Environmental Research and Consultancy Department

Civil Aviation Authority

ERCD REPORT 0406

Techniques used by ERCD for the Measurement and Analysis of Aircraft Noise and Radar Data

S White

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Summary

The Environmental Research and Consultancy Department (ERCD) of the Civil Aviation Authority provides a range of research and advisory services in the field of aviation and the environment. This report describes the equipment and techniques used by ERCD for the measurement and analysis of noise and radar data for that purpose. This report supersedes CAA report CAP 544 "Noise Measurement Equipment and Techniques used by the Directorate of Operational Research and Analysis".

January 2005

The author of this report is employed by the Civil Aviation Authority. The work reported herein was carried out under a Letter of Agreement placed on 30 June 2004 by the Department for Transport. Any views expressed are not necessarily those of the Secretary of State for Transport.

ISBN 1 904862 13 6

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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.

Published by TSO (The Stationery Office) on behalf of the UK Civil Aviation Authority.

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Contents

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Glossary of Terms

A-weighting	A frequency weighting that is applied to the electrical signal within a noise-measuring instrument as a way of simulating the way the human ear responds to a range of acoustic frequencies.
aal	Above Aerodrome Level
ANMAC	Aircraft Noise Monitoring Advisory Committee. The committee is chaired by the Department for Transport and comprises representatives of the airlines, Heathrow, Gatwick and Stansted airports and airport consultative committees.
BAA	BAA plc, the company that owns and operates, amongst others, Heathrow, Gatwick and Stansted airports.
dB	Decibel units describing sound level or changes of sound level. It is used in this report to define differences measured on the dBA scale.
dBA	dBA is used to denote the levels of noise measured on an A-weighted decibel scale.
FDR	Flight Data Recorder (or Quick Access Recorder).
FL	Flight Level, the pressure altitude in hundreds of feet at specified intervals (e.g. a pressure altitude of 12,000 ft is also known as a Flight Level of 120).
GIS	Geographic Information System
GPS	Global Positioning System
ILS	Instrument Landing System
ISO	International Organisation for Standardisation
Leq	Equivalent sound level of aircraft noise in dBA, often called equivalent continuous sound level.
Lmax	The maximum A-weighted sound pressure level of an aircraft noise event.
NATS	National Air Traffic Services Ltd. NATS provides air traffic control services at several major UK airports, including Heathrow, Gatwick and Stansted.
NTK	Noise and Track Keeping monitoring system. The NTK system at the London airports associates radar data from air traffic control radar with related data from specially positioned noise monitors.
QNH	Altimeter sub-scale setting to obtain altitude relative to mean sea level.
SEL	The Sound Exposure Level generated by a single aircraft at the measurement point, measured in dBA. This accounts for the duration of the sound as well as its intensity.
SSR	Secondary Surveillance Radar. SSR data provide aircraft positional information based on range, azimuth and Flight Level.

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1 Introduction

1.1 The Environmental Research and Consultancy Department[1] (ERCD) of the CAA provides a range of research and advisory services in the field of aviation and the environment. This includes the production of annual noise exposure contours for the three London airports, as well as for other regional airports and local authorities in the UK. Over the past 40 years or so, it has built up considerable expertise in aircraft noise modelling and monitoring.

1.2 Much of ERCD's noise monitoring work is undertaken on behalf of the UK Department for Transport (DfT) and overseen by the Aircraft Noise Monitoring Advisory Committee (ANMAC)[2]. This work involves the collection and analysis of aircraft noise, radar and FDR information and other operational data. Recent tasks carried out for the DfT have included the provision of data in support of a review of the departure noise limits and an assessment of the efficacy of the Quota Count system at the London airports.

1.3 At Heathrow, Gatwick and Stansted, routine noise and flight path monitoring is carried out continuously by the airports' Noise and Track Keeping (NTK) systems. The NTK system at each airport matches air traffic control radar data (i.e. aircraft flight paths) to related noise measurements from noise monitors at prescribed ground positions. ERCD obtains data from the airports' NTK systems via its own dedicated server. An overview of the current NTK system is provided in Appendix A. For specialist projects, ERCD also uses its own noise monitoring equipment to measure aircraft noise levels at other relevant locations.

1.4 This report describes the techniques used by ERCD for measuring and analysing noise and radar data from aircraft operations; in particular, at Heathrow, Gatwick and Stansted airports. This report supersedes CAA report CAP 544 "Noise Measurement Equipment and Techniques used by the Directorate of Operational Research and Analysis" (Ref 1). It should be noted however that this document does not provide a technical description of the UK civil aircraft noise contour model (ANCON) - the precise methods by which noise exposure contours are calculated by ERCD are described separately in References 2 and 3.

2 Noise Measurement Equipment

2.1 NTK noise monitors

2.1.1 ERCD obtains the majority of its noise data for research purposes via the BAA London airports' NTK system. The system currently comprises 10 fixed (permanent) noise monitors at Heathrow, 5 at Gatwick and 8 at Stansted. The fixed monitors are positioned at approximately 6.5 km from the start-of-roll positions and are operated by BAA to monitor aircraft that exceed the departure noise limits.

2.1.2 In addition to the fixed monitors, a pool of approximately 25 mobile (temporary) noise monitors is shared among the three London airports and the CAA. These can be deployed anywhere inside the NTK radar coverage area (see paragraph 4.1.2). The locations of the monitoring sites used over the past few years around the London airports, including the current fixed monitors, are shown in **Figures 1 to 3**. Typically,

[1] This department was previously part of the Directorate of Operational Research and Analysis (DORA).

[2] ANMAC advises the Government on policy relating to aircraft noise at Heathrow, Gatwick and Stansted airports.

ERCD will deploy 4 to 6 mobile noise monitors at a particular airport to supplement data from the fixed noise monitors for noise model validation. This means that during the 92-day summer contouring period (16 June to 15 September), more than 250,000 noise measurements are usually collected and analysed at each airport.

2.1.3 The NTK noise monitors differ from conventional hand-held precision sound level meters only in so far as they have to be weatherproof and vandal-proof, so they can be left unattended over long periods of time; the applicable international standards with which they conform are the same (Refs 4 and 5)[3]. The noise measuring equipment in each NTK monitor (fixed and mobile) comprises the following precision instrumentation:

– Larson Davis Model 870 integrating sound level meter (IEC 60651 Type 1)
– Larson Davis Model 875 1/3-octave band real time analyser[4]
– Larson Davis Model 2541 free-field microphone

Technical details on the equipment listed above can be found on the Larson Davis website (http://www.lardav.com/).

2.1.4 The microphones of the fixed and mobile NTK monitors are positioned on masts approximately 6 m and 3.5 m above ground level respectively[5]. **Figures 4 and 5** show typical examples of the fixed and mobile monitor set-ups. Two fixed monitors at each airport are also fitted with additional equipment to record meteorological data. However, because the NTK weather units are currently not routinely calibrated, meteorological measurements for ERCD studies are generally obtained from UK Meteorological Office stations at or near each airport (see paragraph 5.3.4).

2.1.5 Apart from the microphone heights, the main distinction between the fixed and mobile monitors is the way in which each unit is powered and serviced. The fixed monitors are generally connected to the NTK terminals at each airport by means of standard telephone lines (to download the stored data) and are serviced by mains power. However, some fixed sites can only be powered by batteries charged by solar panels, and are equipped with a mobile phone for data transmission.

2.1.6 The mobile monitors are stand-alone units that require on-site visits (typically weekly) to download the data onto a laptop PC and to replace the batteries (the mobile noise data are usually transferred from the laptop to the NTK system within a few days of downloading). Mobile phone connections and solar panels can also be used for mobile sites where regular access is restricted.

2.1.7 When a new fixed or mobile noise monitor is installed, a sound calibration check is performed on-site (and every three months thereafter) using a Larson Davis Model CAL250 calibrator. Daily electrostatic calibration checks are also carried out automatically to confirm the day-to-day performance of the NTK system. Once a year, all noise measuring equipment is removed from service and calibrated externally by an approved calibration agency. This calibration is traceable to UK National Standards.

[3] In May 2002, IEC 60651 and IEC 60804 were replaced by IEC 61672-1 (the new international standard for sound level meters), which specifies two performance categories, Class 1 and Class 2. The new Class 1 standard is broadly equivalent to the previous Type 1 grade of IEC 60651.

[4] The Model 875 analyser is only installed at particular sites when there is a need to monitor Effective Perceived Noise Level (EPNL). This involves analyses of the frequency spectra of noise events as well as the duration of the sound.

[5] The microphones are orientated at an angle of 0° relative to overhead (i.e. pointing straight up).

2.2 Handheld noise monitors

2.2.1 In some situations it is necessary to carry out ‘attended’ noise measurements (see Section 3). For this purpose, ERCD possesses a range of hand-held Type 1 precision sound level meters, which are capable of 1/3-octave band noise measurements. These are often used in conjunction with professional DAT recorders, enabling detailed analyses of environmental noise to be carried out off-site.

2.2.2 ERCD’s current noise measuring equipment consists of the following:

- Brüel & Kjær Type 2260 integrating sound level meter kit
- Brüel & Kjær Type 4226 multifunction sound calibrator
- CEL 593.C1 integrating sound level meter kit (x2)
- Sony TCD-D10 DAT recorder (x2)

Technical details on the sound level meters listed above can be found on the Brüel & Kjær (http://www.bksv.com/) and CEL (http://www.casellacel.com/) websites.

2.2.3 Before and after each series of attended measurements, an on-site sound calibration check is carried out to verify the accuracy of the sound level meter. Each sound level meter and sound calibrator currently in use is also sent to an approved calibration agency on an annual basis to be checked against the relevant UK National Standards.

3 Noise Measurement Techniques

3.1 Attended and unattended monitoring

3.1.1 Noise measurements can either be *attended* or *unattended*. The main advantages and disadvantages of each method are summarised in **Table 1**.

3.1.2 With attended measurements, an observer is needed on site at the noise monitor to note down information relating to each noise event. This method is particularly useful where identification of the noise source is difficult, but it is labour intensive and uneconomical especially when large numbers of readings are required. For this reason, unattended measurements from the NTK noise monitors are very often used, since the equipment can be left alone for long periods after set-up to record aircraft noise events. Nowadays, technological advances have meant that noise monitors can be left alone for days or weeks on end, requiring only an occasional maintenance visit for data download and battery replacement.

3.1.3 Initially it may be appropriate to conduct some attended measurements to determine whether a site is suitable for longer term, unattended monitoring. It might also be considered useful to perform attended measurements after a long period of unattended monitoring as a check.

3.2 Considerations for noise monitoring sites

3.2.1 Normally the choice of measurement site is determined by it being at a certain distance along the flight path, in a particular area or at a specific address. Additional requirements are that the noise monitoring site should be free from excessive ambient (background) noise, free of nearby obstructions such as trees and buildings, and of any large reflective surfaces, and also over flown by as many (required) aircraft as possible. The intervening ground should also be flat with relatively soft or grassy ground cover (see paragraphs 3.4.1 - 3.4.3). However, in practice it is usually necessary to compromise slightly between all these requirements to ensure that the selected sites are also secure and accessible.

3.2.2 Additional considerations for any new fixed or mobile NTK monitor sites are:

- Accessibility for installation and for routine servicing (for fixed sites, building works are required to lay a concrete base and to install the mast and equipment)
- Security and likelihood of vandalism (monitors and their associated equipment have been damaged and destroyed in the past by vandals).
- Land ownership – permissions, restrictions, inconvenience to owner/occupier.
- Possibility for installation of power and telephone connections (for fixed sites). It is now also possible under certain circumstances to operate fixed sites with solar panels charging suitable batteries and with mobile phone technology. This is used particularly at Stansted but also at some of the Heathrow monitors, but this incurs costly routine visits especially during winter months when battery changes often become necessary. Also, the presence of adjacent trees can seriously affect the performance of solar panels, and the panels can be an attractive target for vandals/thieves.

3.2.3 An important factor that can influence the accuracy of any noise measurement is the level of general background noise, which should be as low as possible in order to minimise the influence of non-aircraft noise sources. Ideally, the background noise level should be at least 10 dB below the maximum noise levels of the quietest aircraft types of interest. This factor additionally limits the range of sites that may be used, particularly at greater distances from the airports.

3.3 Typical measurement practices

3.3.1 For attended monitoring, a microphone extension cable is usually fitted to the sound level meter and the microphone raised to a height of 4 m using a special telescopic mast. However, for situations where it is impractical to monitor at 4 m, the sound level meter is normally set up on a standard tripod with the microphone positioned at a height of 1.2 m above ground - see **Figures 6 and 7**.

3.3.2 Before measurements are conducted, the sound level meter is calibrated with a sound calibrator using a pure tone of 94 dB or 114 dB at 1 kHz and the calibration data recorded. A windshield is then fitted to the microphone and a reading of the general background noise level taken. In addition, a note is made of the prevailing atmospheric conditions such as wind strength and direction. A map may also be sketched showing the monitoring location, the position of neighbouring objects, and the nature/state of the ground between the source and receiver. The measurement position may also be surveyed using GPS equipment to determine an exact location.

3.3.3 Depending on the monitor location, noise events may be picked up from other sources such as non-local aircraft flyovers or nearby road traffic. To ensure that extraneous noise events are not recorded during attended monitoring, the meter is usually set up to record the duration of individual aircraft noise events by manually pressing the ‘start’ and ‘stop’ instrument keys. Alternatively, aircraft noise events can be ‘detected’ automatically by means of a user determined threshold trigger level and minimum event duration[6]. For unattended monitoring, optimal configuration of these key parameters can reduce the likelihood of recording extraneous noise events. Generally, threshold levels between 55 dBA and 65 dBA are used at NTK monitoring sites around the London airports, depending on the general level of ambient noise, with typically a 5 second value for minimum event duration.

[6] Triggering occurs when the measured noise level exceeds the threshold level for longer than the user determined minimum duration.

3.3.4 It is normal practice for aircraft noise measurements to be made using the A-weighting filter and 'slow' response settings. Most modern sound level meters have the facility to measure and store a large number of noise parameters concurrently (i.e. broadband, statistical and spectral). However, as a minimum, the maximum sound level (Lmax) and Sound Exposure Level (SEL) of each noise event are usually recorded.

3.3.5 For each event recorded during attended monitoring, the measurement date and start/end times are noted, and the sound source under investigation is described. Any unrelated events of significance during the measurement period are also noted, e.g. extraneous noise from a passing car.

3.3.6 Following completion of the measurements, the sound level meter is calibrated once again to check for any measurement drift. If a significant calibration drift is recorded over the measurement period, it is likely that the equipment could have developed a fault. In such cases, the noise measurements would be discarded and the equipment returned to the manufacturer for servicing.

3.4 Effect of microphone height on measured noise levels

3.4.1 Measured aircraft noise levels can depend on the height of the microphone above the ground surface. This is because sound arrives at the microphone directly from the source and also as ‘echos’ from nearby reflecting surfaces - including the ground itself. True ‘free-field’ measurements can only be obtained from microphones positioned in reflection-free locations. As the ground cannot normally be avoided, this usually requires that the ground surface in the vicinity of the reflection point is acoustically ‘soft’; i.e. sound-absorptive. Monitors are generally sited in non-obstructed areas with soft or grassy ground cover; surfaces to avoid include asphalt, concrete or water, all of which are acoustically ‘hard’.

3.4.2 For most of ERCD’s attended measurement exercises, microphones are placed at a height of 4 m above the ground surface to reduce the likelihood of interference from ground objects. If it is required for a particular noise study, or if it is impractical to measure at 4 m, measurements are recorded at a standard microphone height of 1.2 m. By comparison, the NTK microphones are mounted either 6 m (fixed) or 3.5 m (mobile) above the ground surface, both to minimise the risks of vandalism and also to reduce interference from ground objects.

3.4.3 It is considered unlikely that the differences between these microphone heights would cause any significant mismatch between the recorded noise levels - provided of course that monitors are sited in non-obstructed areas with relatively soft or grassy ground cover. This is because, unless the ground surface is highly reflective, differences would only arise at low elevation angles (between the direction of sound propagation and the ground surface). As data for elevation angles less than 60 degrees are usually excluded for ERCD studies (see paragraph 5.1.5), the effects would be negligible. This has been checked by ERCD on various occasions by comparing aircraft noise levels measured simultaneously (over soft ground) at different microphone heights (between 1.2 m and 6 m). These checks revealed no significant (or consistent) difference between pairs of measurements recorded at the different heights above the ground. Thus, aircraft noise measurements are recorded at the different microphone heights without the need for adjustments.

4 Flight Path Information in the NTK System

4.1 Secondary Surveillance Radar

4.1.1 NTK data on aircraft position and height are obtained from the National Air Traffic Services (NATS) Secondary Surveillance Radar (SSR). Radar 'returns' for each aircraft are given for each revolution of the radar head, typically about once every four seconds. The radar returns provide range (distance between the head and the aircraft) and azimuth (angle relative to north) information, which are converted by the NATS Radar Data Filtering and Processing System to positional data relative to an airfield reference point. The Mode C transponder on the aircraft provides the SSR code ('squawk') and the Flight Level (FL).

4.1.2 The current area of radar coverage in the NTK system at Heathrow is a rectangular area 50 nm (east to west) by 40 nm (north to south), centred on the airfield. The areas of coverage at Gatwick and Stansted are slightly less than this. Currently, heights up to 10,000 ft aal are covered in the NTK systems (17,000 ft at Heathrow).

4.1.3 The NATS radar data are transferred to the NTK system at each airport and then correlated to all relevant aircraft noise measurements; see Appendix A for further details. The NTK data at Heathrow, Gatwick and Stansted airports are then replicated on ERCD's NTK system, which holds data recorded since 1996.

4.2 Accuracy of NTK data

4.2.1 It should be noted that the London airports' NTK system does not in itself add any inaccuracy to the data input to it. To confirm this, ERCD undertook a study to assess the general accuracy of the flight path information contained in the NTK system (Ref 6). For that study, airline FDR data and data recorded on board an ILS calibration aircraft were used by ERCD to check the NTK height and position data. The results indicated that the NTK height data are on average accurate[7] to within ±20 ft. Positional accuracy was found to be within 40 m for the flights analysed. It is therefore concluded that the NTK data are of sufficient accuracy for the studies undertaken by ERCD.

4.2.2 Furthermore, because ERCD studies are generally based on large samples of data rather than individual flights, the effect of much of any possible inaccuracy in the data is mitigated. It is also known that the NTK approach tracks align accurately with the runway centrelines, providing confidence that the NTK tracks are satisfactory, but calibration checks such as those described in Reference 6 provide information at points further away from the airport.

5 Analysis of Radar and Noise Data

5.1 Calculation of slant distance and angle of elevation

5.1.1 For most ERCD studies, NTK radar data are required to position arriving and/or departing aircraft with respect to the noise monitors on the ground. Once the source-to-receiver geometry is known, it is then possible to quantify the measured aircraft noise levels as a function of the 'slant distance', which is the closest distance of the receiver point from the aircraft flight path[8]. However, the current NTK system

[7] In keeping with common usage, the term 'accuracy' is used quantitatively in this report although, strictly speaking, it is a qualitative concept.

[8] The slant distance is often referred to as the 'Point of Closest Approach' (PCA).

software does not calculate the 'true' slant distance. Instead, the 'direct distance' of an aircraft with respect to each noise monitor *at the time of Lmax* is calculated.

5.1.2 Although there is nothing technically wrong with the NTK calculation method, it does rely on precise time synchronisation between the noise monitors and the radar data: if the time stamp of the radar data and the clocks in the noise monitors differ[9] by just one or two seconds, then the NTK values of direct distance will not correspond to the aircraft-monitor geometry at the actual time of Lmax. Therefore, in order to provide a more reliable and consistent basis with which to compare aircraft noise levels recorded at different noise monitors/airports, the slant distances are required. This is achieved by extracting the raw radar points from the NTK system and analysing the data on standard PCs using specially developed ERCD software (although for modern Chapter 3 aircraft where there is little longitudinal directivity, the position of the aircraft at the closest distance will be very close to the time of Lmax).

5.1.3 In ERCD's radar analysis program, the radar data are first smoothed using a three-stage centre-averaging algorithm - a process which is widely recognised internationally for this purpose (Refs 7 and 8). Locations between these smoothed radar 'node' points are then estimated using a localised polynomial fit of each of x, y and z (height) value, independently of time. Closest distances (slant distances) to noise monitors are then found non-analytically, taking into account also any differences in ground elevation between the heights of the monitors and the runway. In addition to the slant distance information, ERCD's radar analysis software also calculates the aircraft height and angle of elevation for each aircraft/monitor at the aircraft's closest point - see **Figure 8**.

5.1.4 For some specialist studies it is also useful to have an indication of aircraft bank angle, since it can have a significant effect on noise levels on the ground (due to lateral directivity of the aircraft noise sources). Because bank angle can be inferred from aircraft speed and turn radius, it too can be readily estimated from an analysis of the smoothed radar data[10]. Comparisons with actual aircraft FDR data have shown that the methodology used by ERCD is robust and that the bank angle estimation errors are relatively small.

5.1.5 Once processed, the flight path information can be imported (as comma-separated text) into a relational database application and then screened if necessary to minimise potential errors due to the effects of lateral attenuation[11] by excluding data from aircraft passing more than 30 degrees from overhead of the noise monitors (i.e. at angles of elevation less than 60 degrees at the point of closest approach).

5.2 Flight profile and mean track analysis

5.2.1 A major aspect of ERCD's noise work involves the production of annual Leq noise contours for the three London airports using the UK civil aircraft noise contour model,

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[9] Although procedures are put in place to ensure that all noise monitors are kept synchronised as far as practicable with UTC (Coordinated Universal Time), a difference of a few seconds is permitted by the NTK system software before a monitor's internal clock is automatically resynchronised.

[10] In the presence of a wind, an aircraft's motion relative to the ground, and therefore its radar track, is not truly representative of its 'flight configuration'. However, for most purposes it can be assumed that the effect of wind on aircraft bank angle is relatively insignificant.

[11] Lateral attenuation is the term used to describe the difference in level between noise radiated downwards and that propagated to the side of an aircraft flight track. Naturally, for certain specialist noise studies data may actually be required at elevation angles less than 60 degrees, but normal practice is to exclude such events so that the noise measurements reflect that of an aircraft overhead.

ANCON (Refs 2 and 3). Ideally, all individual radar tracks would be used to model aircraft noise exposure in the vicinity of an airport. However, with current PC technology, limitations on processing speed make it impractical to consider each aircraft movement separately. Instead, the actual distribution of flight tracks (vertically and laterally) is simplified for modelling purposes by using averaged flight and track profiles.

5.2.2 Mean profiles of height and speed against track distance are calculated separately for each aircraft type at each airport (for both arrivals and departures) from an analysis of raw NTK radar data points using ERCD's specialised radar analysis program. The calculated flight profiles are then subdivided into appropriate linear segments for modelling purposes. **Figure 9** shows an example of the calculated mean height and speed profiles for a sample of Boeing 757-200 departures at Gatwick. For each mean profile, the engine power settings are then estimated using the equations of motion of the aircraft.

5.2.3 Because ANCON uses input data based on observed flight profiles, the estimated power settings (and noise emission) reflect typical airport operation. In contrast, some noise models make generic assumptions regarding power settings and aircraft performance that may not reflect typical operations at the relevant airports.

5.2.4 Accurate noise exposure estimation also requires a realistic simulation of the lateral scatter of flight tracks actually observed in practice. ANCON uses mean ground tracks for each departure route, which are calculated from an analysis of NTK radar data using ERCD's radar analysis software. Also calculated are the proportions of traffic allocated to each route. In order to reflect the actual track dispersion along each departure route, a number of symmetrically spaced dispersed tracks are established. The dispersed departure tracks are based on the statistical variations (i.e. standard deviations) of individual flight paths about each mean track. **Figure 10** shows an example of the mean and dispersed tracks calculated for a sample of departures at Heathrow.

5.2.5 Prior to joining the ILS for final approach, the dispersion of arriving aircraft are modelled by clustering the individual radar tracks onto mean arrival 'spurs'. **Figure 11** shows an example of the modelled approach spurs for a sample of Heathrow arrivals. It can be seen from **Figure 11** that aircraft which have not yet joined the ILS have very little impact on the outer 57 dBA Leq noise contour. It should also be noted that the individual arrival tracks are not distributed across each mean spur in the same way as for departures. Again, the dispersed tracks for both arrivals and departures are calculated using ERCD's specialised radar analysis software.

5.3 Analysis of noise data

5.3.1 The 'noise-to-track' matching algorithm in the current NTK system relies on the time synchronisation between the noise monitors and the radar data. For each recorded noise event, the NTK software determines whether an aircraft passed within a user defined zone around the noise monitor at the time of Lmax. If an aircraft is found, then the software correlates the noise event with that particular flight.

5.3.2 Because of the current nature of operations at the London airports (i.e. the single runways at Gatwick and Stansted, and the segregated mode of operation at Heathrow), it is unlikely, for noise monitors near these airports, that another aircraft would be passing nearby a monitor at around the same time, and so a clock difference of several seconds can usually be tolerated before noise-to-track matching will be affected. Typically, for a monitor that has been carefully set-up and positioned underneath an arrival or departure route, the NTK system software correlates at least 95% of recorded noise events with aircraft operations.

5.3.3 In order to match the NTK noise events for each flight with the corresponding slant distance information (see paragraphs 5.1.1 to 5.1.5), the noise data are exported from the NTK system as comma-separated text and imported into a relational database.

5.3.4 To ensure that noise measurements collected for ERCD studies are as reliable as possible, aircraft noise levels recorded under extreme meteorological conditions are typically excluded from analysis to limit data scatter and the effects of extreme weather variations as much as possible. Mean hourly weather readings, recorded 10 m above ground, are obtained from the UK Meteorological Office stations at each airfield and combined with the NTK noise data. Measurements are then rejected if they do not meet the following criteria recommended by ISO (Ref 9):

- no precipitation;
- wind speed less than 10 kts.

5.3.5 However, for some specialist studies additional screening may be required in order to minimise the effects of atmospheric absorption. If this is necessary, noise measurements are rejected if the values of relative humidity and temperature are such that the sound attenuation in the one-third octave band centred on 8 kHz is greater than 10 dB/100 m (Ref 9).

5.3.6 Even if noise monitors are positioned exactly along noise preferential departure routes or final approach paths, aircraft will rarely fly directly overhead, and a lateral scatter of flight tracks is observed in practice. Therefore, to account for the different slant distances due to the scattering of tracks, adjustments can be made to the measured levels so that they correspond instead to the *heights* of the aircraft above the ground (at a given track distance from the airport). These adjustments are usually made using industry supplied (but locally validated) 'Noise-Power-Distance' (NPD) relationships (Ref 10), which give noise level as a function of engine power at different slant distances from the aircraft.

5.3.7 After screening for unfavourable meteorological conditions and (if necessary) accounting for any lateral deviations from overhead of the noise monitors, the noise data can then be grouped into appropriate aircraft type categories for final analysis. Typically, the groupings are based on specific airframe and engine combinations (e.g. Boeing 767-300 with PW4060 engines). However, for some studies it may be necessary to subdivide even further, for example, by maximum certificated takeoff or landing weight, airline operator, or airport of origin/destination.

6 Conclusion

6.1 This report has described the current techniques used by ERCD to measure and analyse aircraft noise and radar data. ERCD is confident, on the basis of the monitoring and calibration methods described above, and from its knowledge of standards and studies elsewhere in the world, that these methods represent robust good practice and deliver data that are more than sufficiently accurate for the types of studies undertaken.

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Table 1 Advantages and Disadvantages of Attended and Unattended Monitoring

Method	Advantages	Disadvantages
Attended	Only noise events of interest are measured; Intrusion from extraneous noise sources can be identified at time of measurement and the contaminated data discarded; Higher probability of positive identification of noise source; Flexibility in choice of measurement location (i.e. no need for a secure site); Position of aircraft overhead relative to monitor can be noted.	Highly labour intensive; Vehicle probably required for each site; Only limited numbers of readings are practical; Using ERCD noise equipment for attended monitoring usually requires manual matching of noise events to NTK aircraft operations data.
Unattended	Cost effective for taking readings of large numbers of events, particularly when the events are irregular or infrequent; Several monitoring sites can be set up or serviced per day by one operator; Operation possible for 24 hours a day.	Measurements can often include unwanted events; Closely spaced events can be misinterpreted as a single event; Difficult to identify extraneous noise sources, thus individual noise events may be highly contaminated; Equipment needs to be set up in a secure location (e.g. private garden), thus choice of suitable locations may be limited.

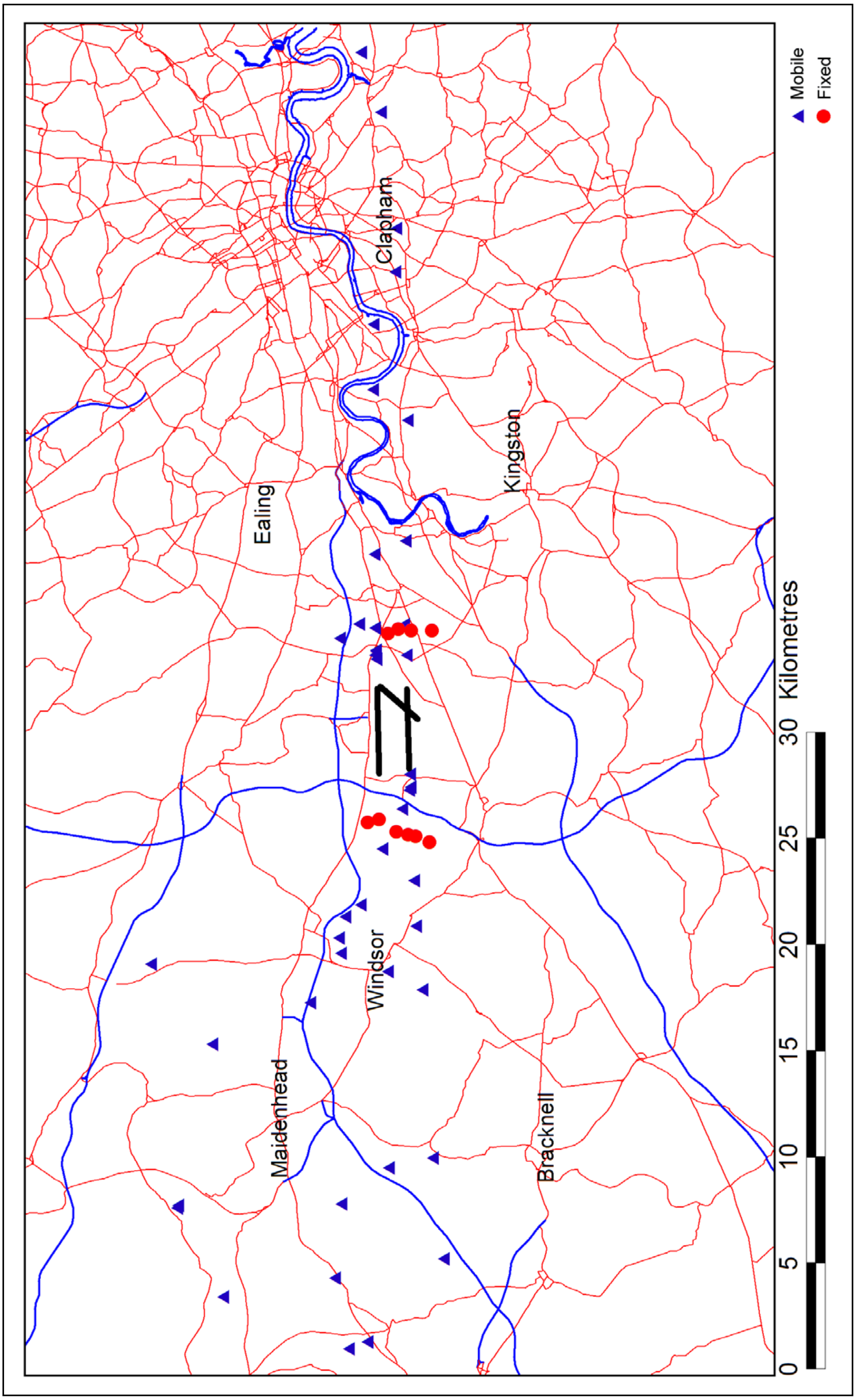

Figure 1 Location of Fixed and Mobile Noise Monitors Around Heathrow

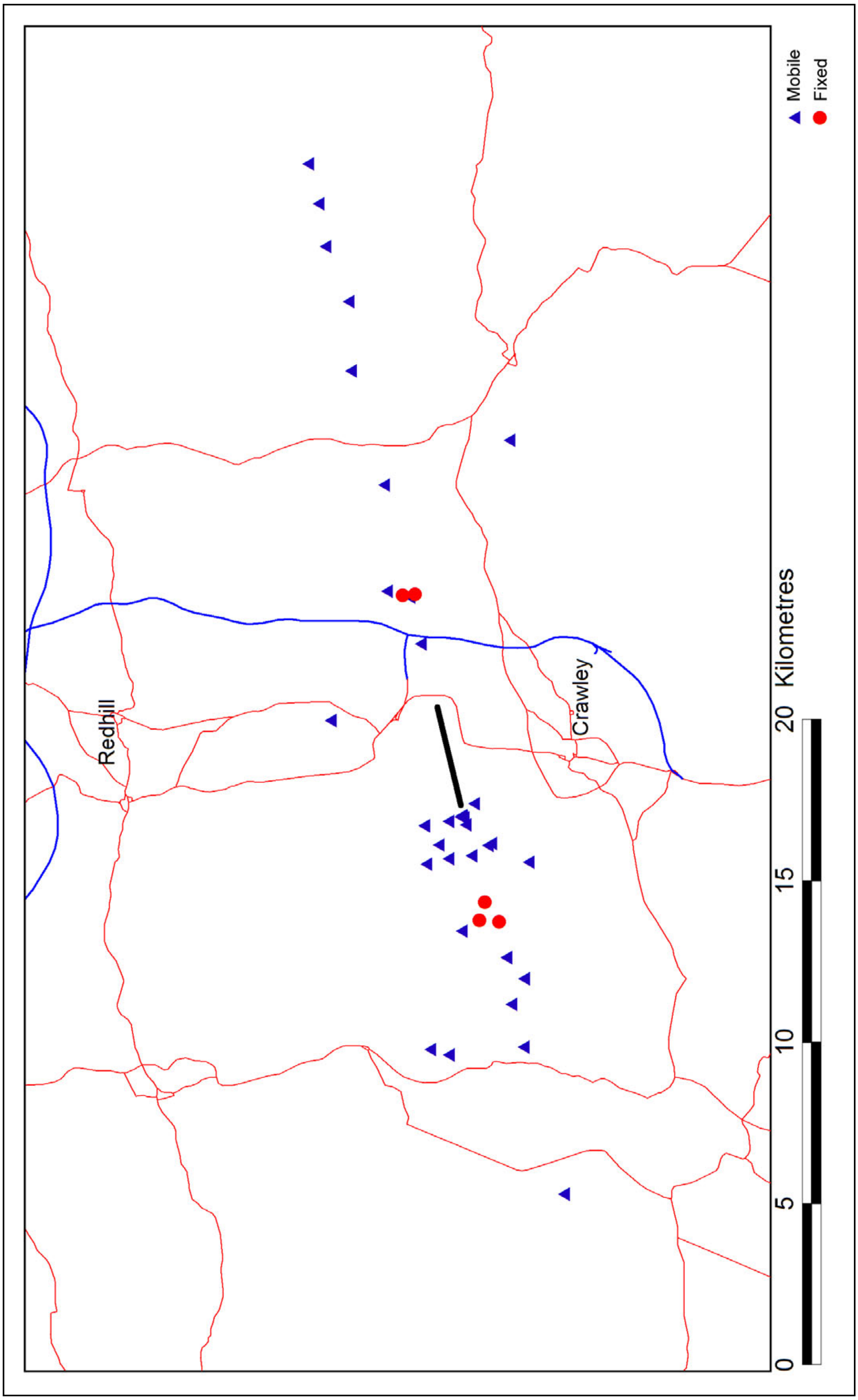

Figure 2 Location of Fixed and Mobile Noise Monitors Around Gatwick

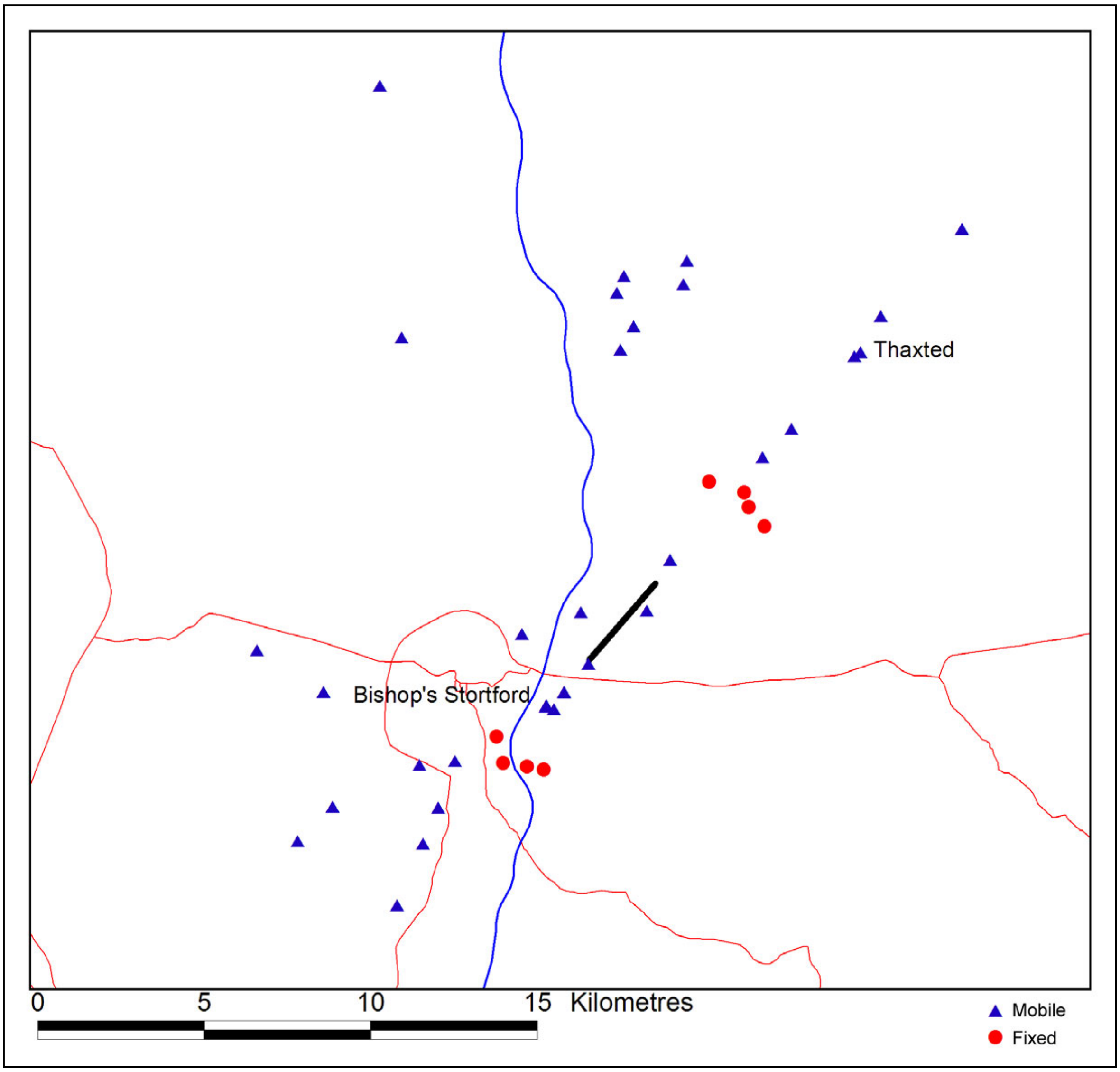

Figure 3 Location of Fixed and Mobile Noise Monitors Around Stansted

Figure 4 6 m NTK Fixed Monitor
(fitted with solar panels)

Figure 5 3.5 m NTK Mobile Monitor

Figure 6 4 m ERCD Attended Monitor

Figure 7 1.2 m ERCD Attended Monitor

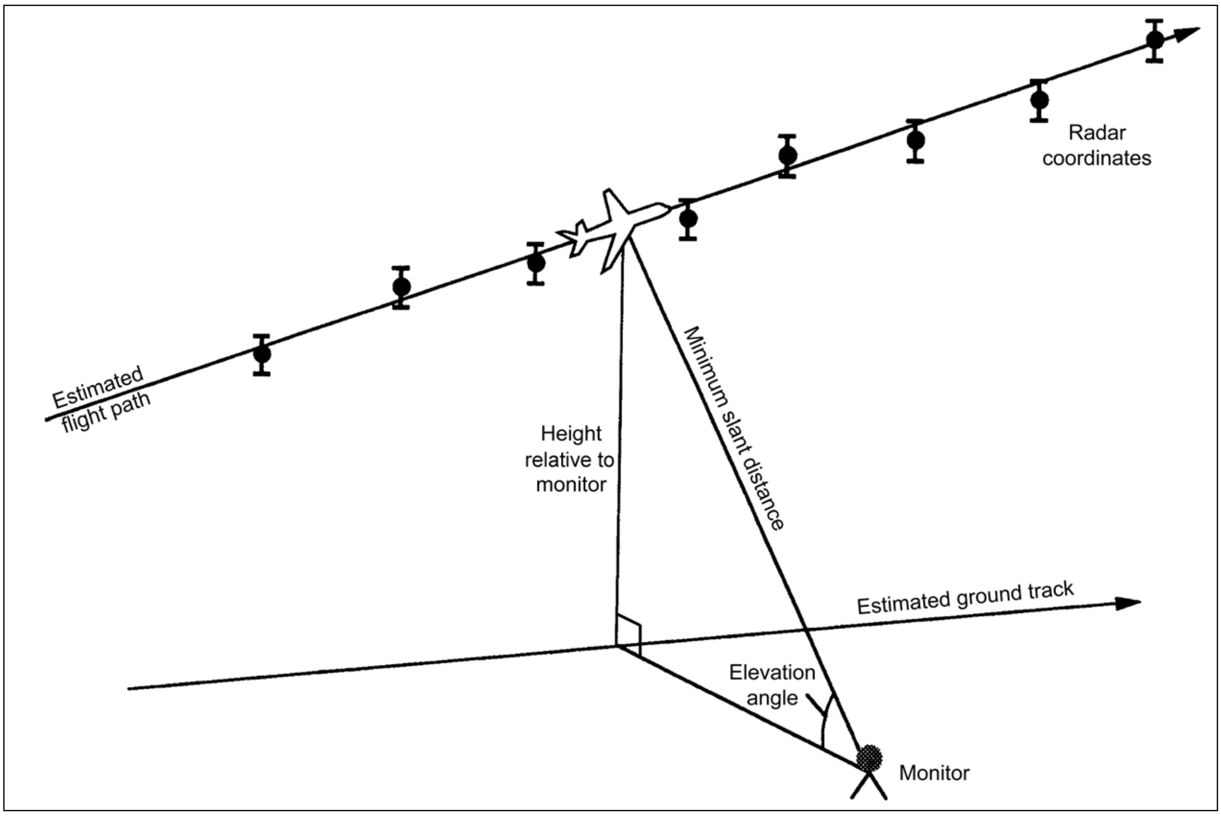

Figure 8 Calculation of Source-to-Receiver Geometry

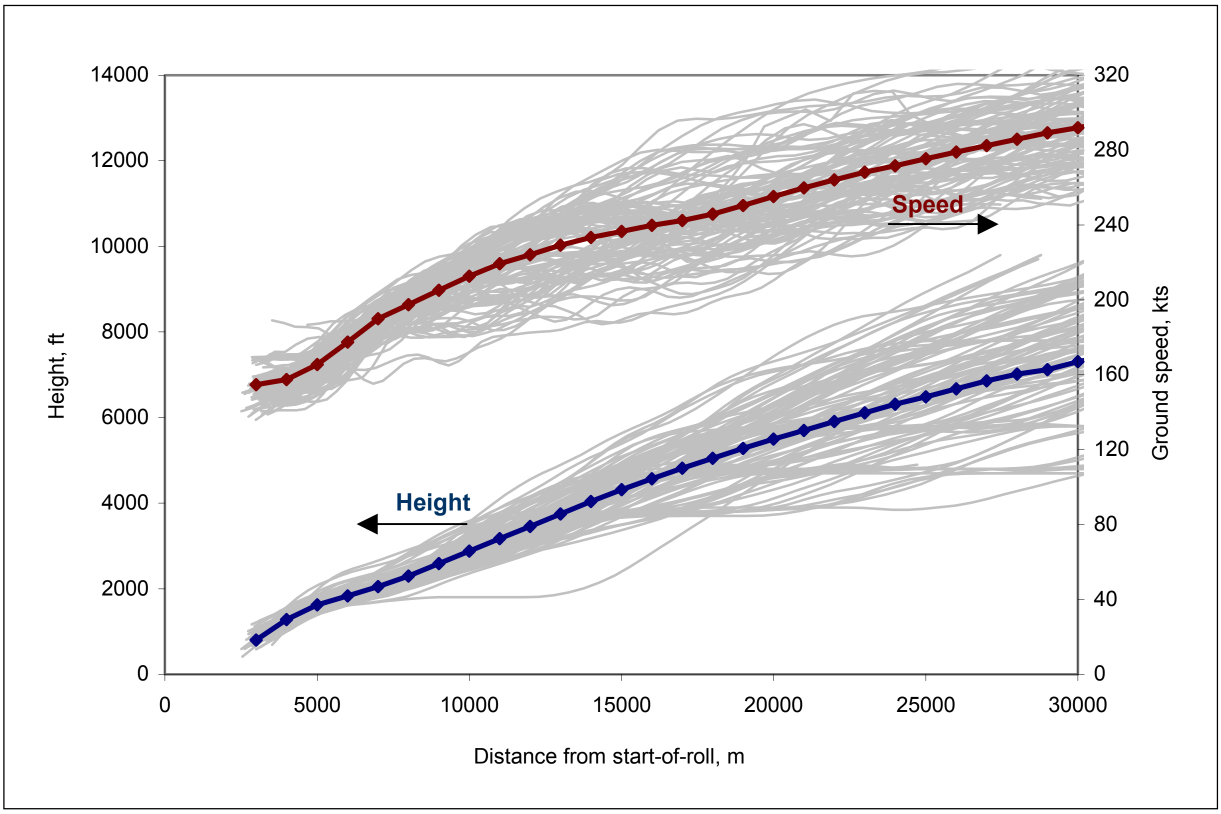

Figure 9 Example of Mean Departure Height and Speed Profiles
(for Boeing 757-200 aircraft, with underlying radar data shown)

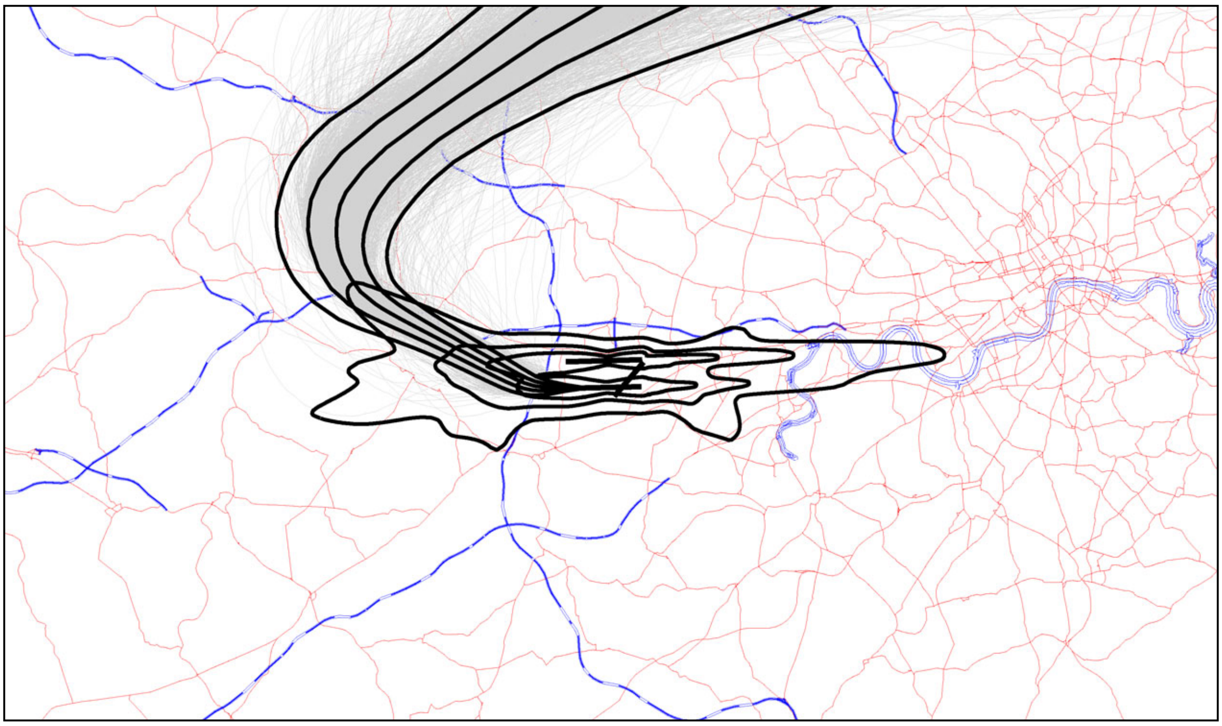

Figure 10 Example of Mean and Dispersed Departure Tracks
(overlaid on Leq Contours with underlying radar data shown for a particular departure route)

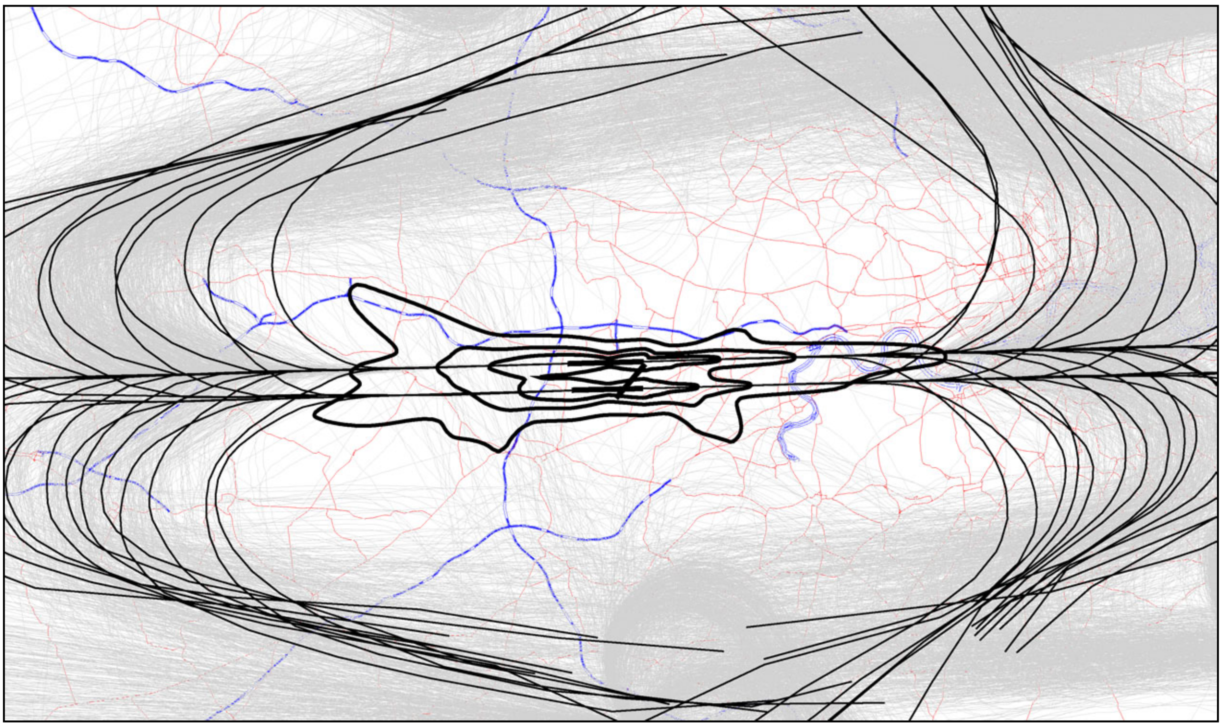

Figure 11 Example of Heathrow Arrival 'Spurs'
(overlaid on Leq Contours with underlying radar data shown)

Appendix A Overview of the NTK System

A1 **What an NTK system does**

A1.1 A Noise and Track Keeping (NTK) system provides information on:

- which aircraft are flying in the vicinity of an airport;
- where they fly to and from;
- where they are in the air;
- how high and how fast they are;
- which runways and routes they are using;
- how much noise they make on the ground; and
- the corresponding weather conditions.

A1.2 ERCD currently uses a system that is supplied by an Australian company, Lochard, one of the world's major suppliers of such systems. The NTK system at CAA House is linked by ISDN line to similar systems operated by BAA at Heathrow, Gatwick and Stansted airports, with whom ERCD staff work closely. All the data on the three BAA airport systems are replicated to the ERCD system.

A2 **Uses of NTK data**

A2.1 Typical uses of NTK data in ERCD are:

- annual noise exposure contour input data for Heathrow, Gatwick and Stansted (e.g. ground tracks, height/speed profiles, noise levels and route/traffic analyses);
- studies on behalf of DfT's ANMAC, e.g. departure limits review, arrivals noise study, Quota Count validation study;
- descent profile monitoring; and
- ad hoc studies.

A2.2 BAA uses the NTK systems mainly to monitor:

- aircraft exceeding the departure noise limits;
- night flight restrictions;
- departure track deviations from the Noise Preferential Routes (NPRs); and
- achievement of the Continuous Descent Approach (CDA) procedure.

A2.3 The NTK system at each airport also provides input to the BAA complaint handling teams and a variety of local studies of aircraft noise, procedures, track keeping, etc.

A3 **Sources of data for the NTK system**

A3.1 **Figure A1** shows the sources of data feeding into the NTK system. At each airport, radar data are used from a default radar head, with a standby head available in each case in the event of failure. Radar head locations and characteristics for Heathrow, Gatwick and Stansted airports are summarised in **Table A1**. Only these radar heads would provide the required low-level coverage at the relevant airport.

A3.2 The radar data are transferred to the London Terminal Control Centre at West Drayton where all the returns for each SSR are combined to provide data for each flight. Code-to-Callsign processing ('CCDS') then provides the flight number corresponding to the SSR code at that time.

A3.3 The data are then returned to a NATS Radar Data Filtering and Processing System (RDFPS) at each airport. This allows:

– Customised filtering for each radar head (e.g. to eliminate known areas where reflections or radar distortion is a problem).

– Filtering of data outside a given rectangular radar coverage area.

– Filtering of data outside a specified altitude range.

– QNH adjustment, by which the Flight Levels (below FL060) are converted to altitude above mean sea level.

– Adjustment from altitude above mean sea level to height above airfield.

– Conversion of range and azimuth values to x-y coordinates relative to a reference point on the airfield (taking into account the ‘slant range effect’ because the radar range is in 3-dimensions, not a distance on the ground).

The RDFPS output is then transferred to BAA via BAA’s Virtual Private Network (VPN).

A3.4 The NTK interfaces at each airport are the Communications Servers. These are essentially stand-alone PCs that store and match all the incoming radar and noise data. Aircraft registration data from the airports’ Flight Information Systems (FIS) are also fed into the NTK systems, which can then be cross referenced with BUCHair, an aircraft registration database, to obtain exact aircraft type and engine details. Finally, the radar positional data are converted within the NTK system to the National Grid coordinate system (OSGB36). Once converted, the radar tracks can then be easily overlaid and viewed on a variety of different Ordnance Survey maps using a GIS-style interface within the NTK.

Table A1 Radar Heads at Heathrow, Gatwick and Stansted

Airport	Main/alternate	Radar	OS coordinate (x, y)	Nominal rotation time (secs)
Heathrow	Main	23 cm	507500, 176030	4
	Alternate	Watchman	508200, 175970	4
Gatwick	Main	Watchman	526710, 140000	4
	Alternate	23 cm (Pease Pottage)	525170, 133080	6
Stansted	Main	Watchman	553090, 222710	4
	Alternate	23 cm (Debden)	555540, 234840	6

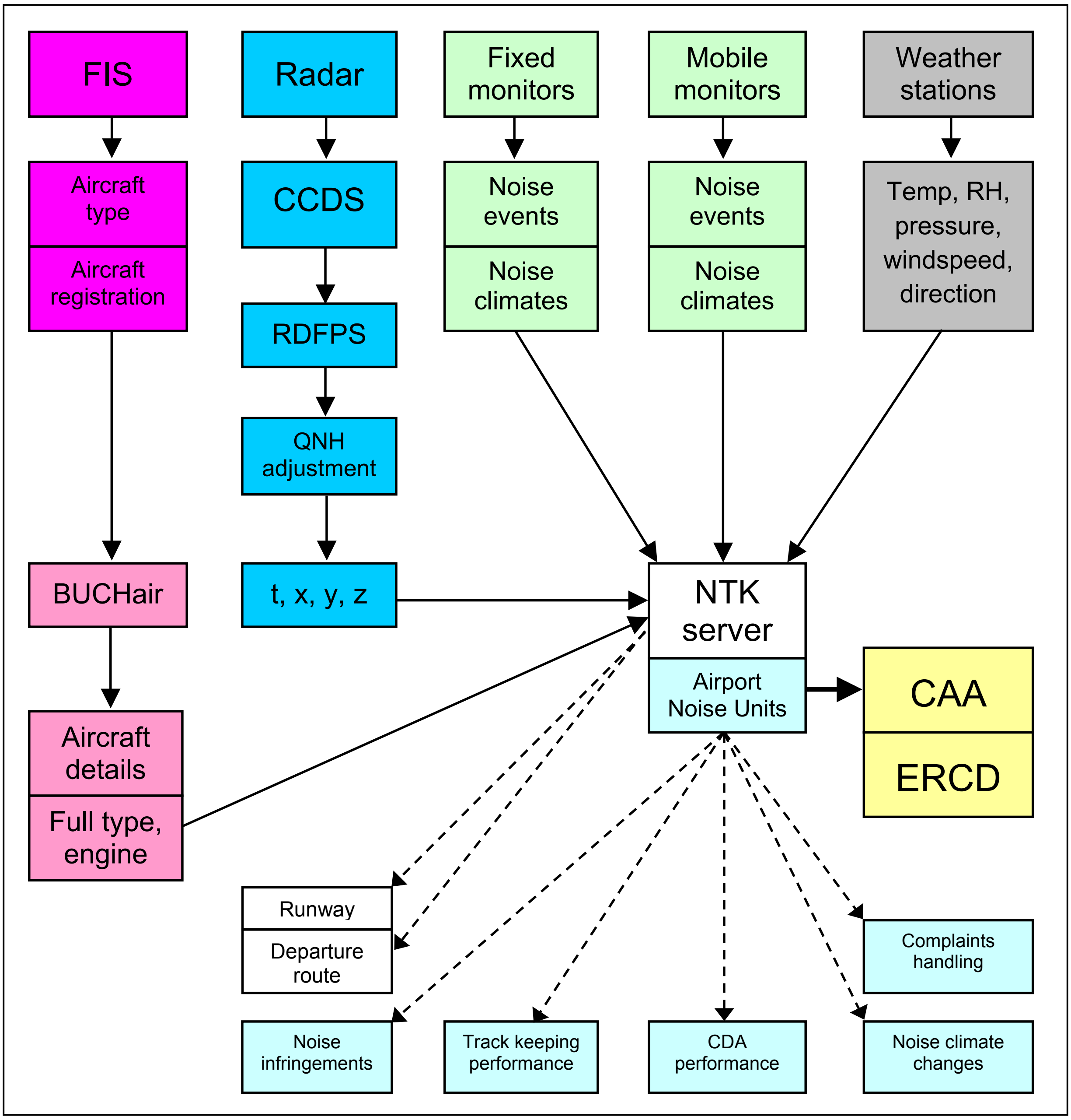

Figure A1 Data Inputs to and Typical Outputs from the NTK System