Environmental Research and Consultancy Department

Noise data for the first 17 months of Boeing 787 operations at Heathrow airport

CAP 1191

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The work reported herein was carried out under a contract placed on 9 December 2013 by Heathrow Airport Limited.

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Summary

This report presents summary information on monitored departure and arrival noise levels for the first 17 months of operation of the Boeing 787 Dreamliner. The report was commissioned by Heathrow Airport Limited, as part of an undertaking set out in their Noise Action Plan to assess the noise performance of all new types introduced at Heathrow airport. Data from the Boeing 787 are compared to the Boeing 767 and Airbus A330, whose operations are most likely to be replaced by the 787 in the coming years.

At the monitor locations around Heathrow, the analysis has shown that the Boeing 787 is significantly quieter than the 767 and A330. The 787 is on average up to 7 dB quieter on departure than the 767, and up to 8 dB quieter than the A330 aircraft. The results also confirm that the 787 is up to 3 dB quieter on arrival than the aircraft types it is intended to replace.

CHAPTER 1

Introduction

The Boeing 787 Dreamliner is a long-range, wide-bodied, twin-engine aircraft which entered scheduled airline service at Heathrow airport with Qatar Airways on 13 December 2012. Over the following 18 months several other airlines also introduced the aircraft into regular service, including British Airways which commenced long haul 787 operations on 1 September 2013 and is now the largest operator of the type at Heathrow.

As a result of advanced engine and airframe technologies, including the use of composite materials to reduce weight, the 787 has been designed to be 20 percent more fuel efficient and significantly quieter than similarly sized aircraft. Boeing provides a choice of two engines on the 787, the GEnx-1B from GE Aviation or the Trent 1000 from Rolls-Royce.

The 787-8 is the first variant of the 787 to be produced and is intended to replace existing 200-250 seat aircraft such as the Boeing 767 and Airbus A330, although some airlines have introduced the 787-8 on routes previously flown by larger aircraft such as the 300 seat Boeing 777. Current production variants of the 787 meet the London airports' QC/0.5 night noise classification on departure, compared to QC/1 or QC/2 for the 767 and A330. On arrival the 787 is classified as QC/0.25 whilst the 767 and A330 can be classified as QC/0.5 or QC/1.

A stretched 787-9 variant entered worldwide airline service in July 2014 and Virgin Atlantic will be the first European airline to receive the new variant when it takes delivery of its first Dreamliner later in the year. A further stretched 787-10 variant is currently in development with first deliveries expected in 2018.

This report presents information and analysis on monitored noise levels of the Boeing 787-8 during both departure and arrival, and compares them to other aircraft types of similar size operating at Heathrow airport. An analysis of flight tracks and height profiles is also provided.

This report was commissioned by Heathrow Airport Limited, as part of an undertaking set out in their Noise Action Plan to assess the noise performance of all new types introduced at Heathrow airport.

CHAPTER 2

Data collection

For this study, noise measurements and radar data were extracted from the Heathrow Noise and Track Keeping (NTK) System for the period 1 December 2012 to 30 April 2014.

Noise data were taken from both fixed and mobile noise monitors that were deployed during the study period. As well as presenting results for the Boeing 787, data have also been extracted and analysed for variants of the Boeing 767 and Airbus A330, as summarised below.

Aircraft type	Maximum take-off weight (tonnes)*
Boeing 787-8	227.9
Boeing 767-300	186.9
Boeing 767-400	204.1
Airbus A330-200	238.0
Airbus A330-300	235.0

*Data taken from European Aviation Safety Agency (EASA) Type Certificate Data Sheet for Noise database (TCDSN), Jets Issue 17

Figure 1 and Table 1 provide information on the noise monitors deployed during the study period. The fixed monitors identified were all deployed for the full 17 month period. The months a particular mobile monitor was deployed is also indicated in Table 1.

Mobile monitors are normally deployed during the summer months, although some are sometimes deployed at other times of the year. Note that some noise monitor results have been excluded from this assessment since they are considerably to the side of the flight paths used by the Boeing 787. This is to enable a more robust comparison to be made between 787 monitored data and other aircraft types.

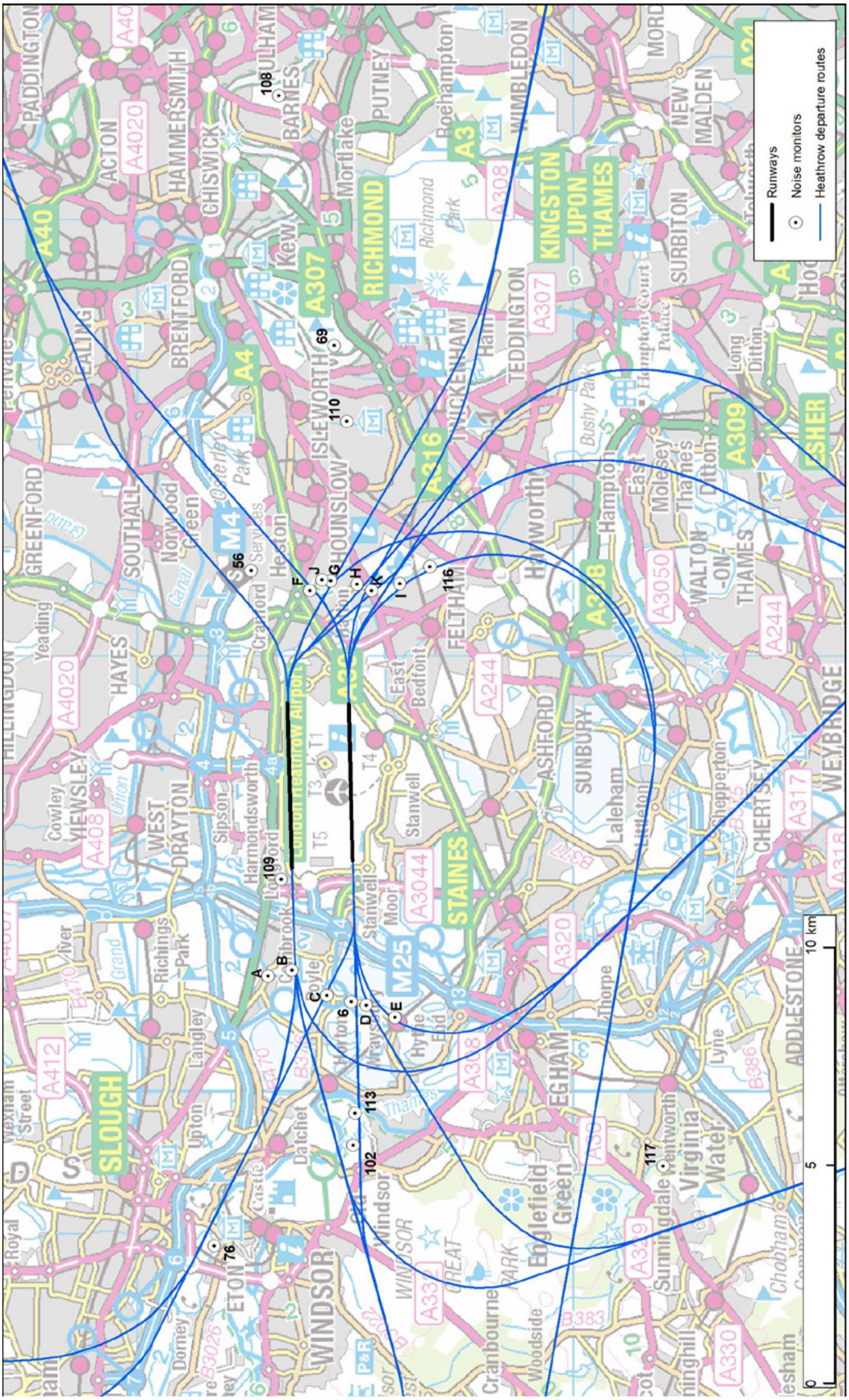
Approximately 15 percent of all noise measurements were rejected due to unacceptable weather conditions, i.e. wind speeds greater than 10 m/s (20 kt) or during periods of precipitation, in accordance with recommended international guidance[1] on aircraft noise monitoring.

1 ISO 20906:2009, Acoustics - Unattended monitoring of aircraft sound in the vicinity of airports

Table 1 Noise monitoring sites

Site		Type	Period of deployment	Distance from start of roll (km)		Distance to touchdown (km)	
				Runway 27L / 27R	Runway 09R	Runway 27L / 27R	Runway 09L / 09R
6	Thames Water, Wraysbury	Fixed	-	6.6 / -	-	-	- / 3.8
A	Colnbrook	Fixed	-	- / 6.0	-	-	-
B	Poyle	Fixed	-	- / 5.9	-	-	2.8 / -
C	Horton	Fixed	-	6.6 / 6.8	-	-	-
D	Coppermill	Fixed	-	6.7 / -	-	-	-
E	Wraysbury Reservoir (South)	Fixed	-	7.3 / -	-	-	-
F	Hounslow West	Fixed	-	-	6.3	-	-
G	Hounslow Cavalry Barracks	Fixed	-	-	6.2	-	-
H	Hounslow Heath	Fixed	-	-	6.2	-	-
I	East Feltham	Fixed	-	-	6.6	-	-
J	Hounslow Cavalry Barracks North	Fixed	-	-	6.3	-	-
K	Hounslow Heath Golf Course	Fixed	-	-	6.1	-	-
56	Berkeley School	Mobile	Dec-12 to Apr-14	-	7.4	-	-
69	Richmond	Mobile	Dec-12 to Sep-13	-	-	8.5 / -	-
76	Eton	Mobile	Jun-13 to Sep-13	12.9 / 12.6	-	-	-
102	Old Windsor	Mobile	Jun-13 to Sep-13	9.9 / 10.1	-	-	- / 7.1
108	Barnes	Mobile	Jun-13 to Sep-13	-	-	- / 14.2	-
109	Longford	Mobile	Dec-12 to Apr-14	- / 3.8	-	-	-
110	Isleworth	Mobile	Dec-12 to Apr-13	-	-	6.8 / -	-
113	Old Windsor	Mobile	Dec-12 to Mar-13	- / 9.4	-	-	-
116	Feltham	Mobile	Aug-13 to Apr-14	-	7.4	-	-
117	Wentworth Golf Course	Mobile	Sep-13 to Apr-14	-	23.4	-	-

Figure 1 Noise monitor locations



CHAPTER 3

Departure noise monitor data

The departure noise monitor data have been separated by runway as in some cases, the distance the aircraft has travelled from the start of roll (SOR) position differs slightly depending on the runway used.[2] The average distance from SOR to each noise monitor has been calculated using radar data extracted from the NTK system.

Table 2 presents data for the Boeing 787 and 767 aircraft in terms of the Sound Exposure Level (SEL) metric. Note that the data have been separated by engine type, although this was not necessarily in anticipation of any expected noise differences between the two 787 variants. The noise monitor data have been sorted in terms of distance from SOR; distance increases as one moves from left to right through the tables. Table 3 presents equivalent departure noise data for the Airbus A330 aircraft.

The SEL metric takes into account both the level of a noise event and the duration of the event. Thus if the level of two events were the same, but one were to last twice as long as the other, the SEL level would increase by 3 dB. SEL is important since it is the 'building block' of overall noise indexes such as L_{eq} and L_{den}.

Data for the simpler L_{max} metric are also provided for information in Tables 4 and 5. The L_{max} metric takes account of the peak level only and not the duration of the event. Typically an SEL value is approximately 10 dB higher than the corresponding L_{max} for the same event. However, nearer the airport where the aircraft are lower and thus the durations shorter, the difference will be slightly less than 10 dB. Conversely further away from the airport where aircraft are higher and durations longer, the difference will be slightly more than 10 dB.

SEL (and L_{max}) are measured and reported on a logarithmic scale. An average SEL value can be calculated on both an arithmetic basis and a logarithmic average basis.
A logarithmic average gives greater weight to higher noise levels and is the calculation method used when generating L_{eq} and L_{den} noise contours. Table 2 gives both logarithmic and arithmetic average SEL values at each monitor location, along with the standard deviation and 95 percent confidence interval (CI) of the mean level.

The reliability of the measured noise levels for each aircraft type can be expressed as a 95 percent confidence interval. This is the interval around the sample mean within which it is reasonable to assume the 'true' value of the mean lies. Due to the relatively large sample sizes obtained, the 95 percent confidence intervals of the departure noise levels in the majority of cases are very small, i.e. less than 0.5 dB.

2 Data for 09L departures were not analysed due to low sample sizes.

Table 2 SEL departure noise levels for the Boeing 787 and Boeing 767

		SEL, dBA										
	Monitor site	**109**	**B**	**A**	**K**	**H**	**G**	**F**	**J**	**I**	**6**	**C**
	Runway	**27R**	**27R**	**27R**	**09R**	**09R**	**09R**	**09R**	**09R**	**09R**	**27L**	**27L**
Aircraft Type	**Dist. from SOR (km)**	**3.8**	**5.9**	**6.0**	**6.1**	**6.2**	**6.2**	**6.3**	**6.3**	**6.6**	**6.6**	**6.6**
Boeing 787-8 (GE GEnx-1B engines)	Log Avg	91.4	88.9	85.2	85.9	85.1	84.0	85.1	84.7	83.5	85.0	84.2
	Mean	91.2	88.7	84.9	84.8	84.5	83.2	83.1	83.2	82.9	84.6	82.9
	Std Dev	1.4	1.5	1.6	3.5	2.4	2.7	4.4	3.7	2.1	1.8	3.4
	Count	362	398	401	235	283	252	254	268	164	359	362
	95% CI	0.1	0.1	0.2	0.4	0.3	0.3	0.5	0.4	0.3	0.2	0.3
Boeing 787-8 (RR Trent 1000 engines)	Log Avg	89.6	87.5	83.8	85.7	83.5	81.3	84.5	84.0	84.6	85.1	82.6
	Mean	89.3	87.3	83.5	85.3	82.7	80.2	82.9	80.8	84.0	84.2	82.1
	Std Dev	1.6	1.5	1.7	2.1	2.6	3.1	3.9	4.2	2.4	3.1	2.1
	Count	232	261	264	118	161	125	77	108	104	250	255
	95% CI	0.2	0.2	0.2	0.4	0.4	0.5	0.9	0.8	0.5	0.4	0.3
Boeing 767-300 (GE CF6-80C2 engines)	Log Avg	95.6	92.2	89.9	89.6	88.0	86.9	86.7	87.0	89.1	89.6	88.7
	Mean	95.2	91.9	89.6	88.7	87.5	85.6	85.1	85.6	87.6	89.2	88.3
	Std Dev	1.9	1.8	1.6	3.1	2.3	3.3	3.7	3.5	4.4	2.0	2.1
	Count	1158	1276	1257	1097	1125	1068	1061	1084	1081	1260	1240
	95% CI	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.3	0.1	0.1
Boeing 767-300 (PW PW4000 engines)	Log Avg	97.1	93.5	90.9	91.3	89.7	88.5	88.2	88.6	90.6	91.0	90.0
	Mean	96.8	93.2	90.6	90.5	89.2	87.2	86.3	87.1	89.3	90.8	89.5
	Std Dev	1.6	1.4	1.7	2.9	2.2	3.2	4.0	3.5	4.0	1.5	2.3
	Count	1130	1256	1243	1096	1118	1068	1062	1084	1114	1180	1161
	95% CI	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1
Boeing 767-300 (RR RB211-524 engines)	Log Avg	96.1	92.7	89.4	90.2	88.3	86.5	88.4	86.3	89.4	90.3	88.8
	Mean	95.9	92.4	89.2	88.1	87.2	85.8	85.5	85.1	87.7	89.8	87.8
	Std Dev	1.5	1.5	1.6	5.0	3.4	2.6	5.2	3.2	4.8	2.1	3.1
	Count	3163	3469	3464	2628	2823	2703	2722	2787	2095	3060	3028
	95% CI	0.1	0.0	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.1
Boeing 767-400 (GE CF6-80C2 engines)	Log Avg	98.4	93.9	90.9	91.5	89.4	87.1	86.0	86.8	90.7	90.7	89.1
	Mean	98.1	93.6	90.7	90.8	88.9	85.9	84.2	85.4	89.9	90.4	88.7
	Std Dev	1.5	1.7	1.3	2.6	2.1	2.9	3.6	3.2	3.2	1.6	1.9
	Count	817	912	896	838	848	812	799	835	850	870	862
	95% CI	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1

Table 2 SEL departure noise levels for the Boeing 787 and Boeing 767 (continued)

		SEL, dBA										
	Monitor site	**D**	**C**	**E**	**56**	**116**	**113**	**102**	**102**	**76**	**76**	**117**
	Runway	**27L**	**27R**	**27L**	**09R**	**09R**	**27R**	**27L**	**27R**	**27R**	**27L**	**09R**
Aircraft Type	**Dist. from SOR (km)**	**6.7**	**6.8**	**7.3**	**7.4**	**7.4**	**9.4**	**9.9**	**10.1**	**12.6**	**12.9**	**23.4**
Boeing 787-8 (GE GEnx-1B engines)	Log Avg	85.3	84.1	84.8	81.0	80.3	78.8	80.1	78.9	79.3	79.0	-
	Mean	84.6	83.9	84.3	80.6	79.1	78.6	79.8	77.7	79.1	78.9	-
	Std Dev	2.8	1.3	2.3	2.1	3.1	1.4	1.9	3.4	1.4	1.3	-
	Count	364	395	225	120	95	10	15	47	22	22	-
	95% CI	0.3	0.1	0.3	0.4	0.6	1.0	1.1	1.0	0.6	0.6	-
Boeing 787-8 (RR Trent 1000 engines)	Log Avg	84.3	82.0	78.7	80.0	83.6	-	82.4	81.1	76.0	75.9	71.8
	Mean	83.3	81.7	78.3	79.6	82.7	-	82.2	80.9	75.8	75.4	71.5
	Std Dev	3.3	1.7	1.8	2.0	3.4	-	1.5	1.1	1.3	2.2	1.8
	Count	248	262	161	42	104	-	11	13	8	11	13
	95% CI	0.4	0.2	0.3	0.6	0.7	-	1.0	0.6	1.1	1.4	1.1
Boeing 767-300 (GE CF6-80C2 engines)	Log Avg	89.1	89.0	85.5	84.8	87.8	84.6	84.4	84.7	83.4	83.0	76.1
	Mean	88.8	88.7	84.5	84.0	86.5	83.9	83.0	83.2	83.1	82.6	75.3
	Std Dev	1.9	1.7	3.3	2.7	4.2	2.8	4.2	4.2	2.0	2.1	2.7
	Count	1269	1234	1127	301	341	229	296	282	92	101	47
	95% CI	0.1	0.1	0.2	0.3	0.5	0.4	0.5	0.5	0.4	0.4	0.8
Boeing 767-300 (PW PW4000 engines)	Log Avg	90.8	90.9	87.5	86.0	88.9	86.3	85.6	86.4	85.2	84.8	77.2
	Mean	90.6	90.7	86.2	84.4	87.4	85.8	84.3	85.2	85.0	84.6	76.2
	Std Dev	1.5	1.5	3.8	4.3	4.5	2.1	3.9	3.7	1.8	1.4	3.1
	Count	1192	1232	1123	280	448	173	250	244	100	88	93
	95% CI	0.1	0.1	0.2	0.5	0.4	0.3	0.5	0.5	0.4	0.3	0.6
Boeing 767-300 (RR RB211-524 engines)	Log Avg	90.2	88.4	86.9	87.3	87.3	84.0	85.5	84.7	84.0	83.5	76.0
	Mean	89.5	88.1	84.9	86.8	86.2	82.7	82.3	82.0	83.4	83.0	75.3
	Std Dev	2.5	1.5	4.5	2.3	3.4	3.6	6.3	5.4	2.3	2.0	2.6
	Count	3082	3422	2371	1064	709	453	386	679	337	336	39
	95% CI	0.1	0.0	0.2	0.1	0.2	0.3	0.6	0.4	0.2	0.2	0.8
Boeing 767-400 (GE CF6-80C2 engines)	Log Avg	90.0	89.5	85.8	84.0	88.8	85.7	86.0	86.3	84.9	84.3	77.1
	Mean	89.7	89.3	85.2	82.3	87.7	85.5	85.3	85.1	84.7	84.2	76.0
	Std Dev	1.6	1.4	2.7	4.4	4.1	1.4	3.2	4.0	1.1	1.3	3.2
	Count	877	894	808	132	320	126	219	219	53	43	70
	95% CI	0.1	0.1	0.2	0.8	0.4	0.3	0.4	0.5	0.3	0.4	0.8

Table 3 SEL departure noise levels for the Airbus A330

		SEL, dBA										
	Monitor site	**109**	**B**	**A**	**K**	**H**	**G**	**F**	**J**	**I**	**6**	**C**
	Runway	**27R**	**27R**	**27R**	**09R**	**09R**	**09R**	**09R**	**09R**	**09R**	**27L**	**27L**
Aircraft Type	**Dist. from SOR (km)**	**3.8**	**5.9**	**6.0**	**6.1**	**6.2**	**6.2**	**6.3**	**6.3**	**6.6**	**6.6**	**6.6**
Airbus A330-200 (GE CF6-80E1 engines)	Log Avg	97.0	92.7	89.2	90.9	88.1	84.3	83.1	83.2	90.8	87.9	85.2
	Mean	96.5	92.4	89.0	90.4	87.8	83.8	81.6	82.4	90.6	87.6	84.3
	Std Dev	2.0	1.6	1.5	2.5	1.6	1.9	3.3	2.6	1.5	1.6	2.6
	Count	191	203	202	174	173	168	144	177	171	197	193
	95% CI	0.3	0.2	0.2	0.4	0.2	0.3	0.5	0.4	0.2	0.2	0.4
Airbus A330-200 (PW PW4000 engines)	Log Avg	97.6	93.2	90.4	90.3	89.1	87.4	87.0	87.4	88.4	90.1	87.9
	Mean	97.3	92.9	90.1	89.9	88.6	85.9	85.0	85.5	87.7	89.7	86.8
	Std Dev	1.6	1.6	1.8	1.9	2.1	3.6	4.0	4.1	3.0	1.9	3.1
	Count	276	295	290	179	183	179	165	183	183	218	213
	95% CI	0.2	0.2	0.2	0.3	0.3	0.5	0.6	0.6	0.4	0.3	0.4
Airbus A330-200 (RR Trent 700 engines)	Log Avg	97.7	92.8	90.7	90.5	89.9	88.3	88.1	88.4	87.5	89.8	88.0
	Mean	97.3	92.4	90.3	89.9	89.5	87.4	86.2	87.1	86.8	89.4	86.9
	Std Dev	2.0	1.9	1.9	2.5	1.9	2.7	3.7	3.2	2.8	1.9	2.9
	Count	836	905	897	776	787	751	788	787	791	853	848
	95% CI	0.1	0.1	0.1	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.2
Airbus A330-300 (GE CF6-80E1 engines)	Log Avg	97.9	93.0	89.0	91.2	88.1	84.1	83.6	83.3	91.0	87.8	84.9
	Mean	97.5	92.7	88.7	91.0	87.9	83.4	81.5	82.3	90.6	87.5	83.8
	Std Dev	1.9	1.8	1.8	1.6	1.5	2.3	3.8	2.8	2.3	1.4	2.6
	Count	211	224	225	187	190	186	141	191	189	215	215
	95% CI	0.3	0.2	0.2	0.2	0.2	0.3	0.6	0.4	0.3	0.2	0.3
Airbus A330-300 (PW PW4000 engines)	Log Avg	98.7	94.3	91.8	90.7	88.9	87.2	87.8	86.4	90.1	91.1	90.1
	Mean	98.5	94.0	91.6	89.2	88.1	86.2	85.5	85.5	88.3	90.7	89.7
	Std Dev	1.1	1.9	1.2	4.1	2.6	2.8	4.6	2.7	4.8	2.0	1.8
	Count	220	251	249	204	208	196	194	204	200	222	219
	95% CI	0.2	0.2	0.2	0.6	0.4	0.4	0.7	0.4	0.7	0.3	0.2
Airbus A330-300 (RR Trent 700 engines)	Log Avg	97.8	93.8	90.8	90.9	89.6	87.9	87.8	87.9	89.5	90.9	88.6
	Mean	97.6	93.5	90.5	90.1	89.1	86.6	85.2	86.1	88.1	90.5	87.7
	Std Dev	1.4	1.8	1.7	3.0	2.2	3.3	4.6	3.8	4.1	1.8	2.8
	Count	1804	1970	1956	1662	1676	1584	1565	1656	1653	1830	1812
	95% CI	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1

Table 3 SEL departure noise levels for the Airbus A330 (continued)

		SEL, dBA										
	Monitor site	**D**	**C**	**E**	**56**	**116**	**113**	**102**	**102**	**76**	**76**	**117**
	Runway	**27L**	**27R**	**27L**	**09R**	**09R**	**27R**	**27L**	**27R**	**27R**	**27L**	**09R**
Aircraft Type	**Dist. from SOR (km)**	**6.7**	**6.8**	**7.3**	**7.4**	**7.4**	**9.4**	**9.9**	**10.1**	**12.6**	**12.9**	**23.4**
Airbus A330-200 (GE CF6-80E1 engines)	Log Avg	87.8	91.4	87.8	88.6	88.4	82.5	85.3	86.6	-	-	-
	Mean	87.4	90.9	87.3	85.4	88.3	80.5	82.2	86.1	-	-	-
	Std Dev	1.7	2.6	2.4	7.7	1.2	3.8	6.6	2.5	-	-	-
	Count	194	202	185	7	73	25	6	11	-	-	-
	95% CI	0.2	0.4	0.3	7.1	0.3	1.6	6.9	1.6	-	-	-
Airbus A330-200 (PW PW4000 engines)	Log Avg	90.0	89.0	87.4	84.8	85.4	83.3	78.9	83.9	85.6	85.8	-
	Mean	89.7	88.8	86.3	84.1	85.1	82.3	77.7	81.4	85.5	85.8	-
	Std Dev	1.6	1.3	3.4	2.2	2.2	3.0	2.8	5.0	0.8	0.5	-
	Count	218	285	207	35	70	42	33	80	49	11	-
	95% CI	0.2	0.2	0.5	0.8	0.5	0.9	1.0	1.1	0.2	0.4	-
Airbus A330-200 (RR Trent 700 engines)	Log Avg	90.5	89.8	89.2	86.0	84.3	84.0	78.7	85.9	85.6	85.9	-
	Mean	90.1	89.6	88.0	84.7	83.5	82.8	77.8	82.9	85.3	85.8	-
	Std Dev	2.1	1.8	3.9	4.2	2.9	3.3	2.5	5.8	1.8	1.2	-
	Count	861	822	799	192	263	163	64	82	34	38	-
	95% CI	0.1	0.1	0.3	0.6	0.4	0.5	0.6	1.3	0.6	0.4	-
Airbus A330-300 (GE CF6-80E1 engines)	Log Avg	87.4	91.8	87.8	89.2	88.5	80.5	84.1	85.0	-	-	-
	Mean	87.2	91.3	87.3	87.3	88.3	79.5	83.3	84.9	-	-	-
	Std Dev	1.4	2.5	2.5	6.1	1.5	2.5	3.8	1.2	-	-	-
	Count	218	222	194	8	69	27	8	10	-	-	-
	95% CI	0.2	0.3	0.4	5.1	0.4	1.0	3.1	0.8	-	-	-
Airbus A330-300 (PW PW4000 engines)	Log Avg	90.4	89.9	85.6	89.6	89.3	86.6	86.6	86.9	85.9	85.1	78.3
	Mean	89.9	89.7	84.6	88.9	87.8	86.3	84.9	84.9	85.8	84.9	77.8
	Std Dev	2.2	1.5	3.5	3.4	3.1	1.9	4.9	5.3	1.4	1.4	2.4
	Count	223	241	195	50	70	18	64	63	21	19	21
	95% CI	0.3	0.2	0.5	1.0	0.7	1.0	1.2	1.3	0.7	0.7	1.1
Airbus A330-300 (RR Trent 700 engines)	Log Avg	90.9	89.9	87.9	84.7	87.2	85.4	86.4	85.5	84.8	85.4	78.2
	Mean	90.5	89.6	86.4	83.5	85.7	84.6	84.2	83.2	84.5	85.1	77.1
	Std Dev	1.9	1.9	3.8	3.7	4.1	2.8	5.4	5.2	1.9	1.8	3.3
	Count	1847	1932	1669	360	582	288	251	335	133	111	93
	95% CI	0.1	0.1	0.2	0.4	0.3	0.3	0.7	0.6	0.3	0.3	0.7

Table 4 L_{max} departure noise levels for the Boeing 787 and Boeing 767

		L_{max}, dBA										
	Monitor site	**109**	**B**	**A**	**K**	**H**	**G**	**F**	**J**	**I**	**6**	**C**
	Runway	**27R**	**27R**	**27R**	**09R**	**09R**	**09R**	**09R**	**09R**	**09R**	**27L**	**27L**
Aircraft Type	**Dist. from SOR (km)**	**3.8**	**5.9**	**6.0**	**6.1**	**6.2**	**6.2**	**6.3**	**6.3**	**6.6**	**6.6**	**6.6**
Boeing 787-8 (GE GEnx-1B engines)	Mean	83.1	81.0	75.6	76.1	74.7	73.4	73.7	74.1	73.1	74.6	72.9
	Std Dev	1.7	2.3	2.0	4.0	2.9	3.3	4.6	4.2	2.5	2.2	3.5
	Count	362	398	401	235	283	252	254	268	164	359	362
Boeing 787-8 (RR Trent 1000 engines)	Mean	80.8	79.2	73.7	76.2	72.5	70.3	73.1	71.7	74.7	73.9	71.2
	Std Dev	1.9	2.0	1.7	2.4	2.7	3.1	4.0	4.2	2.9	3.3	2.5
	Count	232	261	264	118	161	125	77	108	104	250	255
Boeing 767-300 (GE CF6-80C2 engines)	Mean	86.8	83.7	80.6	79.2	77.5	75.6	75.5	76.1	78.0	78.7	77.5
	Std Dev	2.6	2.6	2.5	3.5	2.6	3.6	3.7	3.7	4.8	2.2	2.5
	Count	1158	1276	1257	1097	1125	1068	1061	1084	1081	1260	1240
Boeing 767-300 (PW PW4000 engines)	Mean	89.2	85.0	81.8	81.5	79.8	77.8	77.4	78.2	80.2	81.0	79.2
	Std Dev	2.1	2.1	2.5	3.4	2.5	3.5	4.1	3.8	4.6	1.9	2.8
	Count	1130	1256	1243	1096	1118	1068	1062	1084	1114	1180	1161
Boeing 767-300 (RR RB211-524 engines)	Mean	87.9	83.9	79.8	79.1	77.6	75.8	76.1	75.3	78.2	80.5	77.8
	Std Dev	2.2	2.1	2.0	5.4	3.8	2.9	5.8	3.5	4.8	2.7	3.3
	Count	3163	3469	3464	2628	2823	2703	2722	2787	2095	3060	3028
Boeing 767-400 (GE CF6-80C2 engines)	Mean	90.3	85.6	81.6	81.5	79.2	76.1	75.1	76.1	80.7	79.9	77.8
	Std Dev	1.8	2.6	2.1	3.1	2.6	3.2	3.7	3.5	3.7	1.9	2.2
	Count	817	912	896	838	848	812	799	835	850	870	862

Table 4 L_{max} departure noise levels for the Boeing 787 and Boeing 767 (continued)

		L_{max}, dBA										
	Monitor site	**D**	**C**	**E**	**56**	**116**	**113**	**102**	**102**	**76**	**76**	**117**
	Runway	**27L**	**27R**	**27L**	**09R**	**09R**	**27R**	**27L**	**27R**	**27R**	**27L**	**09R**
Aircraft Type	**Dist. from SOR (km)**	**6.7**	**6.8**	**7.3**	**7.4**	**7.4**	**9.4**	**9.9**	**10.1**	**12.6**	**12.9**	**23.4**
Boeing 787-8 (GE GEnx-1B engines)	Mean	74.5	73.3	74.0	70.4	68.9	67.8	69.5	67.6	68.0	68.0	-
	Std Dev	3.3	1.5	2.4	2.1	3.2	1.5	1.8	2.8	1.3	1.1	-
	Count	364	395	225	120	95	10	15	47	22	22	-
Boeing 787-8 (RR Trent 1000 engines)	Mean	73.2	70.9	68.6	68.8	73.1	-	71.9	70.5	66.0	65.7	61.4
	Std Dev	3.2	1.8	1.6	1.8	3.5	-	1.4	1.0	1.5	1.4	1.4
	Count	248	262	161	42	104	-	11	13	8	11	13
Boeing 767-300 (GE CF6-80C2 engines)	Mean	78.5	78.4	74.2	73.4	76.5	73.1	72.6	73.0	72.2	72.0	64.4
	Std Dev	2.1	2.0	3.1	2.5	4.1	2.9	3.8	4.0	2.0	2.0	2.5
	Count	1269	1234	1127	301	341	229	296	282	92	101	47
Boeing 767-300 (PW PW4000 engines)	Mean	80.8	81.1	76.3	74.9	77.9	75.4	74.0	75.1	74.7	74.2	65.7
	Std Dev	1.9	2.0	3.7	3.8	4.5	2.4	3.9	3.9	1.7	1.6	2.7
	Count	1192	1232	1123	280	448	173	250	244	100	88	93
Boeing 767-300 (RR RB211-524 engines)	Mean	80.1	77.3	74.7	76.6	76.2	72.1	72.7	72.1	73.4	73.1	64.6
	Std Dev	3.2	1.7	4.6	2.5	3.7	3.7	6.3	5.1	2.7	2.3	2.2
	Count	3082	3422	2371	1064	709	453	386	679	337	336	39
Boeing 767-400 (GE CF6-80C2 engines)	Mean	79.3	78.9	74.7	72.5	78.0	74.4	74.7	74.8	73.7	73.4	65.1
	Std Dev	1.9	1.7	2.5	3.5	3.8	1.6	2.8	3.9	1.0	1.5	2.6
	Count	877	894	808	132	320	126	219	219	53	43	70

Table 5 L_{max} departure noise levels for the Airbus A330

		L_{max}, dBA										
	Monitor site	**109**	**B**	**A**	**K**	**H**	**G**	**F**	**J**	**I**	**6**	**C**
	Runway	**27R**	**27R**	**27R**	**09R**	**09R**	**09R**	**09R**	**09R**	**09R**	**27L**	**27L**
Aircraft Type	**Dist. from SOR (km)**	**3.8**	**5.9**	**6.0**	**6.1**	**6.2**	**6.2**	**6.3**	**6.3**	**6.6**	**6.6**	**6.6**
Airbus A330-200 (GE CF6-80E1 engines)	Mean	88.2	84.1	79.8	81.0	77.2	73.1	71.6	72.3	81.6	77.3	74.4
	Std Dev	2.9	2.5	2.1	2.9	1.9	2.1	3.2	2.5	2.4	1.8	2.3
	Count	191	203	202	174	173	168	144	177	171	197	193
Airbus A330-200 (PW PW4000 engines)	Mean	88.6	83.7	80.5	79.8	77.6	74.9	74.4	75.1	77.1	78.6	75.6
	Std Dev	2.1	2.6	2.4	2.4	2.5	4.0	4.4	4.3	3.3	2.2	3.2
	Count	276	295	290	179	183	179	165	183	183	218	213
Airbus A330-200 (RR Trent 700 engines)	Mean	88.6	83.0	80.8	79.7	78.7	76.3	75.5	76.6	75.8	78.4	76.0
	Std Dev	2.6	2.7	2.6	3.1	2.4	3.3	4.1	3.8	2.7	2.3	3.1
	Count	836	905	897	776	787	751	788	787	791	853	848
Airbus A330-300 (GE CF6-80E1 engines)	Mean	89.6	84.8	79.6	82.0	77.5	72.9	71.6	72.4	82.0	77.8	74.4
	Std Dev	2.4	2.6	2.2	2.0	2.0	2.7	3.7	2.9	3.0	1.5	2.4
	Count	211	224	225	187	190	186	141	191	189	215	215
Airbus A330-300 (PW PW4000 engines)	Mean	90.0	84.9	82.2	79.3	78.0	76.3	76.2	75.7	78.8	79.5	78.4
	Std Dev	1.7	2.7	2.2	4.3	3.2	2.7	4.1	2.8	4.8	2.4	2.2
	Count	220	251	249	204	208	196	194	204	200	222	219
Airbus A330-300 (RR Trent 700 engines)	Mean	89.1	84.8	80.7	80.3	78.8	76.3	75.3	76.2	78.2	80.0	76.8
	Std Dev	1.9	2.8	2.5	3.5	2.6	3.7	4.8	4.3	4.5	2.4	3.3
	Count	1804	1970	1956	1662	1676	1584	1565	1656	1653	1830	1812

Table 5 L_{max} departure noise levels for the Airbus A330 (continued)

		L_{max}, dBA										
	Monitor site	**D**	**C**	**E**	**56**	**116**	**113**	**102**	**102**	**76**	**76**	**117**
	Runway	**27L**	**27R**	**27L**	**09R**	**09R**	**27R**	**27L**	**27R**	**27R**	**27L**	**09R**
Aircraft Type	**Dist. from SOR (km)**	**6.7**	**6.8**	**7.3**	**7.4**	**7.4**	**9.4**	**9.9**	**10.1**	**12.6**	**12.9**	**23.4**
Airbus A330-200 (GE CF6-80E1 engines)	Mean	77.5	81.1	76.9	76.4	78.4	69.7	72.3	75.5	-	-	-
	Std Dev	1.9	3.0	2.5	6.1	1.9	4.0	5.5	2.6	-	-	-
	Count	194	202	185	7	73	25	6	11	-	-	-
Airbus A330-200 (PW PW4000 engines)	Mean	78.8	77.4	75.1	72.4	73.6	71.0	66.6	70.2	74.0	-	-
	Std Dev	2.0	1.6	3.1	2.5	2.3	3.1	2.6	4.6	1.1	0.8	-
	Count	218	285	207	35	70	42	33	80	49	11	-
Airbus A330-200 (RR Trent 700 engines)	Mean	79.2	77.9	76.8	73.5	72.2	71.7	66.8	72.0	73.6	74.4	-
	Std Dev	2.5	1.8	3.8	3.0	2.8	3.4	2.1	5.8	1.9	1.4	-
	Count	861	822	799	192	263	163	64	82	34	38	-
Airbus A330-300 (GE CF6-80E1 engines)	Mean	77.7	81.8	77.5	77.7	78.9	68.9	73.5	74.6	-	-	-
	Std Dev	1.5	2.9	2.7	5.3	2.4	3.2	3.7	1.3	-	-	-
	Count	218	222	194	8	69	27	8	10	-	-	-
Airbus A330-300 (PW PW4000 engines)	Mean	78.9	78.8	73.9	78.4	77.6	75.0	74.2	74.6	74.4	73.9	66.6
	Std Dev	2.6	1.9	2.9	2.9	3.0	2.3	4.2	4.7	1.5	1.6	3.0
	Count	223	241	195	50	70	18	64	63	21	19	21
Airbus A330-300 (RR Trent 700 engines)	Mean	80.1	78.5	75.7	72.8	75.3	73.6	74.3	72.9	73.8	74.6	66.4
	Std Dev	2.4	2.2	3.6	3.0	4.3	3.1	5.0	5.0	2.5	2.1	3.2
	Count	1847	1932	1669	360	582	288	251	335	133	111	93

Figure 2 plots the Boeing 787 noise measurement data against the most common 767-300 variant (with RR RB211-524 engines[3]) at Heathrow, and also the larger 767-400. Figure 3 plots the same 787 data against the most common Airbus A330-200 and A330-300 variants (both fitted with RR Trent 700 engines).

The results indicate that the 787, despite having a higher maximum take-off weight, is on average up to 7 dB quieter on departure than the 767, although there is some variation by engine type and from monitor to monitor. The results also indicate that the 787 is on average up to 8 dB quieter than the A330 aircraft. In Figures 2 and 3, the largest average differences between the 787 and the 767 and A330 are 9 dB and 10 dB respectively, both occurring at monitor 76, which is located approximately 13 km from SOR.

Noting that the 787s on departure are classified as QC/0.5 compared to QC/1 or QC/2 for the 767 and A330, and that the midpoints of successive QC bands are 3 dB apart, the measured differences are in general agreement with the differences in QC classification.[4]

3 It should be noted that British Airways operates some RR-powered 767-300s on relatively short 'shuttle' routes between Heathrow and other UK airports, as well as to other destinations such as Frankfurt. As a result these departures will tend to be proportionally lighter, and therefore quieter, than similar 767-300s flying much longer distances.

4 Note, it was not the objective of this study to confirm the QC classification of the Boeing 787, which would have required analysis of EPNL (Effective Perceived Noise Level) measurements.

Figure 2 Comparison of Boeing 787 and Boeing 767 departure SEL noise measurements

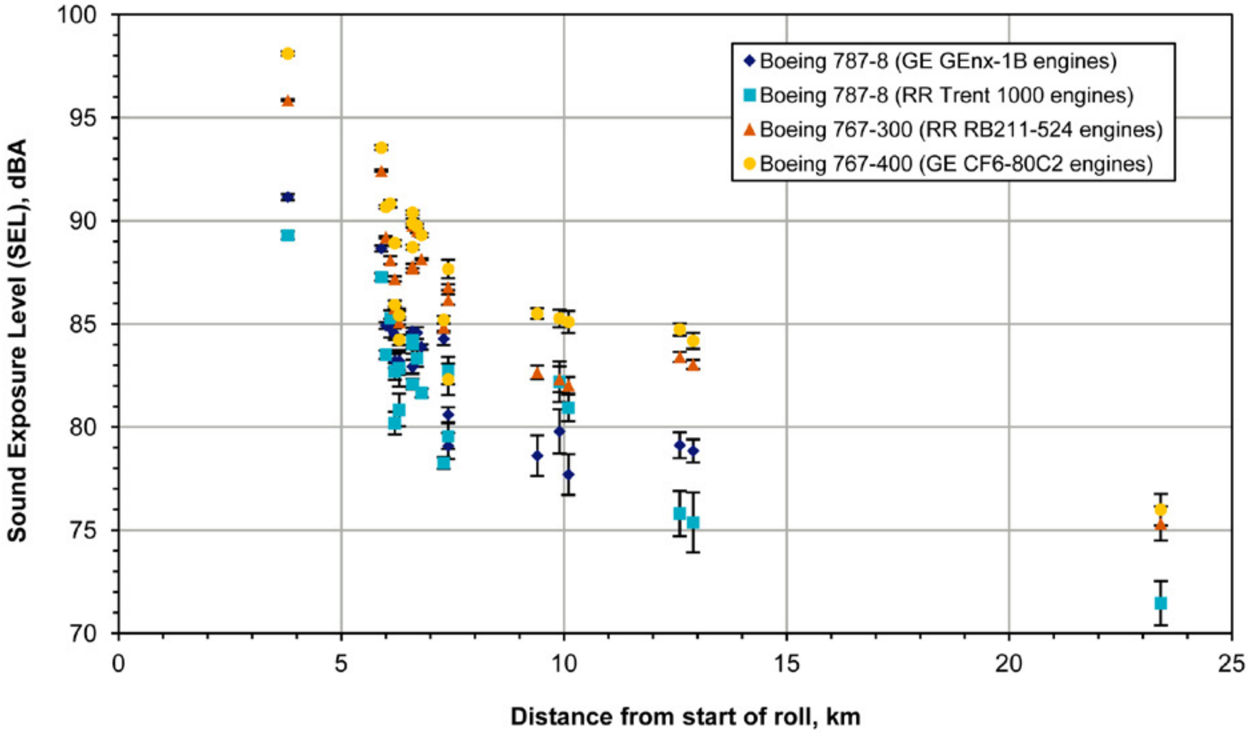
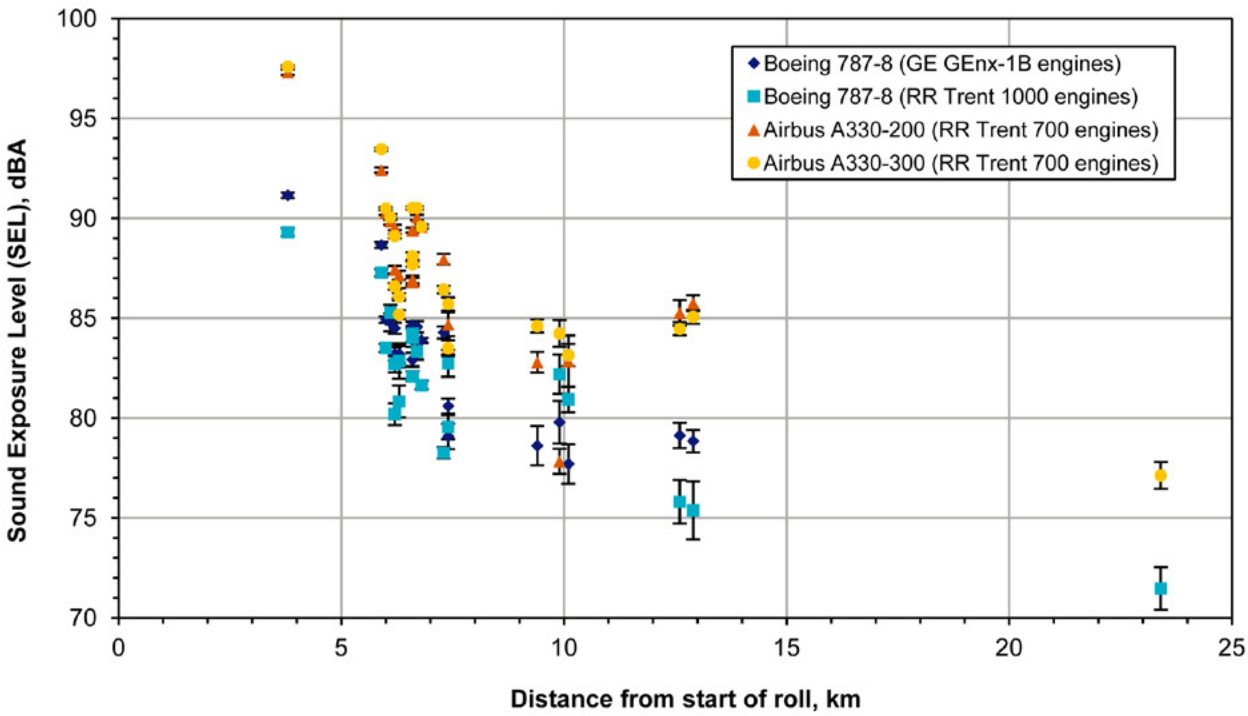


Figure 3 Comparison of Boeing 787 and Airbus A330 departure SEL noise measurements



CHAPTER 4

Arrival noise monitor data

Table 6 presents the SEL arrival data for the Boeing 787 and 767 aircraft. Table 7 presents equivalent data for the Airbus A330 aircraft. The corresponding L_{max} data is also provided for information in Tables 8 and 9.

Figure 4 plots the 787 arrival noise data against the most common 767-300 variant and also the larger 767-400. Figure 5 plots the same 787 data against the most common A330-200 and A330-300 variants.

The results indicate that the 787 is on average up to 3 dB quieter on arrival than the 767 and the A330, although again there is some variation by engine type and from monitor to monitor. In Figure 4, the largest average difference between the 787 and 767 is 4.4 dB at the closest monitor to touchdown (site B, 2.8 km). In Figure 5, the largest average difference between the 787 and A330 is 6.1 dB at the furthest monitor to touchdown (site 108, 14.2 km).

Noting that the 787s on arrival are classified as QC/0.25 compared to QC/0.5 or QC/1 for the 767 and A330, the measured differences are in general agreement with the QC classifications.

Table 6 SEL arrival noise levels for the Boeing 787 and Boeing 767

		SEL, dBA					
	Monitor site	**B**	**6**	**110**	**102**	**69**	**108**
	Runway	**09L**	**09R**	**27L**	**09R**	**27L**	**27R**
Aircraft Type	**Dist. to touchdown (km)**	**2.8**	**3.8**	**6.8**	**7.1**	**8.5**	**14.2**
Boeing 787-8 (GE GEnx-1B engines)	Log Avg	90.4	90.1	85.8	84.7	84.4	79.3
	Mean	90.4	90.0	85.8	84.6	84.3	78.3
	Std Dev	0.8	0.9	0.4	0.7	1.1	3.1
	Count	226	64	10	20	152	97
	95% CI	0.1	0.2	0.3	0.3	0.2	0.6
Boeing 787-8 (RR Trent 1000 engines)	Log Avg	90.1	90.2	-	-	84.5	76.6
	Mean	89.9	90.1	-	-	84.4	76.0
	Std Dev	1.4	1.2	-	-	1.0	2.3
	Count	135	36	-	-	30	21
	95% CI	0.2	0.4	-	-	0.4	1.1
Boeing 767-300 (GE CF6-80C2 engines)	Log Avg	92.9	92.1	87.2	85.3	84.7	78.6
	Mean	92.6	91.9	87.0	85.0	84.3	77.9
	Std Dev	1.8	1.3	1.3	2.1	2.0	2.2
	Count	992	133	248	27	599	343
	95% CI	0.1	0.2	0.2	0.8	0.2	0.2
Boeing 767-300 (PW PW4000 engines)	Log Avg	92.9	92.2	86.6	85.7	84.6	77.5
	Mean	92.8	92.1	86.4	85.5	84.2	76.9
	Std Dev	1.1	1.2	1.3	1.6	2.0	2.2
	Count	856	222	232	31	552	249
	95% CI	0.1	0.2	0.2	0.6	0.2	0.3
Boeing 767-300 (RR RB211-524 engines)	Log Avg	94.6	94.0	87.5	87.2	85.8	77.7
	Mean	94.3	93.8	87.3	87.1	85.7	77.5
	Std Dev	1.7	1.4	1.7	0.8	1.0	1.4
	Count	2981	60	562	17	1517	907
	95% CI	0.1	0.3	0.1	0.4	0.1	0.1
Boeing 767-400 (GE CF6-80C2 engines)	Log Avg	93.7	93.6	87.7	87.1	86.2	79.2
	Mean	93.5	93.3	87.5	86.7	85.8	78.0
	Std Dev	1.5	1.7	1.8	2.1	2.1	3.1
	Count	420	408	209	73	565	172
	95% CI	0.1	0.2	0.3	0.5	0.2	0.5

Table 7 SEL arrival noise levels for the Airbus A330

		SEL, dBA					
	Monitor site	**B**	**6**	**110**	**102**	**69**	**108**
	Runway	**09L**	**09R**	**27L**	**09R**	**27L**	**27R**
Aircraft Type	**Dist. to touchdown (km)**	**2.8**	**3.8**	**6.8**	**7.1**	**8.5**	**14.2**
Airbus A330-200 (GE CF6-80E1 engines)	Log Avg	92.3	91.8	87.6	86.2	86.2	82.1
	Mean	92.0	91.6	87.4	86.0	85.9	81.9
	Std Dev	1.4	1.3	1.3	1.2	1.9	1.4
	Count	133	54	47	7	99	37
	95% CI	0.2	0.3	0.4	1.1	0.4	0.5
Airbus A330-200 (PW PW4000 engines)	Log Avg	91.7	91.3	86.2	85.4	85.7	81.4
	Mean	91.4	91.1	86.0	85	85.4	81.1
	Std Dev	1.4	1.4	1.2	0.9	1.5	1.9
	Count	207	23	44	6	140	72
	95% CI	0.2	0.6	0.4	1.0	0.2	0.4
Airbus A330-200 (RR Trent 700 engines)	Log Avg	91.8	91.0	87.1	86.1	86.1	82.4
	Mean	91.6	91.0	87.0	86.0	85.9	82.1
	Std Dev	1.5	0.8	1.2	1.2	1.3	1.8
	Count	593	200	201	31	459	200
	95% CI	0.1	0.1	0.2	0.4	0.1	0.2
Airbus A330-300 (GE CF6-80E1 engines)	Log Avg	92.5	91.8	87.6	86.7	86.5	81.5
	Mean	92.3	91.7	87.3	86.4	86.2	81.3
	Std Dev	1.2	1.0	1.6	1.7	1.6	1.5
	Count	136	55	43	7	111	57
	95% CI	0.2	0.3	0.5	1.6	0.3	0.4
Airbus A330-300 (PW PW4000 engines)	Log Avg	92.6	93.1	87.0	-	86.0	82.0
	Mean	92.4	93.0	86.9	-	85.9	81.7
	Std Dev	1.5	1.0	1.2	-	1.2	1.6
	Count	198	5	29	-	96	78
	95% CI	0.2	1.2	0.5	-	0.2	0.4
Airbus A330-300 (RR Trent 700 engines)	Log Avg	92.3	91.7	87.4	86.9	86.5	82.4
	Mean	92.2	91.6	87.2	86.8	86.3	82.0
	Std Dev	1.2	0.9	1.3	0.9	1.5	1.8
	Count	1596	105	345	17	834	471
	95% CI	0.1	0.2	0.1	0.5	0.1	0.2

Table 8 L_{max} arrival noise levels for the Boeing 787 and Boeing 767

		L_{max}, dBA					
	Monitor site	**B**	**6**	**110**	**102**	**69**	**108**
	Runway	**09L**	**09R**	**27L**	**09R**	**27L**	**27R**
Aircraft Type	**Dist. to touchdown (km)**	**2.8**	**3.8**	**6.8**	**7.1**	**8.5**	**14.2**
Boeing 787-8 (GE GEnx-1B engines)	Mean	83.0	81.5	74.7	73.9	73.7	67.2
	Std Dev	1.0	0.7	0.5	0.8	1.2	2.9
	Count	226	64	10	20	152	97
Boeing 787-8 (RR Trent 1000 engines)	Mean	82.4	81.0	-	-	73.3	65.1
	Std Dev	1.5	1.3	-	-	1.0	2.1
	Count	135	36	-	-	30	21
Boeing 767-300 (GE CF6-80C2 engines)	Mean	84.8	83.2	76.6	74.5	73.7	67.6
	Std Dev	2.1	1.5	1.8	2.0	2.0	2.5
	Count	992	133	248	27	599	343
Boeing 767-300 (PW PW4000 engines)	Mean	85.1	83.2	75.8	74.9	73.6	66.1
	Std Dev	1.3	1.2	1.4	1.7	2.0	2.1
	Count	856	222	232	31	552	249
Boeing 767-300 (RR RB211-524 engines)	Mean	87.2	85.5	76.8	77.3	74.9	66.3
	Std Dev	2.0	1.7	1.6	1.4	1.1	1.5
	Count	2981	60	562	17	1517	907
Boeing 767-400 (GE CF6-80C2 engines)	Mean	86.0	85.0	76.8	76.3	75.1	67.0
	Std Dev	1.7	1.9	1.7	2.3	2.3	2.8
	Count	420	408	209	73	565	172

Table 9 L_{max} arrival noise levels for the Airbus A330

		L_{max}, dBA					
	Monitor site	**B**	**6**	**110**	**102**	**69**	**108**
	Runway	**09L**	**09R**	**27L**	**09R**	**27L**	**27R**
Aircraft Type	**Dist. to touchdown (km)**	**2.8**	**3.8**	**6.8**	**7.1**	**8.5**	**14.2**
Airbus A330-200 (GE CF6-80E1 engines)	Mean	84.4	82.8	76.9	76.1	75.1	70.5
	Std Dev	1.7	1.7	1.6	1.3	2.1	1.6
	Count	133	54	47	7	99	37
Airbus A330-200 (PW PW4000 engines)	Mean	83.9	82.6	75.4	74.6	74.6	69.8
	Std Dev	1.4	1.3	1.7	0.8	1.7	1.9
	Count	207	23	44	6	140	72
Airbus A330-200 (RR Trent 700 engines)	Mean	84.4	82.4	76.9	75.9	75.1	71.0
	Std Dev	1.8	1.1	2.3	2.3	1.7	2.2
	Count	593	200	201	31	459	200
Airbus A330-300 (GE CF6-80E1 engines)	Mean	84.8	82.8	76.8	76.7	75.6	70.0
	Std Dev	1.4	1.1	2.1	3.0	2.4	1.8
	Count	136	55	43	7	111	57
Airbus A330-300 (PW PW4000 engines)	Mean	84.6	84.1	76.5	-	75.3	70.4
	Std Dev	1.7	1.2	1.5	-	1.3	1.6
	Count	198	5	29	-	96	78
Airbus A330-300 (RR Trent 700 engines)	Mean	85.0	83.0	77.1	76.3	75.6	71.0
	Std Dev	1.4	1.2	2.1	1.2	1.9	2.1
	Count	1596	105	345	17	834	471

Figure 4 Comparison of Boeing 787 and Boeing 767 arrival SEL noise measurements

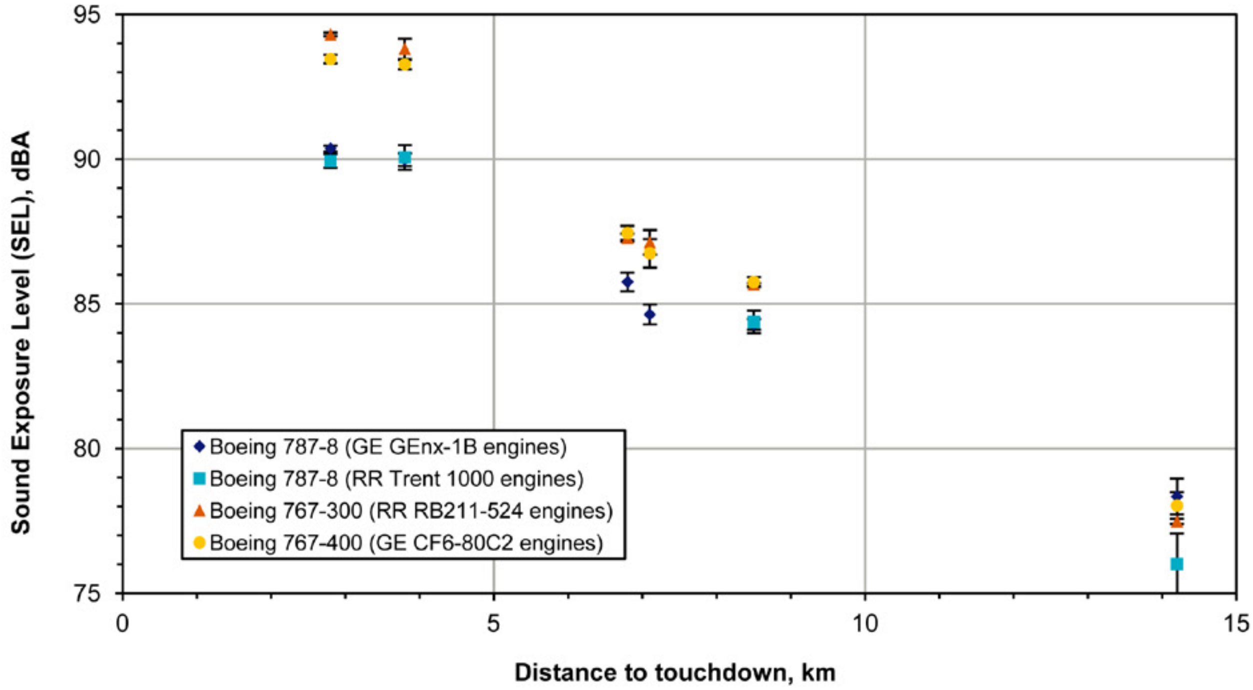
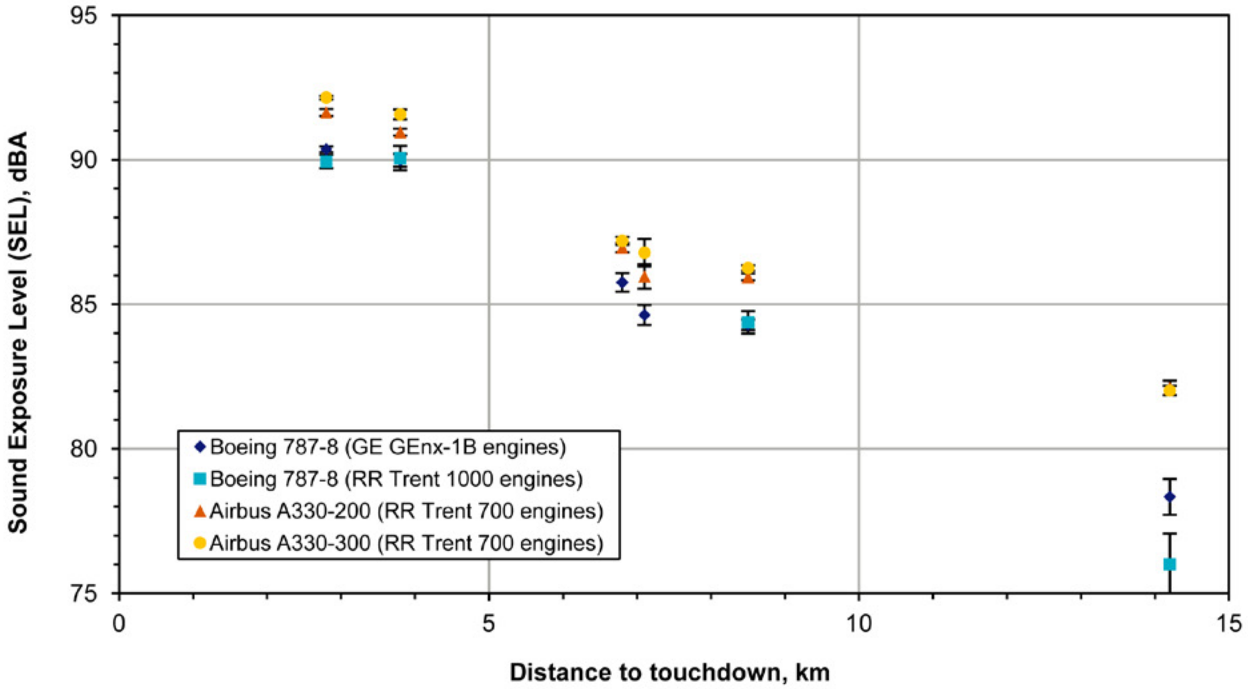


Figure 5 Comparison of Boeing 787 and Airbus A330 arrival SEL noise measurements



CHAPTER 5

Flight tracks and profiles

Departure and arrival tracks

Figure 6 shows the 787 departure flight tracks for the period 12 December 2012 to 30 April 2014, with the significant majority of departures using one of three Standard Instrument Departure (SID) routes and the associated Noise Preferential Routes (NPRs). The SID used on departure is largely dictated by the destination, with departures to North America tending to use Compton (CPT) and departures to Africa, Asia and the Middle East tending to use either Brookmans Park (BPK) or Dover (DVR).

Figure 7 shows the 787 arrival flight tracks over the same monitoring period, where the proportion of arrivals joining the extended runway centrelines from the north and the south is approximately equal.

Figure 6 Boeing 787 departure tracks

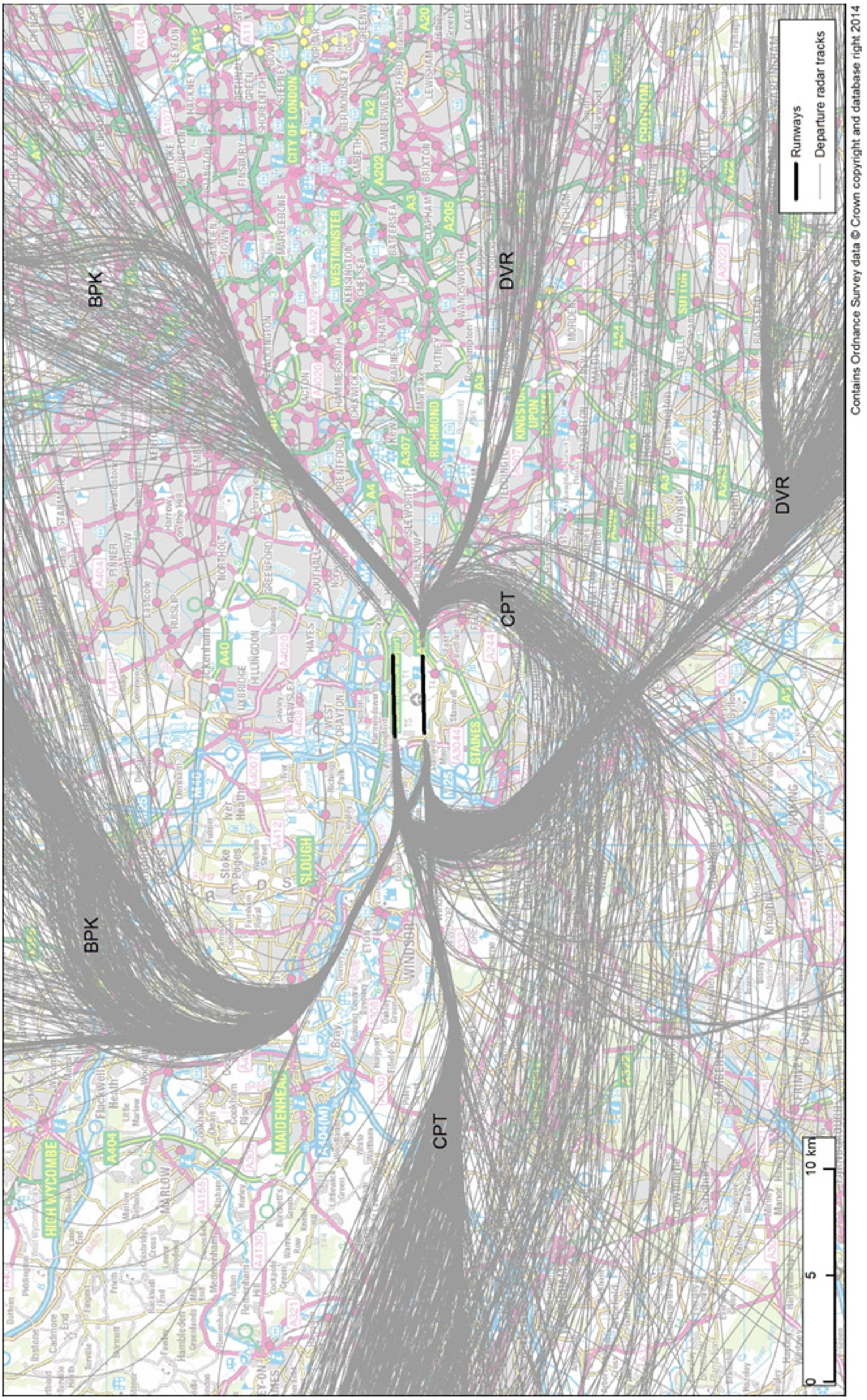
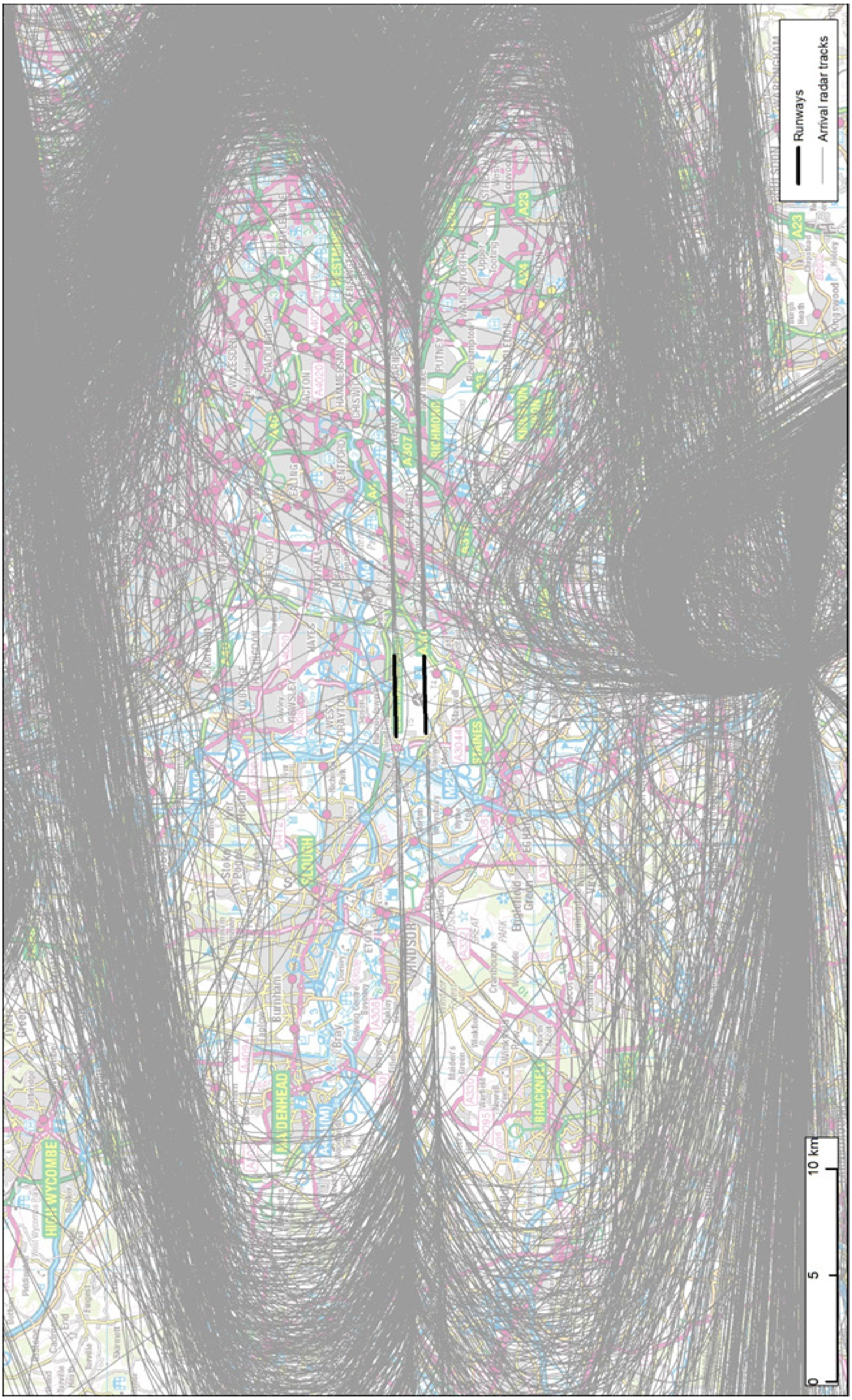


Figure 7 Boeing 787 arrival tracks



Departure profiles

Departure operating procedures can vary significantly between operators of similar aircraft types. Important factors are the engine thrust and flap settings during take-off and initial climb, which together can have a major effect on the aircraft height. All other things being equal, the departure climb gradient decreases as the take-off weight increases. Airline operators will take into account the need to balance reductions in noise, engine wear and fuel consumption amongst other factors.

The International Civil Aviation Organization (ICAO) recommends two types of Noise Abatement Departure Procedure; a close-in procedure (NADP1) designed to mitigate noise at relatively shorter distances and a further-out procedure (NADP2) to mitigate noise at relatively greater distances from the airport. One procedure does not necessarily have a better overall noise impact than another. Instead, changing from one procedure to another tends to redistribute noise from one location to another, including both underneath and to the side of the flight track, resulting in both noise decreases and noise increases. As a general rule however, an NADP2 procedure requires less fuel to reach the cruise altitude compared to NADP1.

Figure 8 compares the average departure height profiles for the 787, 767 and A330. The 787 and 767-300 show very similar flight profiles up to about 15 km from SOR, whereas the 767-400 profile is slightly higher between 7 and 13 km from SOR. The A330 profiles on the other hand are slightly lower than the 787 beyond about 7 to 10 km from SOR. However it should be remembered that each aircraft type shown in Figure 8 represents a number of different operators. Therefore any differences in height profiles may be more reflective of operator differences or differences in the average distance flown[5] (stage length) rather than fundamental differences in aircraft performance.

Figure 9 compares the average departure height profiles for the Boeing 787 separated by airline operator. Results are shown for Air India (AIC), British Airways (BAW), China Southern Airlines (CSN), Ethiopian Airlines (ETH), Qatar Airways (QTR), Royal Brunei Airlines (RBA) and United Airlines (UAL).[6]

Comparisons of the mean profiles indicate that British Airways is implementing an NADP2-type departure procedure that results in a markedly different height profile compared to the other 787 operators, which all appear to be implementing variations of an NADP1-type procedure.

The mean British Airways profile is lower between about 7 and 17 km from SOR, whereas the profiles for Air India and Ethiopian Airlines are slightly higher than the other airlines between 10 and 17 km. Beyond approximately 20 km from SOR the British Airways profile then becomes higher than several of the other height profiles.

5 Aircraft flying longer distances will be proportionally heavier due to the additional fuel carried.

6 Results for LOT Polish Airlines and Aeroméxico are not shown due to low samples sizes.

The mean profile for China Southern Airlines, which operates the 787 on the longest route currently flown by any of the 787 operators at Heathrow (to Guangzhou Airport in China, a distance of 5,100 nautical miles), sits approximately in the middle of the group. It should be noted however that the 787 has a maximum range of up to 8,200 nautical miles. Flight profiles for 787s flying closer to the maximum range may therefore show different trends.

The similarity between the initial flight profiles shown in Figure 9, up to a height of approximately 1000-1500 ft, suggests that all the 787 operators are optimising take-off thrust settings in order to reduce engine wear and associated maintenance costs.

Figure 8 Comparison of average departure height profiles by aircraft type

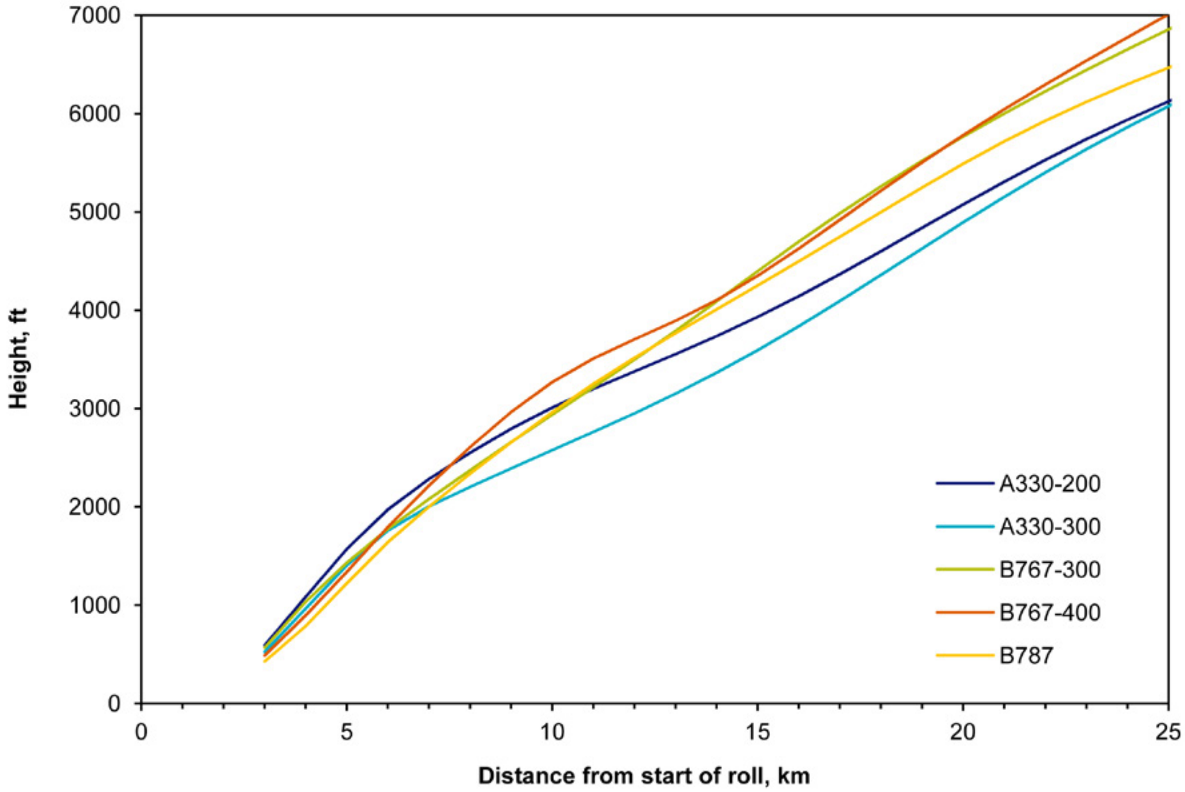
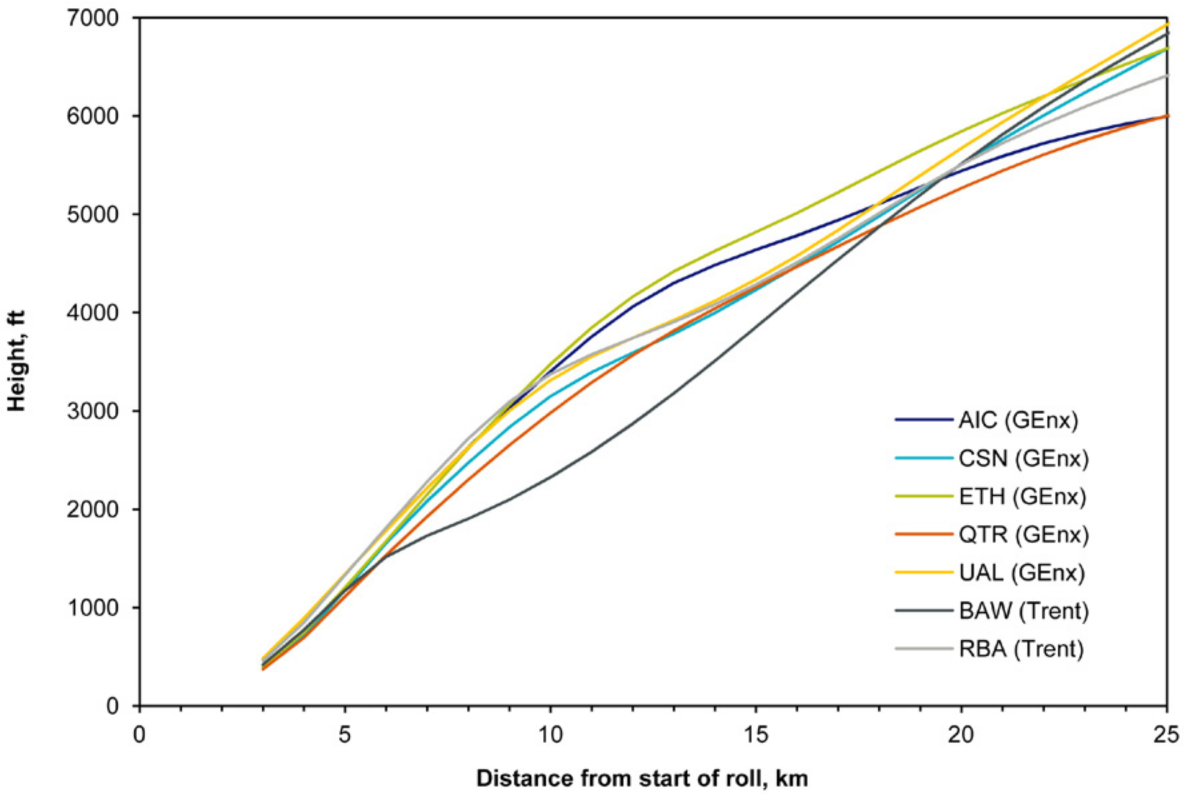


Figure 9 Comparison of average 787 departure height profiles by airline



CHAPTER 6
Conclusions

This report presents summary information on monitored noise levels for the Boeing 787 during the first 17 months of its operation at Heathrow airport. Data have been compared to the Boeing 767 and Airbus A330, whose operations are most likely to be replaced by the 787 in the coming years.

The noise measurement data confirms that the Boeing 787 is significantly quieter than the 767 and A330. The 787 is on average up to 7 dB quieter on departure than the 767, and up to 8 dB quieter than the A330 aircraft. The results also confirm that the 787 is up to 3 dB quieter on arrival than the aircraft types it is intended to replace.

An analysis of radar data has confirmed that across all airline operators, the average departure height profile for the 787 is comparable to the average profiles for the 767 and A330. A comparison of the mean profile for each 787 operator confirms that, as expected, departure operating procedures can vary significantly between different airlines, resulting in markedly different height profiles for the same aircraft type.

Glossary

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, which incorporates a frequency weighting approximating the characteristics of human hearing.

L_{den}

Equivalent sound level of aircraft noise in dBA for the 24-hour annual average period, with 5 dB weightings for evening and 10 dB weightings for night.

L_{eq}

Equivalent sound level of aircraft noise in dBA, often called 'equivalent continuous sound level'.

L_{max}

The maximum sound level measured during an aircraft event.

NPR

Noise Preferential Route. The preferred route for aircraft to fly in order to minimise their noise profile on the ground in the immediate vicinity of the airport.

NTK

Noise and Track Keeping monitoring system. The NTK system associates air traffic control radar data with related data from both fixed (permanent) and mobile noise monitors at prescribed positions on the ground.

QC

Quota Count. The basis of the London airports' night restrictions regime.

SEL

The Sound Exposure Level generated by a single aircraft at the measurement point. This accounts for the duration of the sound as well as its intensity.

SID

Standard Instrument Departure. A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated air traffic service route, at which the en-route phase of a flight commences.