be recognised that airspace design and operation is only one element in determining the quantity of aircraft emissions. The design of aircraft and engines, general growth of air traffic, capacity and load factors of aircraft, airline operating procedures and other factors will all have an influence on aircraft emissions, although these factors are outside the scope of the airspace change process.

80. For the purposes of the assessment of airspace change proposals, it is deemed sufficient to estimate the mass of CO_2 emitted for different options considered. This can be calculated by multiplying the mass of kerosene burned during flight by a factor of 3.18. Determining the quantities of other emissions is considered to be too complex and scientific understanding of the impact too poor for inclusion in environmental assessment of airspace change proposals.

81. The mass of fuel burned and, therefore, CO_2 emitted can be derived from a range of aircraft performance models and simulators. An example is the EUROCONTROL Base of Aircraft Data (BADA) model.

82. Change sponsors must estimate the total annual fuel burn/mass of CO_2 in metric tonnes emitted for the current situation, the situation immediately following the airspace change and the situation after traffic has increased under the new arrangements – 10 years after implementation. Change sponsors must provide the input data for their calculations including any modelling assumptions made. They must state details of the aircraft performance model used including the version numbers of software employed.

Local air quality

83. Action to manage and improve air quality is largely driven by European (EU) legislation. The 2008 ambient air quality directive (2008/50/EC) sets legally binding limits for concentrations in outdoor air of major air pollutants that impact public health such as particulate matter (PM_{10} and $PM_{2.5}$) and nitrogen dioxide (NO_2). As well as having direct effects, these pollutants can combine in the atmosphere to form ozone, a harmful air pollutant (and potent greenhouse gas) which can be transported great distances by weather systems.

84. The 2008 Directive replaced nearly all the previous EU air quality legislation and was made law in England through the Air Quality Standards Regulations 2010, which also incorporates the 4th air quality daughter directive (2004/107/EC) that sets targets for levels in outdoor air of certain toxic heavy metals and polycyclic aromatic hydrocarbons. Equivalent regulations exist in Scotland, Wales and Northern Ireland.

85. Separate legislation exists for emissions of air pollutants with the main legislation being the UNECE Gothenburg Protocol which sets national emission limits (ceilings) for SO_2, NO_X, NH_3 and volatile organic compounds for countries to meet from 2010 onwards. Similar ceilings have since been set in European law under the 2001 National Emission Ceilings Directive (2001/81/EC), which was subsequently made into UK law as the National Emission Ceilings Regulations 2002.

86. In the UK, responsibility for meeting air quality limit values is devolved to the national administrations in Scotland, Wales and Northern Ireland. The Secretary of State for Environment, Food and Rural Affairs has responsibility for meeting the limit values in England and the Department for Environment, Food and Rural Affairs (Defra) co-ordinates assessment and air quality plans for the UK as a whole.

87. The UK Government and the devolved administrations are required under the Environment Act 1995 to produce a national air quality strategy. This was last reviewed and published in 2007. The strategy sets out the UK's air quality objectives.

88. Part IV of the Environment Act 1995 and Part II of the Environment (Northern Ireland) Order 2002 require local authorities in the UK to review air quality in their area and designate Air Quality Management Areas (AQMAs) if improvements are necessary. An AQMA may encompass just one or two streets, or it could be much bigger. Where an AQMA is designated, local authorities are also required to work towards the strategy's objectives prescribed in regulations for that purpose. An air quality action plan describing the pollution reduction measures must then be put in place. These plans contribute to the achievement of air quality limit values at local level.

89. The Department for Transport's guidance on the environmental objectives issued to the CAA states that while the CAA should prioritise noise below 4,000 feet, consistent with the altitude-based priorities and the Government's policy to give particular weight to the management and mitigation of noise in the immediate vicinity of airports, there could be circumstances where local air quality may be a consideration because emissions from aircraft taking off, landing or while they are on the ground have the potential to contribute to overall pollution levels in the area. This could lead to a situation where prioritising noise creates unacceptable costs in terms of local air quality or might risk breaching legal limits. The CAA should therefore take such issues into account when it considers they are relevant, for example, when determining airspace changes affecting the initial departure or the final arrival stage of a flight.

90. Due to the effects of mixing and dispersion, emissions from aircraft above 1,000 feet are unlikely to have a significant impact on local air quality. Therefore the impact of airspace design on local air quality is generally

negligible compared to changes in the volume of air traffic, and local transport infrastructures feeding the airport. However, airspace change sponsors should include consideration of whether local air quality could be impacted when assessing airspace change proposals.

91. Change sponsors must produce information on local air quality impacts **only** where there is the possibility of pollutants breaching legal limits following the implementation of an airspace change. The CAA deems that this is only likely to become a possibility where:

- there is likely to a change in aviation emissions (by volume or location) below 1,000ft, and
- the location of the emissions is within or adjacent to an identified AQMA.

92. If both conditions are met and an assessment of local air quality is required, modelling of impacts must be undertaken using a recognised and validated emissions model such as ADMS-Airport or AEDT. Concentrations should be portrayed in microgrammes per cubic metre ($\mu g.m^{-3}$). They should include concentrations from all sources whether related to aviation and the airport or not. Four sets of concentration contours should be produced:

- current situation – these may already be available as part of the airport's regular environmental reporting or as part of the airport master plan
- situation immediately following the airspace change
- situation after traffic has increased but assuming the proposed change has not been implemented – 10 years after the proposed implementation date
- situation after traffic has increased under the new arrangements – 10 years after the proposed implementation date.

Tranquillity

93. The consideration of impacts upon tranquillity is with specific reference to National Parks and Areas of Outstanding Natural Beauty (AONB), plus any locally identified 'tranquil' areas that are identified through community engagement and are subsequently reflected within an airspace change proposal's design principles.

94. The Department for Transport's Air Navigation Guidance recognises that given the finite amount of airspace available, it will not always be possible to avoid overflying National Parks or AONBs, and that there are no legislative requirements to do so as this would be impractical. The Government's policy continues to focus on limiting and, where possible, reducing the number of people in the UK significantly affected by aircraft noise and the health impacts it can bring. As a consequence, this is likely to mean that one of the key principles involved in airspace design will require avoiding overflight of more densely populated areas below 7,000 feet. However, when airspace changes are being considered, it is important that local circumstances, including community views on specific areas that should be avoided, are taken into account where possible. Therefore, in line with the Department for Transport's altitude-based priorities, airspace change sponsors are encouraged, where it is practical, to avoid overflight of National Parks or AONBs below 7,000 feet.

95. In terms of portraying 'tranquillity' or any impacts upon it, there is no universally accepted metric by which tranquillity can be measured, although some attempts have been made. For example, Campaign to Protect Rural England (CPRE) presented a set of tranquillity maps for England in October 2006.[5] However, it is not obvious how such a methodology could be reliably adapted for aircraft noise. Indeed, discussions with the researchers who produced the maps indicated the

[5] http://www.cpre.org.uk/what-we-do/countryside/tranquil-places

difficulties in applying such maps for the purposes of assessing the environmental impact of an airspace change.

96. The CAA will maintain a watch on research and ideas about the definition and measurement of tranquillity, but no formal guidance can be issued at present. Change sponsors may use the techniques described under operational diagrams to communicate to consultees how the airspace will be used. Assessment by the CAA of these aspects will be on a case-by-case basis until methodologies are well established.

Additional reports relevant to airspace change proposals

ERCD Report 0904: Metrics for Aircraft Noise

97. This paper provides an overview of the metrics used to measure aircraft noise. The review outlines the methods used to measure noise internationally and the main strengths and weaknesses of each metric.

ERCD Report 1104: Environmental Metrics for FAS

98. This report describes a selection of metrics that may be used to quantify and explain various environmental impacts. There are primary impacts, which can be thought of as direct environmental indicators, and also secondary measures, which are not directly related, but which may be associated with or resulting from the primary metrics. The aim of the report is to include descriptions of a selection of metrics that have been consulted upon as part of the development of the Future Airspace Strategy (FAS). It should be noted that the inclusion of such metrics in this report does not necessarily mean they are in actual use at present.

CAP 1378: Airspace Design Guidance: Noise Mitigation Considerations when Designing PBN Departure and Arrival Procedures

99. This document explores the impacts and possibilities of using Performance-Based Navigation (PBN) routes to mitigate noise impacts.