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Exercise Keevil : Noise levels of six military helicopters

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ABSTRACT

For a number of years the National Physical Laboratory, supported by the Ministry of Defence, has been developing AIRNOISE, a mathematical model for computing aircraft noise contours. The model is now being extended to include helicopter operations. In order to provide basic source noise data for the model, a special noise trial - Exercise Keevil - has been conducted at RAF Keevil in Wiltshire. One helicopter of each of six types performed a variety of flight operations over an array of microphones. Information on aircraft position and speed were obtained by video tracking techniques. This report describes the trial and presents the results obtained.

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CONTENTS

ILLUSTRATIONS

TABLES

1 INTRODUCTION

For a number of years the National Physical Laboratory, supported by the Ministry of Defence has been developing AIRNOISE, a mathematical model for computing aircraft noise contours [1]. The model is used by the RAF Institute of Health and Medical Training to determine eligibility for compensation for noise nuisance. Details of the compensation criteria and the background to them have been described by Berry and Weston [2]. NPL is currently working on the extension of the model's capabilities to allow it to be used for helicopter operations at airfields and helicopter landing sites. Although there exist a number of noise databases for a wide range of helicopter types [3], they were found to be inappropriate for the helicopter types of primary interest to the Ministry of Defence. It was therefore decided that a new noise trial was required to obtain basic source noise data for use in the AIRNOISE model. This report describes the trial and presents the results obtained. Details of the helicopter noise model itself and of the way the noise measurement database presented in this report is used in the model will be the subject of a separate report.

2 FLIGHT TEST PROGRAMME

The helicopter types used in the trial were Wessex (Mk 1), Puma (Mk 1), Gazelle, Sea King (Mk 4), Lynx (Mk 1) and Chinook CH47C (Mk 1).

The noise trial took place at RAF Keevil. This is an old wartime airfield. The base is disused though the main runways and surrounding airfield are maintained for operational training. It was selected because of its availability for sole use by the trial team and for its relative remoteness from residential areas. The operational aspects of the trial were supported by No. 1 Group RAF Upavon who contributed air traffic control facilities and fire/rescue cover. Figure 1 shows an overall view of the airfield.

On arrival at the airfield each helicopter landed close to the Control Tower, and the crew were briefed on the planned flight programme in order to come to an agreed set of flight operations. The starting point of the briefing was the list of operations shown in Table 1. Typically each aircraft performed a series of standard departures and approaches based on designated landing pads at either end of Runway 13/31, level flights in both directions along the line of this runway, special departures and approaches, and hover conditions over a marked hover pad at H on Figure 1. For each helicopter approximately 18 flight conditions were tested, over a period of 45 minutes to 1 hour. Radio communication was maintained with the crew and repeat or modified conditions were included as necessary. At the end of the sequence of flights the crew returned to the Control Tower to de-brief and to return a special record sheet with information on engine and blade data, airspeed and height, etc.

3 NOISE MEASUREMENTS

The main NPL microphone array consisted of five sets at 100 metre spacing centred on the intersection of Runway 13/31 with the main runway (06/24). A further set, designated NPL 4, was deployed in line with the flight track. The location of the sets is shown on Figure 1. Each set consisted of a microphone at the conventional height of 1.2 m, and another in the ground plane.

RAF IHMT used a similar array along Runway 01/19, with conventional and ground plane microphones. Locations are also shown in Figure 1.

Each microphone signal was recorded digitally using either DAT or PCM systems, together with IRIG B time-code signals. Data from the ground plane microphones are not included in this report, but are being analysed separately as part of the programme of work on this topic reported on previously by Payne [4].

4 AIRCRAFT TRACKING

Techniques developed at NPL for video tracking are described in Appendix 1. NPL teams operated two video camera systems at the Control Tower. In addition a vertical camera was used at the centre of the NPL microphone array directly under the flight track. The RAF IHMT operated one camera system situated at the southern end of runway 01/19 such that its field of view covered their microphone array. A second camera was positioned at the south-east end of runway 13/31, pointing directly down the runway to determine any lateral offset to the planned flight track.

Using the techniques outlined in Appendix 1, values for the height of the helicopter and the time when it was directly over the centre of the microphone array were calculated. Slant distances between each microphone location and the flight track were then obtained for all events. Ground speeds were also calculated. In the case of the NPL sites both the vertical camera and the sideline cameras were used and a mean value determined. Where departure or approach operations were involved, flight profiles and rate of climb/descent were also determined. This information is not given in this report but is being used in the interpretation of the noise data for modelling purposes.

5 DATA ANALYSIS AND RESULTS

5.1 NPL analysis

Each recorded signal was replayed in the laboratory through a Cirrus Research 2.36 data acquisition integrating sound level meter. This stores successive values of the equivalent continuous A-weighted sound pressure level, $L_{Aeq,\ 125\ ms}$, for later transfer to a portable computer (PC). Firstly the complete sequence of events for each helicopter at each site was stored as a single record. An example is shown in Figure 2 for the Lynx. The analysis software then allows each separate event to be examined in detail on the PC screen. By this process values of L_{Amax}, the maximum value of $L_{Aeq,\ 125\ ms}$ occuring during an event, and of the associated Sound Exposure Level, L_{AE}, were obtained.

5.2 RAF IHMT analysis

Each recorded signal was replayed through a Bruel and Kjaer type 2131 frequency analyser. The 1/3 - octave band spectra were sampled every 125 ms and stored on computer. Several noise measures were then calculated, including L_{Amax} and L_{AE}. More detailed 1/3 - octave band data and other measures remain available for more detailed analysis in future.

5.3 Results

The data on noise levels and slant distances have been assembled in a spreadsheet format and are presented in Tables 2 to 19. For the parts of the trial where the helicopter was in hover, only values of L_{AE} are given. Where slant distance data for RAF IHMT sites are in brackets, this denotes the use of NPL data.

6 CONCLUSIONS

A successful trial has been conducted, giving a unique set of noise data on six military helicopters flying a range of standard and special operations. This noise measurement database can now be interpreted to provide the essential input data for the modified AIRNOISE model.

7 ACKNOWLEDGEMENTS

NPL acknowledge the financial support of the Ministry of Defence. The authors wish to recognise the vital part played in this trial by their colleagues at NPL and RAF IHMT, by helicopter pilots and aircrew, and also the work of DD Nav MoD in providing the helicopters. Appendix 1 on video tracking techniques was provided by Richard Payne of NPL.

8 REFERENCES

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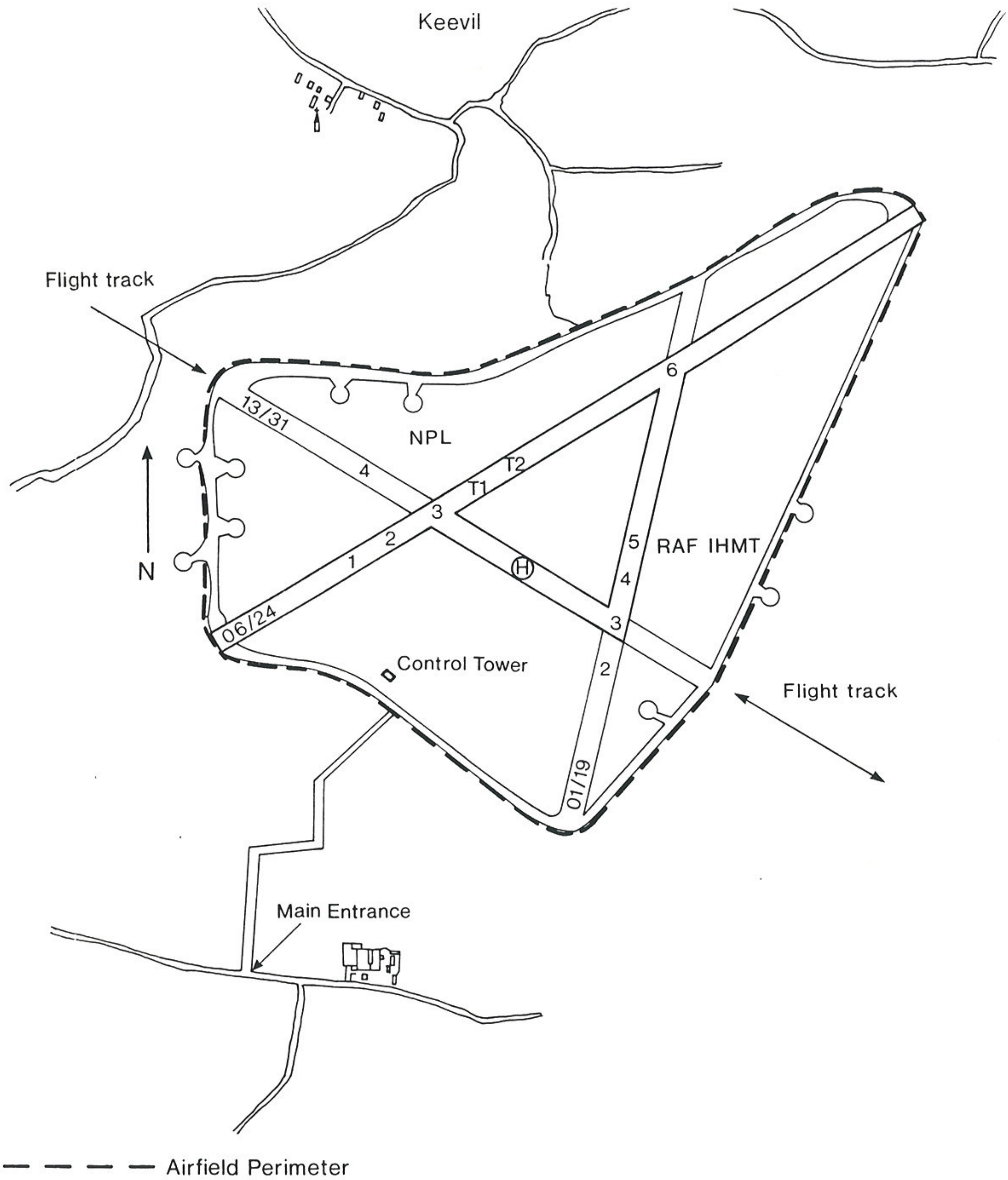

Figure 1 RAF Keevil airfield and measurement locations

(A)

(B)

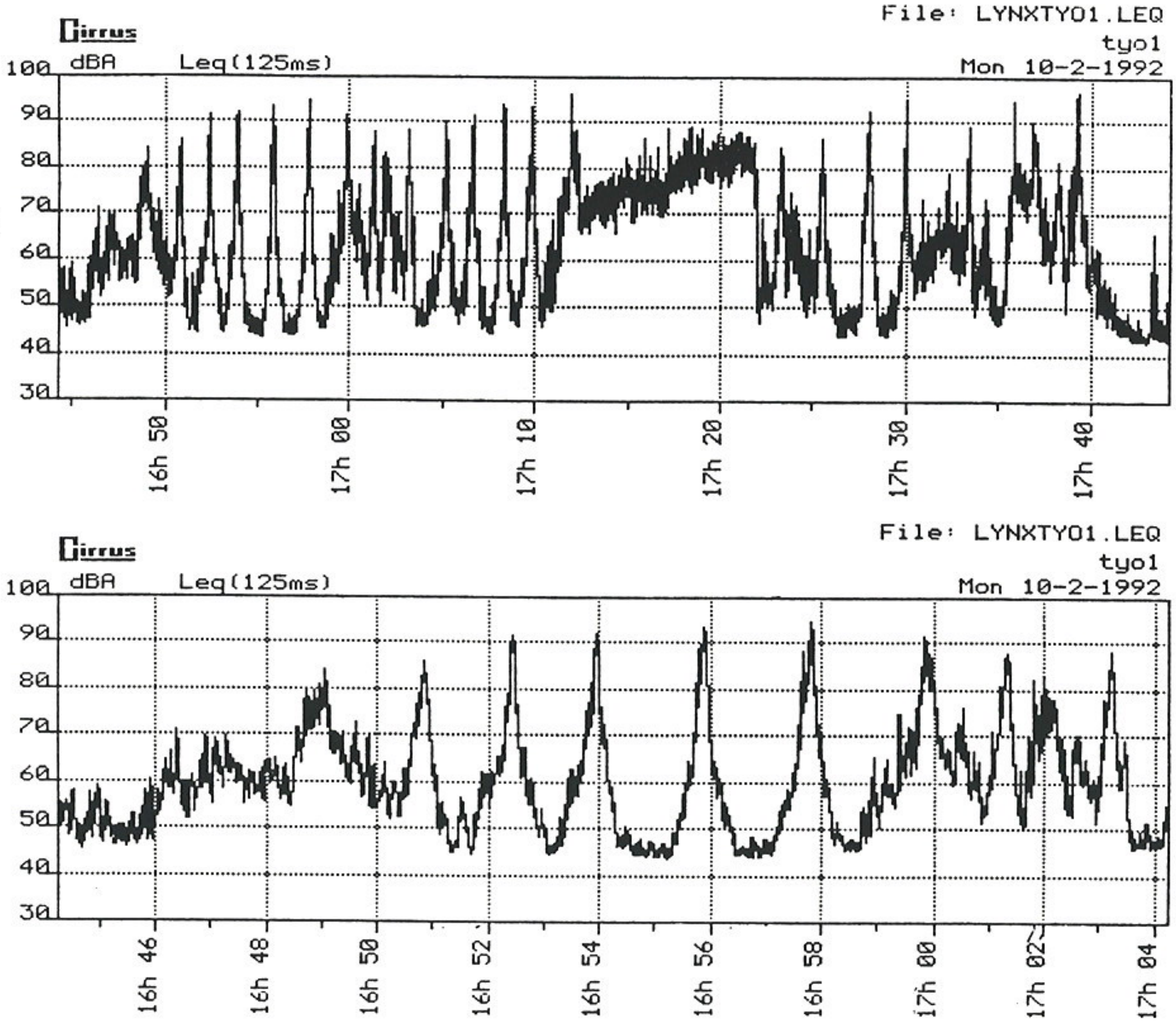

Figure 2 Time-history of noise at NPL site T1 for Lynx

(A) Whole trial

(B) Detail of first 20 minutes

Table 1 Basic flight programme for noise trial briefing

1	Standard take-off
2	Level flight : 150 ft : cruise speed
3	As 2, opposite direction
4	Level flight : 150 ft : max. speed
5	As 4, opposite direction
6	Standard approach from 500 or 1000 feet
7	Accelerated special take-off
8	Level flight : 300ft : cruise speed
9	As 8, opposite direction
10	Level flight : 300 ft : max. speed
11	As 10, opposite direction
12	Special descent to hover point
13	Hover at 10 ft *
14	Hover at 50 ft *
15	Hover taxi and accelerated take-off
16	Level flight : 150 ft : low pitch angle
17	Level flight : 150 ft : high pitch angle
18	Additional run as required

* Hover tests:

(i) Start on heading along runway, towards NW, hold for 30 secs

(ii) Rotate 30 degrees counter clockwise, hold for 30 secs

(iii) Repeat every 30 degrees to 180 degrees

Table 2 Noise measurement database – Wessex

Helicopter: Wessex

Noise descriptor: L_{Amax}

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	87.6	83.4	87.6	86.6	83.8	82.5	88.3	87.8	88.2	84.1	82.2
2	LEVEL 150 90	SE	93.6	93.9	90.5	84.0	90.3	83.8	88.0	90.5	90.5	87.1	85.9
3	LEVEL 150 90	NW	93.6	93.5	90.3	87.6	87.8	82.7	89.5	93.1	87.8	85.5	85.5
4	LEVEL 150 110	SE	95.6	95.9	88.5	84.7	91.0	84.5	90.2	97.1	91.7	86.2	86.1
5	LEVEL 150 110	NW	95.7	97.3	95.1	89.9	87.9	84.4	91.6	95.6	89.7	85.9	86.1
6	STD APP	NW	98.0	100.7	91.1	89.8	84.7	80.6	92.2	91.7	90.1	87.6	95.2
7a	ACC T/O	NW	91.7	82.1	90.2	85.3	86.4	92.7	89.6	103.5	88.7	83.2	80.4
7b	ACC T/O	NW	83.0	84.3	82.2	82.9	80.9	79.6	90.3	92.8	91.9	83.6	79.9
8	LEVEL 300 90	SE	90.2	89.9	88.9	84.1	86.1	85.1	86.7	89.2	87.1	88.3	81.1
9	LEVEL 300 90	NW	91.5	89.4	89.0	86.2	86.3	82.5	88.4	88.0	85.8	83.9	85.5
10	LEVEL 300 110	SE	90.7	91.4	87.3	84.2	87.7	83.4	87.9	89.2	89.6	87.0	82.3
11	LEVEL 300 110	NW	90.0	92.1	89.6	90.0	86.1	84.2	88.8	92.3	87.7	86.9	80.4
12	SPL APP	NW	85.4	65.0	–	–	–	83.9	86.3	100.0	86.3	81.7	78.1
13	HOVER 10'		–	–	–	–	–	–	–	–	–	–	–
14	HOVER 50'		–	–	–	–	–	–	–	–	–	–	–
16	LEVEL 150	NW	93.3	94.7	89.7	86.5	86.7	80.1	87.8	94.6	87.3	82.6	79.1
17	LEVEL 150	NW	99.7	97.9	92.2	87.7	88.6	84.9	91.1	100.8	89.7	85.2	80.2
18	ACC T/O	NW	103.7	97.8	92.4	86.4	87.5	82.4	89.9	104.9	88.0	83.7	78.9
19	SPL APP	NW	102.5	101.2	91.1	84.8	89.9	83.2	86.5	86.9	91.1	89.8	81.3
20	LEVEL 150 110	SE	96.4	95.4	90.1	87.5	89.1	87.0	88.7	97.1	90.4	86.9	76.7
21	LEVEL 150 110	NW	97.0	97.0	91.9	89.7	91.1	84.0	90.2	97.2	89.1	85.9	78.8
22	STD APP	SE	103.9	88.6	105.2	104.0	–	86.9	94.0	90.4	88.5	84.9	75.5
23	STD APP	SE	101.7	106.9	91.1	82.6	–	–	80.3	79.8	80.3	74.4	70.9

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 3 Noise measurement database – Wessex

Helicopter: Wessex **Noise descriptor: L_{AE}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	92.2	91.2	93.5	92.6	90.4	90.1	96.3	94.8	94.7	93.2	90.5
2	LEVEL 150 90	SE	95.1	95.5	92.8	89.5	92.8	88.9	91.9	87.7	93.7	91.9	89.9
3	LEVEL 150 90	NW	96.1	96.0	95.8	92.1	92.4	89.0	95.4	95.0	93.3	91.4	90.1
4	LEVEL 150 110	SE	96.7	96.5	92.9	89.8	94.1	89.7	93.1	96.5	95.0	91.6	90.4
5	LEVEL 150 110	NW	97.6	98.6	96.6	93.6	93.5	89.7	96.3	97.1	94.2	91.8	91.2
6	STD APP	NW	101.5	105.5	82.0	94.6	93.9	89.7	96.8	98.4	95.8	93.8	101.4
7a	ACC T/O	NW	96.7	91.3	95.1	94.1	93.8	92.5	95.0	102.6	93.8	91.0	85.8
7b	ACC T/O	NW	91.2	90.1	90.2	91.0	87.9	88.5	94.5	95.2	94.1	91.7	87.4
8	LEVEL 300 90	SE	93.2	92.7	91.5	89.3	90.3	90.1	90.4	92.2	91.3	92.0	87.2
9	LEVEL 300 90	NW	94.8	93.9	94.7	92.9	91.1	88.6	93.7	93.0	92.0	91.8	88.8
10	LEVEL 300 110	SE	93.5	94.1	91.3	89.8	91.1	89.8	91.3	92.2	93.5	92.5	86.9
11	LEVEL 300 110	NW	94.3	95.3	94.7	93.9	91.2	89.7	94.1	94.6	92.4	92.4	87.4
12	SPL APP	NW	95.2	–	–	–	–	92.9	92.5	99.7	92.3	89.4	83.9
13	HOVER 10'		99.8	91.2	92.8	89.6	100.1	95.9	98.5	104.6	95.0	96.4	92.4
14	HOVER 50'		105.5	91.8	97.8	92.7	105.8	101.9	99.9	101.6	98.1	99.9	94.1
16	LEVEL 150	NW	97.1	98.8	96.0	94.2	93.5	89.2	93.7	98.9	93.7	90.6	85.1
17	LEVEL 150	NW	99.5	99.1	96.4	92.9	93.3	89.4	95.0	99.8	93.8	90.4	85.9
18	ACC T/O	NW	103.1	97.8	97.3	92.1	92.8	87.7	94.4	103.2	92.6	90.2	80.1
19	SPL APP	NW	102.3	101.7	94.9	89.4	93.6	88.2	90.4	93.8	94.7	92.5	82.8
20	LEVEL 150 110	SE	96.0	96.5	92.9	89.7	93.3	89.2	91.8	96.2	94.6	90.1	80.0
21	LEVEL 150 110	NW	98.5	97.7	95.8	92.4	93.2	88.8	93.0	97.8	93.7	91.0	81.4
22	STD APP	SE	104.1	93.2	–	105.2	–	–	90.2	94.8	95.4	95.7	80.1
23	STD APP	SE	102.4	102.5	–	–	–	–	84.2	88.6	86.2	84.2	77.1

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 4 Slant distances – Wessex

Helicopter: Wessex **Slant Distances (m)**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	123	111	145	214	141	209	121	67	121	209	504
2	LEVEL 150 90	SE	49	49	102	186	102	186	108	(49)	108	198	502
3	LEVEL 150 90	NW	43	43	100	185	100	185	105	(43)	105	197	502
4	LEVEL 150 110	SE	42	42	99	185	99	185	105	(42)	105	197	502
5	LEVEL 150 110	NW	41	41	99	185	99	185	104	(41)	104	196	502
6	STD APP	NW	48	73	113	191	120	199	194	166	194	260	514
7a	ACC T/O	NW	216	116	165	241	131	194	102	18	102	203	504
7b	ACC T/O	NW	189	189	209	261	209	261	152	114	152	228	523
8	LEVEL 300 90	SE	76	76	118	195	118	195	122	(76)	122	207	506
9	LEVEL 300 90	NW	71	71	115	194	115	194	120	(71)	120	205	505
10	LEVEL 300 110	SE	77	77	118	196	118	196	123	(77)	123	207	506
11	LEVEL 300 110	NW	76	76	118	195	118	195	123	(76)	123	207	506
12	SPL APP	NW	–	–	–	–	–	–	100	18	104	203	500
13	HOVER 10'		440	240	298	374	216	236	290	250	240	270	500
14	HOVER 50'		440	240	298	374	217	236	290	250	240	270	500
16	LEVEL 150	NW	34	34	96	183	96	183	102	(34)	102	195	501
17	LEVEL 150	NW	33	33	96	183	96	183	102	(33)	102	195	501
18	ACC T/O	NW	87	20	94	184	92	181	102	18	102	201	506
19	SPL APP	NW	–	–	–	–	–	–	177	146	177	248	505
20	LEVEL 150 110	SE	35	35	96	183	96	183	102	(35)	102	195	501
21	LEVEL 150 110	NW	34	34	96	183	96	183	102	(34)	102	195	501
22	STD APP	SE	–	–	–	–	–	–	272	227	212	252	510
23	STD APP	SE	–	–	–	–	–	–	330	276	271	291	512

Abbreviations:

STD T/O	Standard take–off
ACC T/O	Accelerated take–off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 5 Noise measurement database – Puma

Helicopter: Puma

Noise descriptor: L_{Amax}

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	107.0	106.9	95.4	91.2	96.8	90.9	99.7	104.1	97.0	86.9	86.2
2	LEVEL 150 125	SE	95.5	97.1	92.3	91.4	94.9	90.2	96.7	95.1	96.7	91.5	85.1
3	LEVEL 150 125	NW	93.6	94.8	93.1	89.2	93.8	90.4	96.1	96.1	93.9	92.9	84.3
4	LEVEL 150 130	SE	97.1	96.8	95.6	90.4	94.0	89.0	96.5	95.7	95.5	90.5	84.7
5	LEVEL 150 130	NW	93.2	94.8	94.2	90.9	95.6	91.4	97.4	96.0	96.5	93.5	85.4
6	STD APP	NW	94.0	90.0	88.6	85.7	85.7	85.1	87.4	86.8	84.6	84.1	87.6
7a	ACC T/O	SE	101.1	102.9	95.3	90.6	94.7	87.7	84.3	85.8	84.9	88.0	81.9
7b	ACC T/O	SE	100.9	101.3	98.1	93.4	95.4	88.1	93.3	98.9	91.5	92.4	83.4
8	LEVEL 300 125	NW	88.9	89.1	92.3	90.8	92.3	89.3	94.5	90.9	92.9	90.1	90.1
9	LEVEL 300 125	SE	88.9	90.7	90.5	89.9	90.5	87.1	91.0	90.7	91.5	90.6	89.4
10	LEVEL 300 130	NW	93.2	90.3	91.8	90.4	92.5	90.0	95.4	89.3	93.9	90.7	86.8
11	LEVEL 300 130	SE	94.6	91.7	92.7	88.3	91.0	89.6	90.5	93.1	92.8	91.8	88.2
12	SPL APP	NW	81.5	91.1	87.9	82.6	90.2	91.0	88.4	88.0	98.9	101.5	92.2
13	HOVER 10'		–	–	–	–	–	–	–	–	–	–	–
14	HOVER 50'		–	–	–	–	–	–	–	–	–	–	–
15A	ACC T/O	NW	79.5	81.6	82.5	78.6	82.2	85.8	93.7	95.8	91.7	90.4	88.4
15B	ACC T/O	NW	82.8	92.0	88.1	87.4	88.5	88.6	94.3	102.6	96.6	92.3	84.1
16	LEVEL 100 70	SE	95.9	94.5	91.9	91.2	92.7	86.2	89.8	93.9	93.0	85.2	78.1
17	LEVEL 100 70	NW	95.4	97.3	92.4	87.4	91.4	88.5	93.7	97.6	91.9	88.6	82.7
18	STD T/O	NW	83.7	87.2	87.6	89.4	91.4	86.1	94.2	105.0	96.8	92.3	82.0
19	ACC T/O	SE	103.5	90.1	90.2	89.6	89.9	87.1	83.0	82.2	87.9	82.7	81.1
20	STD T/O	NW	81.8	87.1	87.1	86.3	86.2	85.1	96.0	105.0	97.1	89.3	76.4

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 6 Noise measurement database – Puma

Helicopter: Puma

Noise descriptor: L_{AE}

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	104.3	105.1	98.9	95.3	99.9	93.3	103.4	104.5	101.3	93.8	90.0
2	LEVEL 150 125	SE	96.6	97.5	97.6	95.2	96.2	93.2	99.5	95.8	98.3	93.9	88.7
3	LEVEL 150 125	NW	96.2	97.0	96.8	94.3	97.7	93.6	99.4	96.8	98.0	96.6	87.8
4	LEVEL 150 130	SE	97.3	96.9	97.4	95.1	96.5	92.0	99.5	96.0	97.3	91.3	87.7
5	LEVEL 150 130	NW	95.5	96.8	97.5	94.4	98.6	94.8	100.4	97.5	99.2	97.1	88.4
6	STD APP	NW	100.2	97.1	97.9	94.4	95.3	92.2	97.0	94.5	93.8	93.7	93.2
7a	ACC T/O	SE	99.1	100.9	96.4	94.0	96.4	93.4	94.3	93.2	93.7	95.0	85.1
7b	ACC T/O	SE	99.0	99.2	99.1	95.2	96.5	91.5	98.0	97.2	94.9	94.3	86.2
8	LEVEL 300 125	NW	94.0	94.3	96.1	94.7	96.4	94.0	99.0	94.4	97.8	95.9	91.9
9	LEVEL 300 125	SE	92.4	92.8	93.6	94.4	94.3	91.4	95.0	91.8	95.0	93.1	92.2
10	LEVEL 300 130	NW	94.7	94.5	96.2	95.6	96.6	94.2	98.5	93.4	98.0	96.5	89.9
11	LEVEL 300 130	SE	94.3	93.1	95.5	93.4	94.3	92.3	94.0	92.5	95.7	94.1	90.4
12	SPL APP	NW	89.3	97.3	93.8	89.4	97.7	98.9	96.3	91.6	103.8	107.4	96.1
13	HOVER 10'		90.7	102.4	94.8	89.9	103.6	103.5	100.6	106.7	99.0	102.3	96.8
14	HOVER 50'		91.6	109.3	101.6	93.5	109.6	105.7	101.1	105.0	102.2	101.0	97.4
15A	ACC T/O	NW	85.9	88.3	86.8	84.2	89.9	91.6	97.1	96.3	97.7	97.1	90.2
15B	ACC T/O	NW	90.8	93.9	94.2	94.3	95.3	93.6	97.0	102.2	99.9	96.8	86.9
16	LEVEL 100 70	SE	97.7	96.7	95.6	94.8	95.3	92.6	93.2	95.5	95.5	90.8	82.1
17	LEVEL 100 70	NW	99.8	100.2	97.4	93.5	97.3	92.8	97.2	99.9	98.2	95.7	85.4
18	STD T/O	NW	93.8	95.9	96.5	96.2	96.4	93.9	101.4	106.5	102.8	98.6	87.1
19	ACC T/O	SE	102.2	93.3	95.3	94.0	93.8	92.2	88.9	89.3	89.8	86.6	85.5
20	STD T/O	NW	91.8	94.0	95.2	95.4	94.6	93.0	100.2	105.3	102.6	93.5	85.8

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 7 Slant distances – Puma

Helicopter: Puma **Slant distance (m)**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	14	13	91	181	91	180	100	9	100	200	500
2	LEVEL 150 125	SE	47	47	102	186	102	186	107	(47)	107	198	502
3	LEVEL 150 125	NW	41	41	99	185	99	185	104	(41)	104	196	502
4	LEVEL 150 130	SE	47	47	101	186	101	186	107	(47)	107	198	502
5	LEVEL 150 130	NW	47	47	102	186	102	186	107	(47)	107	198	502
6	STD APP	NW	70	89	124	197	130	205	211	186	211	273	518
7a	ACC T/O	SE	12	26	92	180	96	185	240	218	240	293	515
7b	ACC T/O	SE	21	21	92	181	93	181	123	72	123	212	502
8	LEVEL 300 125	NW	85	85	124	199	124	199	128	(85)	128	210	507
9	LEVEL 300 125	SE	91	91	128	202	128	202	132	(91)	132	213	508
10	LEVEL 300 130	NW	86	86	125	200	125	200	144	105	144	222	511
11	LEVEL 300 130	SE	98	98	133	205	133	205	163	128	163	234	516
12	SPL APP	NW	–	–	–	–	–	–	102	22	102	201	500
13	HOVER 10'		440	240	298	374	216	236	290	250	240	270	500
14	HOVER 50'		440	240	298	374	216	236	290	250	240	270	500
15A	ACC T/O	NW	–	–	–	–	–	–	127	77	127	209	506
15B	ACC T/O	NW	268	160	205	274	164	213	104	27	104	198	509
16	LEVEL 100 70	SE	29	29	94	182	94	182	100	(29)	100	194	501
17	LEVEL 100 70	NW	31	31	95	183	95	183	101	(31)	101	194	501
18	STD T/O	NW	306	166	217	290	163	209	101	13	101	200	509
19	ACC T/O	SE	34	86	117	191	133	210	222	198	222	277	520
20	STD T/O	NW	242	160	199	266	168	219	101	14	101	198	507

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 8 Noise measurement database – Gazelle

Helicopter: Gazelle **Noise descriptor: L_{Amax}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	93.2	89.0	83.1	82.9	92.9	82.6	80.8	83.3	82.2	80.0	72.3
2	LEVEL 150 120	SE	93.7	90.7	83.7	78.2	92.8	79.0	80.0	87.4	85.1	80.6	74.8
3	LEVEL 150 120	NW	91.1	89.8	87.1	81.9	90.4	78.4	85.2	91.4	82.2	77.9	74.7
4	LEVEL 150 156	SE	99.7	98.7	84.8	78.6	95.1	81.6	82.4	91.9	86.9	80.9	77.9
5	LEVEL 150 156	NW	91.2	92.2	87.9	82.5	92.0	78.8	85.4	91.3	84.5	79.9	74.1
6	STD APP	SE	83.6	83.9	80.1	78.6	89.0	79.8	79.5	80.5	82.7	81.2	77.0
7	ACC T/O	SE	101.4	101.6	86.1	79.9	92.9	81.4	78.4	82.3	83.6	80.7	78.0
8	LEVEL 300 120	SE	87.2	87.9	86.2	80.9	89.8	81.0	82.6	83.8	84.8	82.7	76.8
9	LEVEL 300 120	NW	82.5	83.3	83.1	81.0	88.5	79.9	82.4	84.4	82.0	81.0	77.1
10	LEVEL 300 156	SE	85.5	86.9	84.3	79.0	90.8	79.9	81.6	84.4	83.0	80.6	74.2
11	LEVEL 300 156	NW	87.2	87.0	84.0	81.1	90.0	79.9	83.5	84.7	82.3	80.2	76.5
12	SPL APP	NW	–	82.0	83.9	76.9	86.2	80.8	97.4	94.1	84.1	84.0	78.1
13	HOVER 10'		–	–	–	–	–	–	–	–	–	–	–
14	HOVER 50'		–	–	–	–	–	–	–	–	–	–	–
15	ACC T/O	NW	85.8	85.6	85.8	83.2	93.4	82.3	87.4	101.5	86.3	80.9	79.2
16	BLADE SLAP APP	SE	92.1	98.2	88.7	83.7	93.4	83.4	86.3	89.7	88.5	81.3	78.8
17	LEVEL 100 156	SE	100.9	102.0	86.0	78.6	95.0	82.6	82.8	99.0	88.5	83.2	76.2
18	ACC T/O	NW	78.9	80.8	78.9	82.0	86.0	81.2	87.0	92.9	86.6	82.0	78.1
19	ACC T/O	SE	111.3	109.4	84.4	78.9	84.2	80.9	81.2	93.0	84.4	82.4	80.4

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 9 Noise measurement database – Gazelle

Helicopter: Gazelle **Noise descriptor: L_{AE}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	94.8	91.1	90.2	86.5	97.6	88.6	88.8	89.4	88.0	88.0	80.2
2	LEVEL 150 120	SE	93.4	91.8	87.6	84.5	95.9	84.8	85.7	89.3	88.6	85.8	81.1
3	LEVEL 150 120	NW	92.8	93.2	91.4	88.2	94.6	84.4	89.5	92.5	87.6	84.1	80.9
4	LEVEL 150 156	SE	97.1	96.5	88.1	83.0	96.6	86.2	86.5	92.6	90.1	87.5	82.2
5	LEVEL 150 156	NW	92.8	93.6	92.1	88.1	96.4	85.1	88.9	92.2	88.6	85.7	79.9
6	STD APP	SE	89.2	90.4	88.2	85.7	97.0	88.1	86.3	90.0	90.1	90.4	86.2
7	ACC T/O	SE	101.0	103.0	91.8	86.4	98.1	88.7	86.2	86.5	88.5	88.5	81.1
8	LEVEL 300 120	SE	89.7	89.5	89.6	86.0	94.7	86.5	87.4	88.1	88.4	87.5	82.3
9	LEVEL 300 120	NW	87.1	88.0	88.9	87.5	94.3	86.5	87.9	87.1	87.6	87.5	82.2
10	LEVEL 300 156	SE	89.8	90.5	89.1	85.6	94.5	85.8	87.2	88.1	87.5	85.7	79.9
11	LEVEL 300 156	NW	89.9	90.2	89.8	88.0	94.8	86.1	88.3	89.1	88.2	86.4	80.8
12	SPL APP	NW	90.4	86.2	89.5	84.0	90.1	86.3	97.8	96.4	94.7	93.3	87.9
13	HOVER 10'		84.9	85.1	80.4	75.6	87.6	84.3	89.4	92.1	84.2	91.1	89.3
14	HOVER 50'		86.4	98.0	85.8	82.4	102.7	97.2	97.7	101.4	101.8	100.2	93.6
15	ACC T/O	NW	91.0	92.2	93.0	90.9	98.8	88.2	91.4	100.5	91.4	86.5	83.1
16	BLADE SLAP APP	SE	94.6	96.2	94.4	92.0	–	90.2	84.9	86.8	88.5	86.8	80.1
17	LEVEL 100 156	SE	97.9	98.7	89.1	84.0	97.3	86.3	86.7	97.1	91.1	87.5	81.1
18	ACC T/O	NW	88.4	87.6	86.6	89.2	93.6	87.2	93.3	98.1	92.2	89.0	83.4
19	ACC T/O	SE	107.5	105.6	88.6	86.9	98.1	85.9	88.9	93.6	91.3	89.7	86.5

Abbreviations:

STD T/O	Standard take–off
ACC T/O	Accelerated take–off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 10 Slant distances – Gazelle

Helicopter: Gazelle

Event	Description		Slant distance (m) NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	34	46	100	185	103	187	126	78	126	192	504
2	LEVEL 150 120	SE	29	29	94	182	94	182	100	(29)	100	194	501
3	LEVEL 150 120	NW	32	32	96	183	96	183	101	(32)	101	195	501
4	LEVEL 150 156	SE	19	19	92	181	92	181	98	(19)	98	193	500
5	LEVEL 150 156	NW	32	32	96	183	96	183	101	(32)	101	195	501
6	STD APP	SE	75	50	106	190	100	184	270	220	200	230	500
7	ACC T/O	SE	17	45	98	183	103	189	138	95	138	204	505
8	LEVEL 300 120	SE	63	63	110	191	110	191	115	(63)	115	202	504
9	LEVEL 300 120	NW	81	81	121	198	121	198	126	(81)	126	209	507
10	LEVEL 300 156	SE	57	57	107	189	107	189	121	68	121	206	505
11	LEVEL 300 156	NW	65	65	111	191	111	191	118	63	118	208	504
12	SPL APP	NW	–	–	–	–	–	–	113	53	113	195	500
13	HOVER 10'		440	240	298	374	216	236	290	250	240	270	500
14	HOVER 50'		440	240	298	374	216	236	290	250	240	270	500
15	ACC T/O	NW	139	69	123	206	105	184	100	21	100	179	502
16	BLADE SLAP APP	SE	18	18	92	181	92	181	291	252	242	179	500
17	LEVEL 100 156	SE	13	13	91	180	91	180	97	(13)	97	192	504
18	ACC T/O	NW	142	142	168	229	168	229	108	42	108	196	508
19	ACC T/O	SE	7	7	90	180	90	180	124	74	124	204	505

Abbreviations:

STD T/O	Standard take–off
ACC T/O	Accelerated take–off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 11 Noise measurement database – Sea King

Helicopter: Sea King **Noise descriptor: L_{Amax}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	85.3	88.7	91.6	86.6	89.6	87.4	91.8	93.6	90.9	86.1	75.2
2	LEVEL 150 90	SE	94.2	94.3	91.9	83.6	90.7	85.3	89.2	91.8	89.3	86.5	78.1
3	LEVEL 150 90	NW	91.8	93.1	91.0	85.8	90.3	84.4	90.0	91.4	89.2	86.9	76.3
4	LEVEL 150 120	SE	98.9	97.6	95.6	86.7	93.5	89.3	92.8	95.5	92.7	89.3	79.5
5	LEVEL 150 120	NW	95.2	97.0	93.9	86.0	92.7	87.7	94.1	95.2	90.7	86.7	78.1
6	STD APP	NW	66.6	90.9	81.5	64.2	87.7	89.4	85.8	102.1	86.7	88.8	73.0
7a	ACC T/O	NW	84.4	87.4	86.7	87.0	85.4	86.0	93.3	104.0	91.8	88.9	79.1
7b	ACC T/O	NW	95.9	105.0	92.6	82.8	89.0	83.1	92.4	111.0	90.4	85.5	78.6
8	LEVEL 300 90	SE	87.2	87.1	87.8	83.2	87.3	84.6	85.5	86.1	86.2	86.4	78.8
9	LEVEL 300 90	NW	88.3	86.2	88.7	86.1	87.0	85.7	87.2	86.0	87.3	85.2	76.4
10	LEVEL 300 120	SE	90.5	90.6	90.0	87.3	90.8	87.6	85.8	89.2	88.3	87.5	79.9
11	LEVEL 300 120	NW	88.3	89.4	92.0	86.6	89.3	87.0	90.3	89.0	88.9	88.1	80.2
12	SPIRAL APP	NW	72.7	75.7	75.9	70.4	76.9	81.5	82.8	89.6	95.2	86.2	81.7
13	HOVER 10'		–	–	–	–	–	–	–	–	–	–	–
14	HOVER 50'		–	–	–	–	–	–	–	–	–	–	–
15A	ACC T/O	NW	77.8	84.8	76.6	73.0	81.1	79.8	89.3	88.9	86.0	85.9	77.6
15B	ACC T/O	NW	80.4	85.7	84.4	82.7	82.9	86.6	94.2	106.8	91.1	85.3	78.2
16	LEVEL 100 90	SE	93.2	92.8	91.0	84.0	89.7	86.1	89.0	93.7	88.4	86.8	77.7
17	LEVEL 100 90	NW	93.1	95.5	92.4	83.0	90.8	84.7	89.3	95.8	89.7	86.8	76.9
18	STD APP	NW	97.6	89.7	89.9	85.5	85.6	81.8	84.9	85.9	83.8	83.5	75.3
19	ACC T/O	NW	83.4	86.4	82.5	80.8	80.5	82.6	91.2	90.8	87.9	87.4	77.8

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 12 Noise measurement database – Sea King

Helicopter: Sea King

Noise descriptor: L_{AE}

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	NW	92.7	94.4	96.5	92.1	95.4	92.8	98.0	98.1	97.3	94.2	84.8
2	LEVEL 150 90	SE	96.3	96.3	95.7	89.2	91.5	90.6	93.5	94.0	94.5	92.6	85.2
3	LEVEL 150 90	NW	95.3	96.0	96.9	91.7	94.9	90.9	94.9	95.0	94.8	93.2	84.9
4	LEVEL 150 120	SE	99.8	98.6	97.5	91.6	96.3	93.8	95.3	96.8	96.0	93.8	86.0
5	LEVEL 150 120	NW	97.4	97.7	98.6	91.5	96.4	92.5	96.9	96.8	95.6	93.7	85.6
6	STD APP	NW	75.9	91.2	84.6	79.3	91.4	94.2	94.6	105.4	96.9	99.7	78.5
7a	ACC T/O	NW	93.5	94.6	95.7	93.4	93.0	93.7	98.3	103.5	96.7	93.7	86.2
7b	ACC T/O	NW	98.3	103.7	97.0	87.5	93.8	88.9	96.3	107.2	94.8	91.6	86.4
8	LEVEL 300 90	SE	91.7	91.9	91.7	87.9	92.2	91.0	89.8	90.6	91.5	92.1	85.2
9	LEVEL 300 90	NW	92.3	92.8	95.1	91.2	93.7	92.0	93.4	92.0	93.5	92.7	84.1
10	LEVEL 300 120	SE	93.5	93.5	93.5	89.9	93.9	92.3	90.9	91.9	92.6	93.6	86.0
11	LEVEL 300 120	NW	93.7	94.1	96.6	91.8	94.3	92.7	94.9	93.5	94.2	93.9	87.3
12	SPIRAL APP	NW	84.7	84.6	83.3	79.4	85.6	88.7	92.2	95.7	99.7	76.0	89.9
13	HOVER 10'		–	92.3	87.0	80.7	91.7	95.3	99.3	101.1	93.5	99.5	90.8
14	HOVER 50'		–	103.1	97.9	88.6	101.8	101.5	102.3	104.0	104.5	104.5	94.0
15A	ACC T/O	NW	84.0	89.1	85.6	81.7	87.9	89.1	97.9	95.8	95.9	96.5	82.2
15B	ACC T/O	NW	91.4	92.7	92.5	91.0	92.5	93.9	98.2	104.9	96.2	92.6	83.4
16	LEVEL 100 90	SE	95.2	95.4	94.9	88.3	94.4	90.6	92.6	95.0	93.0	90.9	81.9
17	LEVEL 100 90	NW	97.1	97.9	97.4	91.2	95.4	90.6	95.5	97.1	95.3	92.2	83.2
18	STD APP	NW	101.5	96.4	97.3	91.4	94.6	91.5	93.0	93.9	93.4	93.7	80.2
19	ACC T/O	NW	89.7	93.2	91.4	88.8	89.5	91.6	98.6	97.1	96.5	95.1	84.2

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 13 Slant distances – Sea King

Helicopter: Sea King

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
			Slant distance (m)										
1	STD T/O	NW	102	86	127	203	122	197	107	37	107	197	505
2	LEVEL 150 90	SE	46	46	101	186	101	186	106	(46)	106	197	502
3	LEVEL 150 90	NW	49	49	103	187	103	187	108	(49)	108	198	502
4	LEVEL 150 120	SE	52	52	104	187	104	187	109	(52)	109	199	503
5	LEVEL 150 120	NW	47	47	101	186	101	186	107	(47)	107	198	502
6	STD APP	NW	–	–	–	–	–	–	102	18	102	197	500
7a	ACC T/O	NW	212	142	182	249	156	212	101	14	101	196	509
7b	ACC T/O	NW	11	11	91	180	91	180	100	9	100	198	500
8	LEVEL 300 90	SE	102	102	136	207	136	207	140	(102)	140	217	510
9	LEVEL 300 90	NW	84	84	123	199	123	199	128	(84)	128	210	507
10	LEVEL 300 120	SE	99	99	134	205	134	205	135	90	135	218	508
11	LEVEL 300 120	NW	87	87	125	200	125	200	122	69	122	204	506
12	SPIRAL APP	NW	–	–	–	–	–	–	158	60	47	144	500
13	HOVER 10'		440	240	298	374	216	236	290	250	240	270	500
14	HOVER 50'		440	240	298	374	216	236	290	250	240	270	500
15A	ACC T/O	NW	–	–	–	–	–	–	219	149	127	174	522
15B	ACC T/O	NW	266	174	214	280	178	225	100	9	100	200	510
16	LEVEL 100 90	SE	39	39	98	184	98	184	104	(39)	104	196	501
17	LEVEL 100 90	NW	35	35	96	183	96	183	102	(35)	102	195	501
18	STD APP	NW	48	74	113	191	120	199	171	138	171	238	511
19	ACC T/O	NW	300	234	250	295	250	295	178	147	178	245	508

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 14 Noise measurement database – Lynx

Helicopter: Lynx

Noise descriptor: L_{Amax}

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	89.9	88.4	86.3	83.6	85.8	81.2	82.5	84.2	80.9	82.1	72.8
2	LEVEL 150 120	NW	97.6	96.5	93.0	87.6	91.3	86.9	90.5	97.2	91.0	88.8	84.1
3	LEVEL 150 120	SE	93.8	94.3	89.3	84.7	91.9	86.9	89.0	95.9	92.2	88.0	79.7
4	LEVEL 150 150	NW	100.6	101.8	94.4	92.3	93.3	88.7	93.1	98.0	94.5	90.1	75.5
5	LEVEL 150 150	SE	96.5	96.6	94.1	89.3	94.6	89.8	91.9	97.0	94.1	91.8	81.2
6	STD APP	NW	97.6	93.2	87.2	81.6	91.6	87.6	84.0	85.8	82.5	84.1	80.2
7A	ACC T/O	SE	–	94.7	88.7	85.9	87.6	82.2	84.7	89.8	83.0	84.9	82.4
7B	ACC T/O	SE	–	98.5	89.8	82.1	88.2	81.2	86.1	93.5	88.1	85.5	73.3
8	LEVEL 300 120	NW	–	92.0	90.0	86.6	89.8	85.4	90.4	94.3	89.8	87.0	75.1
9	LEVEL 300 120	SE	–	93.5	91.9	88.1	91.5	89.0	91.0	96.3	92.4	89.5	77.0
10	LEVEL 300 150	NW	–	98.1	93.9	92.8	93.6	88.3	92.3	98.7	94.2	89.2	79.6
11	LEVEL 300 150	SE	–	95.8	94.1	88.4	93.4	90.3	91.6	94.8	91.5	91.6	80.6
12	SPL APP	NW	–	90.2	86.4	82.0	96.1	102.4	84.7	89.4	88.9	93.5	78.5
13	HOVER 10'		–	–	–	–	–	–	–	–	–	–	–
14	HOVER 50'		–	–	–	–	–	–	–	–	–	–	–
15A	ACC T/O	NW	85.7	85.3	84.9	81.8	84.1	82.7	84.9	95.8	86.4	84.1	78.0
15B	ACC T/O	NW	83.7	87.5	85.8	84.2	86.3	82.7	86.5	102.0	85.8	82.2	77.6
16	LEVEL 150 90	SE	97.2	96.9	93.5	88.5	92.5	87.7	88.7	98.0	88.1	86.3	76.7
17	LEVEL 150 150	NW	101.8	103.2	93.4	96.6	95.3	88.1	94.3	96.0	93.7	88.1	79.2
18	ACC T/O	SE	98.7	93.6	89.9	85.0	89.1	83.7	82.5	85.9	82.1	83.1	80.1
19	QUICK STOP APP	SE	98.0	94.5	88.9	84.1	94.7	86.2	86.3	97.0	97.0	91.2	84.4
20	ACC T/O	SE	87.4	84.3	83.1	82.7	81.1	80.8	79.6	82.2	79.1	80.5	74.4

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 15 Noise measurement database – Lynx

Helicopter: Lynx **Noise descriptor: L_{AE}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	94.9	93.3	92.1	90.2	91.5	89.6	89.0	91.7	87.7	89.4	78.8
2	LEVEL 150 120	NW	98.0	98.1	97.6	94.3	96.7	93.1	96.5	98.3	96.5	94.0	88.8
3	LEVEL 150 120	SE	96.7	96.6	94.8	92.7	96.6	93.2	94.1	98.6	95.2	93.7	84.6
4	LEVEL 150 150	NW	101.1	102.1	98.6	96.9	99.1	95.4	97.9	97.6	99.2	96.1	82.1
5	LEVEL 150 150	SE	98.7	97.3	99.0	95.8	91.8	96.4	97.5	98.6	97.8	97.6	88.0
6	STD APP	NW	104.4	97.7	94.5	92.0	96.5	93.8	90.6	94.4	91.1	92.9	86.4
7A	ACC T/O	SE	–	97.1	93.9	89.5	93.8	88.8	88.3	94.0	89.5	94.2	87.7
7B	ACC T/O	SE	–	98.8	93.2	88.1	93.0	88.5	90.6	97.1	93.6	91.1	79.1
8	LEVEL 300 120	NW	–	95.9	94.7	94.0	94.6	92.2	93.9	97.2	94.7	93.6	82.3
9	LEVEL 300 120	SE	–	95.1	94.8	93.3	96.3	93.4	94.1	98.5	96.1	95.4	81.9
10	LEVEL 300 150	NW	–	99.2	97.3	96.1	98.4	95.4	96.2	100.4	97.8	96.1	85.0
11	LEVEL 300 150	SE	–	97.5	97.5	94.8	95.9	95.3	93.0	98.4	95.5	96.3	84.8
12	SPL APP	NW	–	99.3	94.9	91.4	100.8	105.0	91.4	97.0	95.5	102.5	86.6
13	HOVER 10'		–	101.9	90.8	84.3	98.7	100.2	91.3	102.8	100.4	101.5	89.4
14	HOVER 50'		–	108.2	100.5	94.0	106.2	105.7	99.9	107.7	103.6	101.3	95.9
15A	ACC T/O	NW	90.4	91.1	90.7	89.4	91.0	89.2	93.4	98.5	92.4	91.4	83.0
15B	ACC T/O	NW	90.0	93.1	92.8	90.2	93.2	89.1	94.5	99.6	93.9	92.3	83.1
16	LEVEL 150 90	SE	100.8	100.3	98.8	95.7	97.3	94.4	94.7	100.0	95.0	94.6	84.5
17	LEVEL 150 150	NW	101.6	102.6	98.8	95.6	98.8	93.6	97.9	96.9	98.6	94.9	83.4
18	ACC T/O	SE	99.0	95.7	93.9	90.0	93.6	88.8	88.9	92.2	88.9	90.8	83.8
19	QUICK STOP APP	SE	100.4	98.4	95.8	93.8	97.8	92.7	94.7	102.8	100.8	99.1	89.9
20	ACC T/O	SE	93.8	91.0	90.5	89.4	89.2	89.7	86.7	89.7	86.8	88.6	79.8

Abbreviations:

STD T/O	Standard take–off
ACC T/O	Accelerated take–off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 16 Slant distances – Lynx

Helicopter: Lynx — **Slant distance (m)**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	57	76	115	192	121	199	162	127	162	238	508
2	LEVEL 150 120	NW	48	48	102	186	102	186	107	(48)	107	198	502
3	LEVEL 150 120	SE	48	48	102	186	102	186	107	(48)	107	198	502
4	LEVEL 150 150	NW	50	50	103	187	103	187	108	(50)	108	198	502
5	LEVEL 150 150	SE	55	55	106	188	106	188	111	(55)	111	200	503
6	STD APP	NW	67	97	128	199	137	211	179	148	179	244	512
7A	ACC T/O	SE	12	44	97	183	104	189	162	127	162	237	509
7B	ACC T/O	SE	15	20	92	181	93	181	108	40	108	202	501
8	LEVEL 300 120	NW	84	84	123	199	123	199	128	(84)	128	210	507
9	LEVEL 300 120	SE	87	87	125	200	125	200	130	(87)	130	211	508
10	LEVEL 300 150	NW	83	83	122	198	122	198	129	81	129	216	507
11	LEVEL 300 150	SE	91	91	128	202	128	202	133	88	133	209	508
12	SPL APP	NW	–	–	–	–	–	–	171	82	131	201	500
13	HOVER 10'		440	240	298	374	216	236	290	250	240	270	500
14	HOVER 50'		440	240	298	374	217	236	290	250	240	270	500
15A	ACC T/O	NW	121	97	136	210	128	200	102	22	102	201	506
15B	ACC T/O	NW	100	70	118	198	110	189	100	10	100	196	503
16	LEVEL 150 90	SE	46	46	101	186	101	186	106	(46)	106	197	502
17	LEVEL 150 150	NW	34	34	96	183	96	183	102	(34)	102	195	501
18	ACC T/O	SE	6	40	96	182	102	188	166	132	166	240	511
19	QUICK STOP APP	SE	36	36	97	184	97	184	193	154	135	223	500
20	ACC T/O	SE	73	103	132	201	141	214	203	176	203	265	550

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 17 Noise measurement database – Chinook

Helicopter: Chinook **Noise descriptor: L_{Amax}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	93.7	90.3	85.9	79.4	84.5	77.5	80.6	86.4	81.9	80.0	76.1
2	LEVEL 150 135	NW	99.2	96.1	88.9	83.1	95.4	93.1	86.9	95.9	96.5	94.1	83.1
3	LEVEL 150 135	SE	102.7	97.1	93.6	90.0	87.4	85.6	92.5	100.8	89.9	86.7	76.2
4	LEVEL 150 150	NW	103.2	105.6	92.7	87.5	94.5	90.9	89.2	99.8	94.3	92.3	82.2
5	LEVEL 150 150	SE	105.9	103.6	95.3	92.1	89.2	85.1	94.5	104.1	91.4	87.8	79.0
6	STD APP	NW	96.5	94.9	89.8	82.6	87.8	82.8	92.3	96.0	88.6	87.4	76.5
7A	ACC T/O	SE	95.1	89.7	86.5	83.5	84.6	80.7	80.2	82.0	80.9	79.9	72.4
7B	ACC T/O	SE	100.6	100.0	86.4	82.1	87.4	82.7	80.4	84.8	83.6	82.1	80.0
8	LEVEL 300 135	NW	92.3	95.5	85.7	81.8	89.4	91.8	89.3	98.7	91.9	92.2	81.2
9	LEVEL 300 135	SE	101.3	99.9	91.8	88.2	88.6	84.8	89.3	94.2	88.1	86.5	79.7
12	SPL APP	NW	85.6	–	89.9	81.1	91.8	89.6	89.7	89.7	90.9	97.0	85.8
13	HOVER 10'		–	–	–	–	–	–	–	–	–	–	–
14	HOVER 50'		–	–	–	–	–	–	–	–	–	–	–
15A	ACC T/O	NW	80.7	84.2	81.6	77.4	83.0	78.9	83.1	92.6	84.4	85.5	75.6
15B	ACC T/O	NW	79.4	84.7	81.7	78.3	84.0	80.6	81.8	95.2	84.1	81.8	74.3
16	LEVEL 100	SE	96.3	96.9	84.7	79.2	89.0	79.0	85.0	100.3	88.5	82.5	70.8
17	LEVEL 100	NW	107.5	108.2	93.2	89.9	95.6	90.2	90.8	105.6	93.4	90.5	79.6
18	LEVEL 300 150	NW	97.1	96.0	87.5	85.4	93.5	87.9	91.7	104.5	91.6	91.1	84.7
19	LEVEL 300 150	SE	103.0	98.7	97.9	92.3	86.7	86.4	96.8	102.5	89.8	87.2	80.0
20	SPL APP	NW	83.2	84.6	85.2	82.8	85.8	80.7	88.7	89.9	89.4	99.4	86.0

Abbreviations:

STD T/O	Standard take–off
ACC T/O	Accelerated take–off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 18 Noise measurement database – Chinook

Helicopter: Chinook **Noise descriptor: L_{AE}**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	98.5	94.9	92.8	89.3	91.2	86.9	87.6	90.7	88.8	87.9	82.2
2	LEVEL 150 135	NW	101.8	100.7	95.0	90.7	98.3	95.4	92.1	98.3	97.6	95.8	90.4
3	LEVEL 150 135	SE	102.8	99.2	96.9	94.3	93.5	89.8	96.6	101.2	93.7	91.6	83.1
4	LEVEL 150 150	NW	105.9	106.1	97.7	93.0	98.9	95.3	95.5	103.5	99.5	96.8	88.1
5	LEVEL 150 150	SE	105.6	103.8	100.3	96.1	95.8	91.9	99.9	105.1	96.2	93.5	85.5
6	STD APP	NW	103.2	101.2	97.5	92.6	96.2	92.3	98.6	100.9	96.3	94.5	82.7
7A	ACC T/O	SE	98.7	93.2	92.0	88.4	91.3	87.6	87.4	88.1	88.1	88.5	79.9
7B	ACC T/O	SE	99.2	99.0	93.0	90.4	91.6	88.7	88.3	86.6	89.9	88.5	86.3
8	LEVEL 300 135	NW	96.3	97.5	93.3	90.2	95.7	94.6	95.2	100.7	98.5	96.7	88.8
9	LEVEL 300 135	SE	102.5	101.2	96.4	93.6	93.6	91.2	94.1	94.8	93.5	92.8	84.0
12	SPL APP	NW	94.1	97.8	96.0	94.1	98.8	99.1	96.0	98.4	101.0	104.4	91.1
13	HOVER 10'		90.8	99.4	89.4	83.4	96.0	91.4	90.8	94.4	83.8	83.5	86.8
14	HOVER 50'		92.2	103.1	94.6	88.2	100.6	100.4	101.0	103.5	101.9	102.1	89.9
15A	ACC T/O	NW	90.0	89.0	89.0	88.0	90.5	88.0	92.1	96.7	92.7	94.9	81.6
15B	ACC T/O	NW	88.7	90.9	89.9	87.1	90.9	88.0	91.4	97.5	91.7	92.1	81.7
16	LEVEL 100	SE	97.7	96.9	90.9	87.4	91.0	86.5	91.0	100.7	92.2	89.4	77.4
17	LEVEL 100	NW	106.6	107.9	96.5	93.5	98.0	94.8	94.6	104.7	97.4	95.7	85.3
18	LEVEL 300 150	NW	100.0	99.5	94.9	92.1	97.7	94.7	95.7	104.1	97.6	96.9	92.2
19	LEVEL 300 150	SE	102.3	101.4	100.5	96.2	94.7	92.3	99.5	103.1	94.9	94.0	88.0
20	SPL APP	NW	92.4	98.1	93.3	92.9	96.1	94.9	97.8	99.5	98.4	102.8	94.6

Abbreviations:

STD T/O	Standard take-off
ACC T/O	Accelerated take-off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

Table 19 Slant distances – Chinook

Helicopter: Chinook — **Slant distance (m)**

Event	Description		NPL Site 1	NPL Site 2	NPL Site 3	NPL Site 4	NPL Site T1	NPL Site T2	IHMT Site 2	IHMT Site 3	IHMT Site 4	IHMT Site 5	IHMT Site 6
1	STD T/O	SE	34	47	100	185	103	188	119	65	119	200	503
2	LEVEL 150 135	NW	52	52	104	187	104	187	109	(52)	109	199	503
3	LEVEL 150 135	SE	52	52	104	187	104	187	109	(52)	109	199	503
4	LEVEL 150 150	NW	50	50	103	187	103	187	108	(50)	108	198	503
5	LEVEL 150 150	SE	50	50	103	187	103	187	108	(50)	108	198	503
6	STD APP	NW	59	74	114	192	119	197	135	91	135	216	507
7A	ACC T/O	SE	38	64	107	188	114	195	145	105	145	222	507
7B	ACC T/O	SE	21	21	92	181	93	181	124	73	124	205	502
8	LEVEL 300 135	NW	78	78	119	196	119	196	124	(78)	124	207	506
9	LEVEL 300 135	SE	93	93	129	202	129	202	133	(93)	133	213	508
12	SPIRAL APP	NW	–	–	–	–	–	–	102	18	102	201	500
13	HOVER 10'		440	240	298	374	216	236	290	250	240	270	500
14	HOVER 50'		440	240	298	374	217	236	290	250	240	270	500
15A	ACC T/O	NW	152	123	157	225	147	211	109	45	109	205	508
15B	ACC T/O	NW	151	99	142	217	126	196	101	13	101	200	503
16	LEVEL 100	SE	33	33	96	183	96	183	102	(33)	102	195	501
17	LEVEL 100	NW	36	36	97	184	97	184	103	(36)	103	195	501
18	LEVEL 300 150	NW	77	77	118	196	118	196	123	(77)	123	207	506
19	LEVEL 300 150	SE	89	89	126	201	126	201	131	(89)	131	211	508
20	SPIRAL APP	NW	–	–	–	–	–	–	110	24	95	193	500

Abbreviations:

STD T/O	Standard take–off
ACC T/O	Accelerated take–off
LEVEL 150 90	Level flyover at 150ft, 90kts
STD APP	Standard approach
SPL APP	Special approach

APPENDIX 1 Video tracking techniques

Reprinted from SAE Aerospace Information Report AIR 902

AIRCRAFT TRACKING

A BRIEF DESCRIPTION OF VIDEO TECHNIQUES USED AT THE NATIONAL PHYSICAL LABORATORY, UK

INTRODUCTION

The NPL video tracking system evolved from a requirement to measure the position of an aircraft during manoeuvres that involve turns and changes in altitude as well as straight and level flight. In addition it was decided that the system should use low cost domestic equipment.

Three techniques have been developed, each for a specific tracking task;

(a) a single "horizontal" camera system, that is suitable for use when the aircraft is flying a straight ground track;

(b) a two camera system, that can be used when the aircraft is flying curved ground tracks;

(c) a single "vertical" camera system, positioned underneath the aircraft flight track to provide altitude data.

Techniques (a) and (b) are designed to be used when the aircraft flight path is a considerable distance from the measurement location and a knowledge of aircraft dimensions is not required; the aircraft position is estimated relative to a single recognition point (eg nose or tail). Technique (c) requires details of the actual size of the aircraft to be tracked and is effectively the video equivalent of the still camera method in AIR 902.

A brief description of each technique is given below.

TECHNIQUE (a) – TRACKING BY A SINGLE HORIZONTAL CAMERA

This technique can be used when an aircraft flies on a constant heading and hence follows a straight ground track.

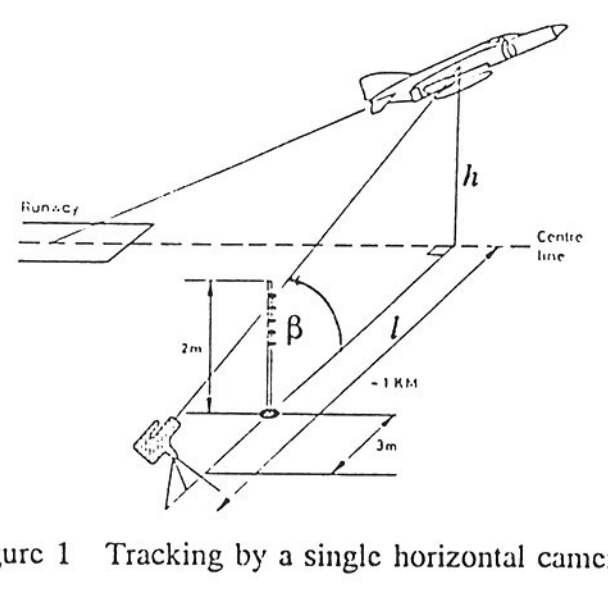

Figure 1 Tracking by a single horizontal camera.

A single video camera is set up at a lateral distance of about 1 km from the flight track (see Figure 1). A graduated pole, 2 m in height, is placed at the centre of the camera's field of view, with graduations so spaced that at a distance of 3 m, they subtend angles at the camera of two degree intervals. The bearing of the pole and camera are arranged by magnetic compass to be approximately at right angles to the flight track, and the ground co-ordinates of the camera are located accurately with the aid of a large-scale map.

The aircraft flypast is recorded on video tape, and the recording is then replayed on a television monitor. The replay is paused as the image of the aircraft passes behind the graduated pole, and the elevation of the aircraft above the horizon, β, is determined with reference to the markings on the pole. The distance, l, from the camera to the intercept on the ground track is known and hence the altitude of the aircraft, h, is determined simply using the Tangent formula, as follows:

$$h = l \tan \beta \qquad \text{.... (1)}$$

TECHNIQUE (b) - TRACKING BY TWO CAMERAS

This technique can be used where an aircraft makes a turn in flight, usually immediately after take-off or during approach..

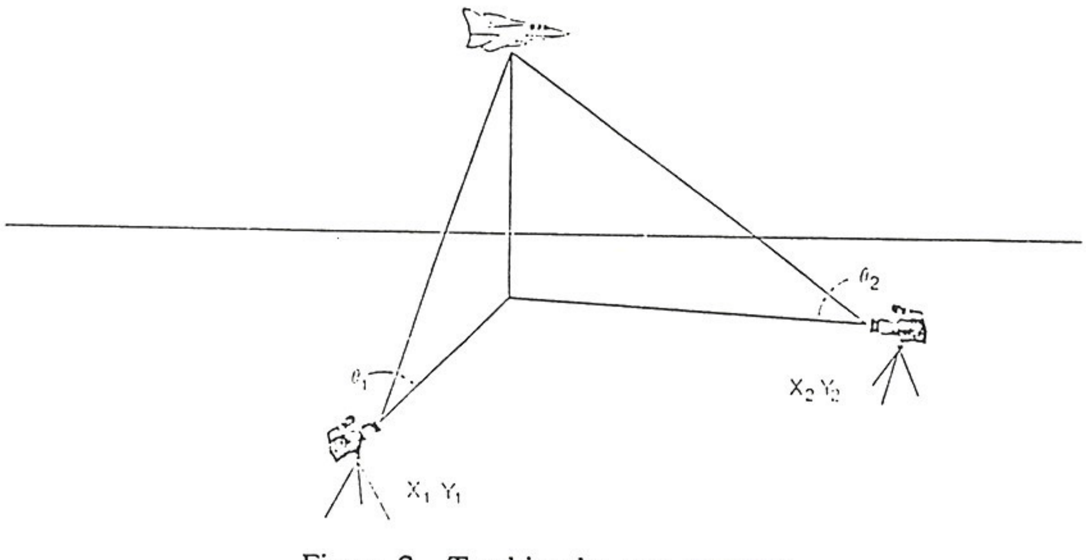

Figure 2 Tracking by two cameras.

The two cameras are positioned at known ground co-ordinates, each with a graduated pole 3 m away, (as with the single camera described above). The cameras are orientated so that their fields of view overlap in an area of sky through which the aircraft is to fly (see Figure 2), and the angles of view are arranged to provide the maximum coverage of the event to be tracked. However, care must be taken to ensure that the cameras do not directly face one another, since small changes in the bearing of an aircraft from the two sites would then result in large inaccuracies in the determination of aircraft position.

Ideally the cameras are positioned with their viewing axes as close to right angles to one another as can be achieved. The graduated pole at the centre of the field of view of each camera provides a datum from which the respective camera bearings are determined using a compass. Careful filming of local landmarks, together with their noted bearings enables later verification and, where necessary, correction of camera bearings. (Note: To align with the large-scale map used, these bearings might have to be converted from magnetic north to grid north.)

The image of the aircraft is recorded on video tape simultaneously with an IRIG B time code signal. The recordings are replayed and sections of synchronous recording from each site are located. The images of the aircraft are then "frozen" at one-second intervals and co-ordinate readings are taken, either manually from a graticule superimposed on a monitor screen or automatically using suitable image processing software. The coincident azimuth and elevation angles of the aircraft from each camera position are determined throughout its movement across the monitor screen, from the co-ordinates of the aircraft on the screen, the bearing of the mast and the calibration of the screen graticule. This information is then processed using the formulae derived below to determine the map co-ordinates of the aircraft's ground track, and the aircraft height and speed at 1 second intervals.

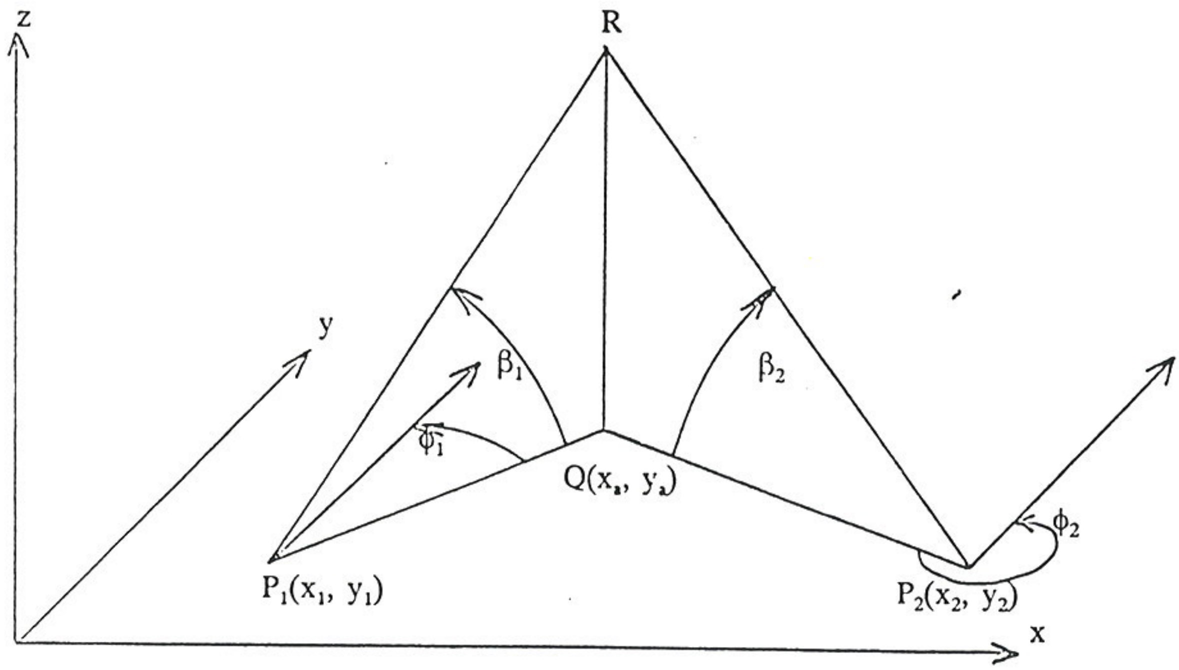

Figure 3 Geometry for determination of instantaneous ground co-ordinates and altitude of an aircraft in flight.

Referring to Figure 3, the ground co-ordinates in the x-y plane of the positions of cameras 1 and 2, respectively P_1 (x_1, y_1) and P_2 (x_2, y_2), are known. At an instant captured on the video recordings the aircraft is at point R, vertically above point Q on the ground whose co-ordinates (x_a, y_a) are to be determined. The altitude RQ is also to be determined. The azimuth grid bearings (x-y plane) of P_1Q and P_2Q, respectively ϕ_1 and ϕ_2, are determined by measurement from the monitor screen, and so are the elevation angles, β_1 and β_2, of the aircraft from the two camera positions.

Let P_1Q be defined by:

$$y_1 = m_1x_1 + c_1 \qquad \text{.... (2)}$$

and let P_2Q be defined by:

$$y_2 = m_2x_2 + c_2 \qquad \text{.... (3)}$$

The gradient of equation (2), m_1, is given by:

$$m_1 = \tan (90-\phi_1) = 1/\tan \phi_1 \qquad \text{.... (4)}$$

and the gradient of equation (3), m_2, is given by:

$$m_2 = \tan (90-\phi_2) = 1/\tan \phi_2 \qquad \text{.... (5)}$$

AT P_1, x_1 and y_1 are known, so the intercept of equation (2) is given by:

$$c_1 = y_1 - m_1 x_1 = y_1 - x_1/\tan \phi_1 \qquad \text{.... (6)}$$

and similarly the intercept of equation (3) is given by:

$$c_2 = y_2 - m_2 x_2 = y_2 - x_2/\tan \phi_2 \qquad \text{.... (7)}$$

At Q, (x_a, y_a),

$$m_1x_a + c_1 = y_a = m_2x_a + c_2 \qquad \text{.... (8)}$$

so that

$$x_a = (c_1 - c_2) / (m_2 - m_1) \qquad \text{.... (9)}$$

and

$$(y_a - c_1) / m_1 = x_a = (y_a - c_2) / m_2 \qquad \text{... (10)}$$

so that

$$y_a = (m_2 c_1 - m_1 c_2) / (m_2 - m_1) \qquad \text{... (11)}$$

The aircraft altitude is given by:

$$RQ = P_1Q \tan \beta_1 = P_2Q \tan \beta_2 \qquad \text{... (12)}$$

where

$$P_1Q = \sqrt{[(x_a - x_1)^2 + (y_a - y_1)^2]} \qquad \text{... (13)}$$

and

$$P_2Q = \sqrt{[(x_a - x_2)^2 + (y_a - y_2)^2]} \qquad \text{... (14)}$$

RQ should be identical from either determination, but in practice small differences may occur due to slight inaccuracies in measurement of the bearing and elevation angles from the monitor screen. In practice, therefore, RQ is taken as the mean of the two determinations, ie

$$\mathbf{RQ = (P_1Q \tan \beta_1 + P_2Q \tan \beta_2) / 2} \qquad \text{... (15)}$$

TECHNIQUE (c) – SINGLE VERTICAL CAMERA FOR HEIGHT DATA

This technique can be used for an aircraft in straight and level flight.

The video camera is positioned directly beneath the flight path pointing vertically upwards. Accurate vertical alignment of the viewing axis is achieved using spirit levels. The video recording of the flyover is replayed on a television monitor with a screen dimension w, along the axis of a chosen aircraft dimension. The image of the aircraft is "frozen" in the middle of the screen and d, the chosen dimension, measured. If the actual magnitude of this aircraft dimension is D, the aircraft altitude, h, may be estimated from:

$$h = D\, w \,/\, 2\, d \tan(\theta/2) \qquad \text{... (16)}$$

where θ is the camera field of view and is the video camera equivalent of f, the focal length such that;

$$f = w \,/\, 2 \tan(\theta/2) \qquad \text{... (17)}$$

Note: the field of view of the camera, in degrees, may be determined by pointing the camera at a screen positioned a fixed distance away. If the edges of the image seen through the camera are marked on the screen and measured, the field of view is readily determined.