London Heathrow Airport Limited

3.2° Slightly Steeper Approach Trial 2017

Final Report

V1.0. May 2018

Authors

John Henderson	Principle Consultant
Ed Boorman	Consultant and Analyst
Steve Gregson	Consultant and Analyst

Table of Contents

Executive Summary

1. Heathrow declared that a successful outcome from the trials would be to have gathered sufficient data with no adverse impact to safety or operational performance. The 1st trial met these objectives but the CAA requested data on aircraft performance for all months of a year in order to have a full picture of the effect of temperature on RNAV approaches.

2. This 2nd trial established that the warmer temperatures did not have any adverse operational or environmental impact. The improved vertical benefit gained during the warmer 2nd trial did not appear to translate into a measurable increased average noise benefit compared to the 1st trial however, it should be noted that the noise monitors only collected data for approaches to 27L, as per the 1st trial.

3. The trial met all objectives with no adverse impact to safety or operational performance. It is evident that 3.2° approaches has no negative effect on Heathrow's operation whilst local residents were exposed to less aircraft noise, without changing the lateral dispersion of aircraft tracks over the ground.

Objective	1st Trial Outcome	2nd Trial Outcome
CDA	3.2º compliance of 85.7% versus 85.9% overall compliance	3.2º CDA compliance of 86.5% versus 88.7% overall compliance
TBS	No detrimental impact	No detrimental impact
RoT	No detrimental impact	No detrimental impact
Go-around	No detrimental impact (3 out of 351 were on a 3.2º approach)	No detrimental impact (5 out of 237 were on a 3.2º approach)
Speed	Slightly improved overall speed adherence on final approach	Slightly improved overall speed adherence on final approach
Joining point	1.27nm closer to threshold (due to RNAV, not the 3.2º approach angle)	1.2nm closer to threshold (due to RNAV, not the 3.2º approach angle)
Landing Gear	Medium jets: Same but higher / Heavies: Later similar height	Medium jets: Same but higher / Heavies: Later similar height
Landing Rate	No impact	No impact
Height	Low temperature reduced average angle to 3.14º but height benefit as expected	Average angle 3.24º saw improved height benefit
Community	29 out of 50,274 comments, queries and complaints related to trial	9 out of 32,050 comments, queries and complaints related to trial
Airline	No issues with 3.2º approach angle	No issues with 3.2º approach angle
ATC	No detrimental impact due to 3.2º approach	No detrimental impact due to 3.2º approach
Environment	Min: +0.1dBA / Average: -0.5dBA / Max: -1.4dBA (SEL)	Min: +0.1dBA / Average: -0.5dBA / Max: -1.9dBA (SEL)

Table 17: Trial Objective Summary Table

4. The noise analysis and modelling confirms that 3.2° approaches do provide a small noise benefit to local communities. It should be noted that the magnitude of that average benefit is small (c.-0.5dBA) and unlikely to be perceptible on the ground[1]. However, 3.2° approaches would actively progress a reduction in Heathrow's noise footprint and is considered a necessary incremental step towards even steeper approaches or a standardised 3.2° approach for all of Heathrow's arrivals in the future.

5. Heathrow have commenced the Airspace Change Process to retain their 3.2° RNAV approaches as a permanent feature.

[1] A reduction in the order of 3 dBA is widely considered to be required in order to be 'just perceptible'. See CAP1378 Page 99 and Planning Policy Guidance 24 (Glossary)

2nd Trial Results

6. During the 2nd trial, there were 1,815 3.2° RNAV arrivals with the British Airways (BAW) fleet accounted for 83% of all 3.2° RNAV Approaches.

7. The trial was successful, meeting all objectives with no adverse impact to safety or operational performance. It is evident that 3.2° approaches would have no negative effect on Heathrow's operation whilst exposing local residents to less aircraft noise.

Objective		2nd Trial Outcome
CDA		3.2º CDA compliance of 86.5% versus 88.7% overall compliance
TBS		No detrimental impact
RoT		No detrimental impact
Go-around		No detrimental impact (5 out of 237 were on a 3.2º approach)
Speed		Slightly improved speed adherence on final approach
Joining point		1.2nm closer to threshold (due to RNAV, not the 3.2º approach angle)
Landing Gear		Med jets: Same but higher / Heavies: Later similar height
Landing Rate		No impact
Height		Average angle 3.24º saw improved height benefit
Community		9 out of 32,050 comments, queries and complaints related to trial
Airline		No issues with 3.2º approach angle
ATC		No detrimental impact due to 3.2º approach
Environment		Min: +0.1dBA / Average: -0.5dBA / Max: -1.9dBA (SEL)

Table 1 – 2nd Trial Objective Summary Table

8. The RNAV approach angle is affected by temperature. The higher the temperature, the steeper the approach angle. The lower the temperature the shallower the angle. Owing to this, trial data confirms that the average RNAV approach angle achieved during this 2nd trial was 3.24°[2].

9. Pre-trial concerns raised by some airlines regarding a potential increase in the number of go-arounds, earlier landing gear deployments and poorer speed adherence along final approach did not materialise during the 1st or 2nd trial. However, a trend has been observed during the 2nd trial of slightly poorer final approach speed adherence by the British Airways medium sized fleet, which may be worthy of further investigation.

[2] Average temperatures between 0600 and 2230 were 18.10°C producing an average RNAV approach angle of approximately 3.24°. During the 1st trial the average angle was 3.14°.

Introduction

Background

10. This report is concerned with the 2nd slightly steeper, RNAV, approach trial at London Heathrow Airport – 25/05/2017 to 11/10/2017. However, for ease of comparison, this report includes some results from the 1st trial next to those from this 2nd trial.

11. A full background into the rationale, operation and results of the 1st trial, conducted in Q4 2015 to Q2 2016, is detailed in the final report for that trial: *LHR 3.2 Slightly Steeper Approach Trial Report Aug 2016*.

12. The 1st trial could be split between colder winter months and warmer spring and summer months. It was found that the ambient temperature was a factor into the actual approach gradient achieved by aircraft. This was due to the nature of the RNAV approaches being influenced by the temperature and resulting barometric conditions. A full description of this facet of RNAV approaches is fully explained in the 1st trial report.

13. The 1st trial had a positive impact on noise, a negligible impact on the Heathrow operation and no detrimental impact to safety.

14. This 2nd trial was conceived partly in response to the temperature effect. It was felt that having data on aircraft performance for all months during a year, would be required in order to have a full picture of the effect of temperature on RNAV approaches and confirm the theory that during warmer months a 3.2° RNAV approach could actually be greater than 3.2°.

15. As the 1st trial provided a small noise improvement and negligible impact on airport operations it was advantageous to run a 2nd trial in an effort to gather a complete dataset and evidence picture. This would prepare for the possibility of permanently replacing the existing 3.0° RNAV approaches with slightly steeper 3.2° RNAV approaches.

Objectives of the 2nd trial

16. Similar to the 1st trial, the purpose of the 2nd trial was to better understand how an increased glideslope would impact Heathrow operationally whilst at the same time endeavour to measure the benefit in noise reduction that could be achieved. The output is also expected to feed into SESAR[3] and CAA's Future Airspace Strategy[4].

17. Heathrow declared that a successful trial would be one that enabled sufficient data gathering, with no adverse impact to safety or operational performance.

18. More specifically, Heathrow set out to understand the impact of warmer temperatures on the approach angles flown in relation to Continuous Descent Approaches, speed adherence on final approach, runway occupancy time, number of go-arounds, landing gear deployment, aircraft height on final approach, final approach joining point and tracks over the ground, aircraft noise distribution and the overall suitability of 3.2° approaches to support a high intensity operation.

[3] http://www.sesarju.eu
[4] https://www.caa.co.uk/fas/

The Trial

19. The trial took place between 25th May 2017 and 11th October 2017. During these dates, Heathrow's existing 3° RNAV approaches were replaced with 3.2° RNAV approaches.

20. It is the pilot's decision as to which type of approach is flown however, Heathrow encouraged airlines, via forums such as the UK Flight Safety Committee, face to face meetings and email contact, to adopt the 3.2° RNAV approach as much as possible.

Limitations of the trial

21. The majority of the analysis carried out compares the differences between the 3.2° slightly steeper RNAV approach and the existing 3° ILS approach. However, there are several subtle differences between ILS and RNAV approaches, such as the final approach joining point and the effect of temperature on Baro-VNAV approaches. Therefore, some of the findings from the trial are as a result of comparing RNAV approaches to ILS approaches and not just specifically 3.0° to 3.2° approaches.

22. The number of RNAV approaches undertaken during the 4.5 months was low in comparison to the number of ILS approaches but this is as expected. During the trial 3.2° RNAV approaches made up under 2% of all approaches into Heathrow which provided sufficient numbers for trend analysis. RNAV approaches normally make up less than 1% of arrivals. The main reasons for lower number of RNAV arrivals compared to ILS arrivals are:

- ILS has been the standard for over 50 years and crews are much more familiar with them than RNAV approaches, which are relatively new on a global level. With Heathrow's huge and diverse operation, many crews are long-haul[5] meaning that they may only fly into Heathrow once every couple of months. In addition, at the end of a long flight when crews are tired, many will opt for the approach they feel most comfortable. Not all the aircraft using Heathrow have the capability to fly RNAV approaches. 62% of all the 3.2° RNAV approaches during the 2nd trial were performed by the A320 family, a short to medium-haul aircraft.

- Unlike ILS, the RNAV approaches are not available in poor meteorological conditions. There was one day throughout the 4.5 month trial period where no 3.2° RNAV approaches were performed.

[5] Flight duration in excess of 6 hours

Trial Participation

23. The 2nd trial 3.2° RNAV dataset covers 1.9% of all arrivals in the four months - comparing 1,815 3.2° RNAV approaches to 92,624 3.0° ILS approaches.

Runway	Trial 1 3.2° RNAV Approaches	%
09L	747	30%
09R	35	1%
27L	854	35%
27R	833	34%
Total	2469	100%

Runway	Trial 2 3.2° RNAV Approaches	%
09L	229	13%
09R	13	1%
27L	896	49%
27R	677	37%
Total	1815	100%

Table2: Number of 3.2˚ Approaches during the 1st and 2nd trial period by Runway

24. Figure 1.1 contains a trend line showing the curved trend based on the number of 3.2° RNAV Approaches each day. As can be seen, after the initial enthusiasm at the start of the 1st trial, participation levelled off after the first two months albeit to a slightly higher rate than pre-trial.

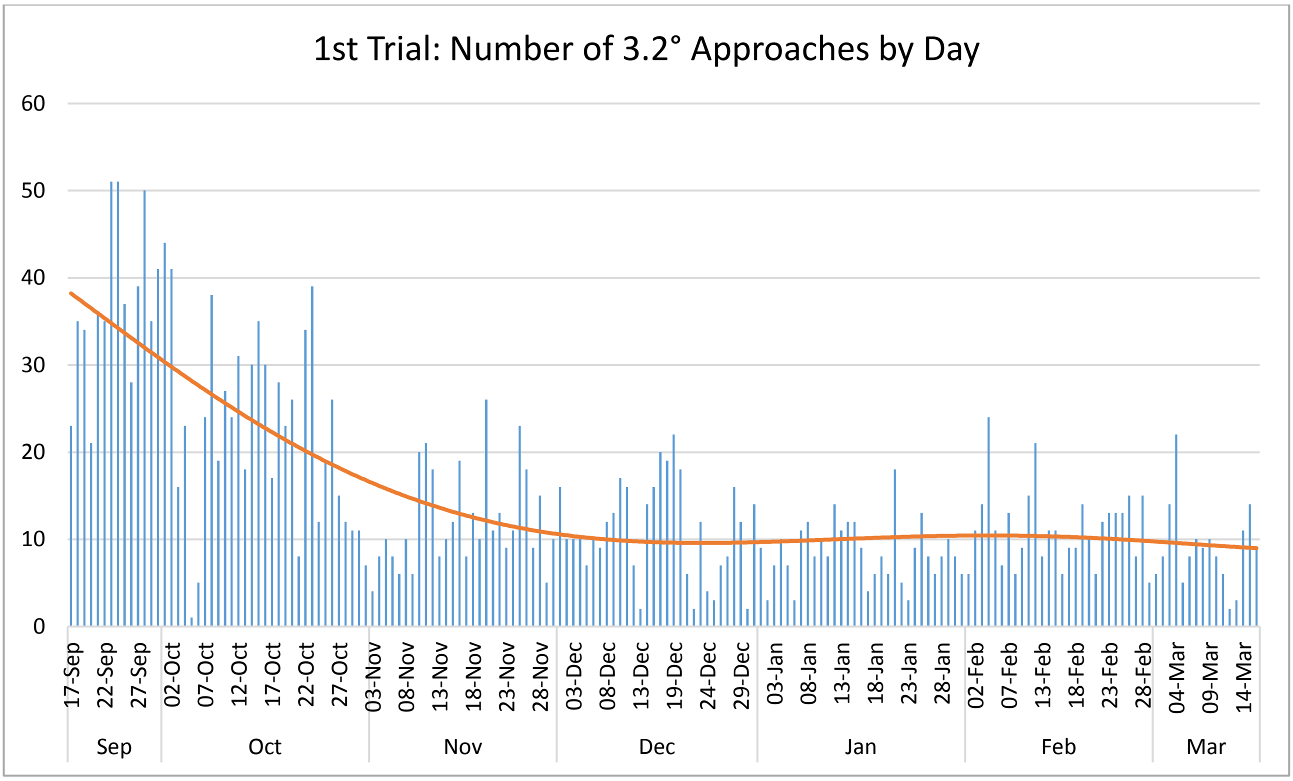


Figure 1.1: Number of 3.2˚ Approaches per day during the 1st trial.

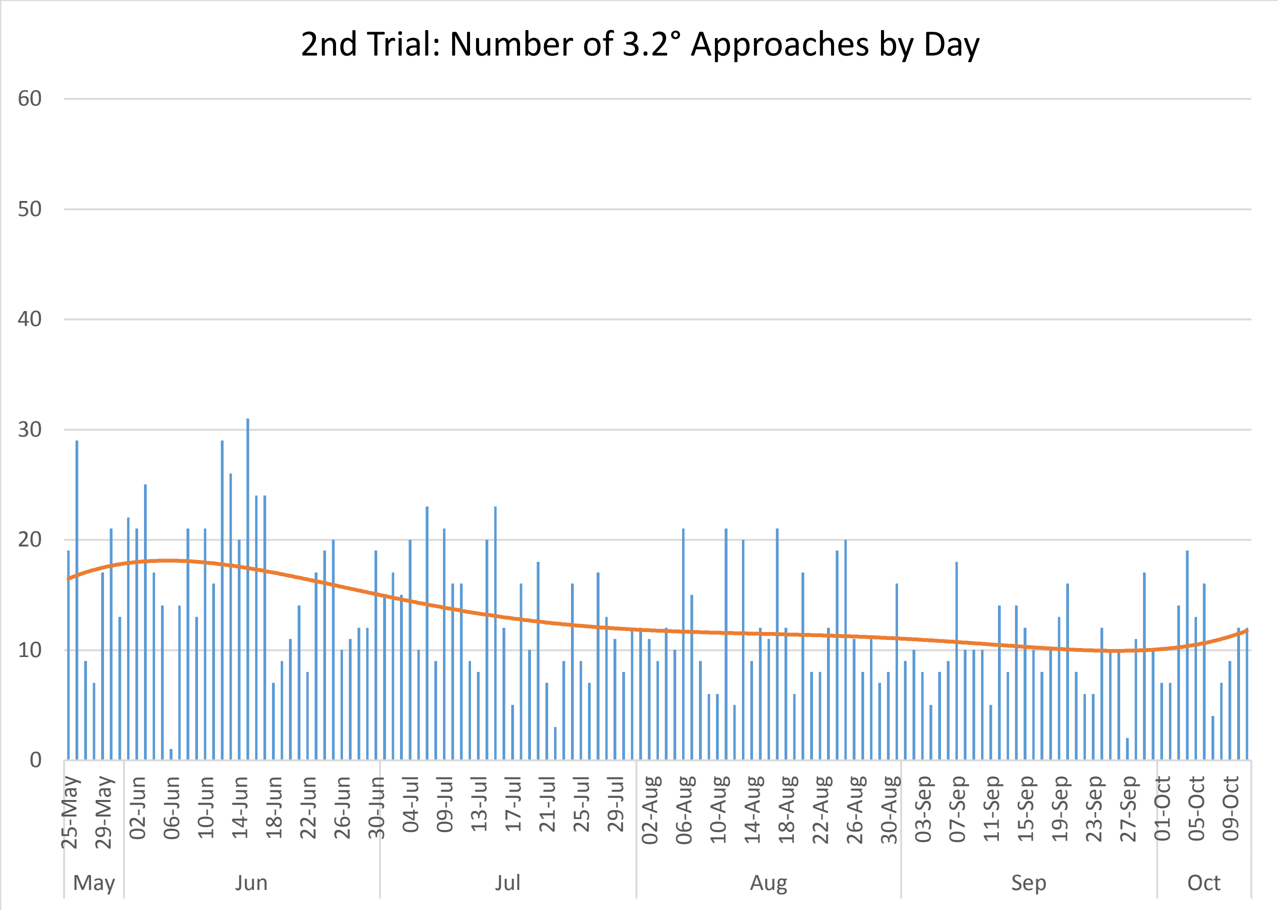


Figure 1.2: Number of 3.2˚ Approaches per day during the 2nd trial.

Airline Participation

25. During the 1st trial the British Airways (BAW) fleet accounted for 85% of all 3.2° RNAV Approaches.

26. During the 2nd trial again, British Airways accounted for the largest share of the RNAV approaches with an 83% share.

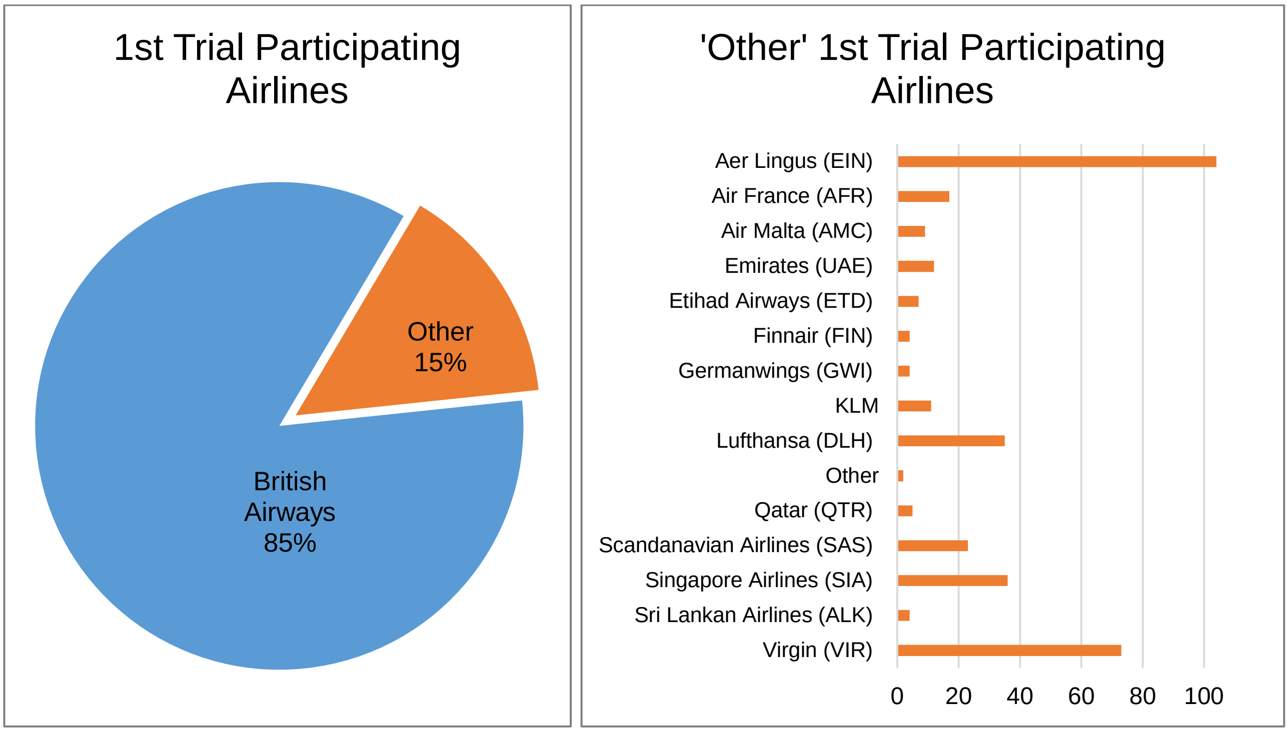


Figure 2.1: 1st Trial – Breakdown of airline participation

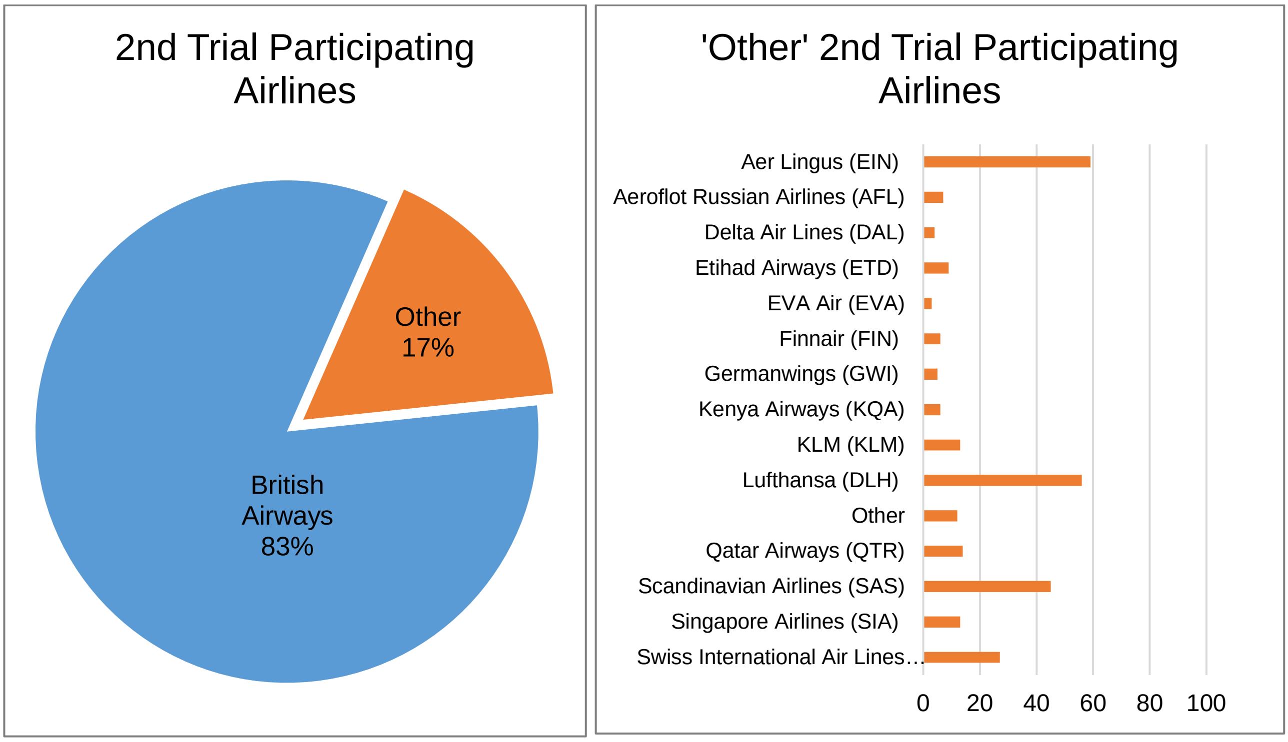


Figure 2.2: 2nd Trial – Breakdown of airline participation

27. Table 3.1 below compares the Heathrow fleet mix as a percentage of all movements to the numbers of 3.2° RNAV approaches flown during the 1st trial period.

	All Approaches		1st Trial 3.2° Approaches	
Aircraft	**Count**	**%**	**Count**	**%**
A320	63962	56.1%	1706	69.1%
A330	4350	3.8%	20	0.8%
A340	2030	1.8%	28	1.1%
A380	3981	3.5%	88	3.6%
B737 Next Gen	3733	3.3%	10	0.4%
B747	5430	4.8%	119	4.8%
B767	6582	5.8%	8	0.3%
B777	15235	13.4%	308	12.5%
B787	4842	4.3%	177	7.2%
Executive Jet	658	0.6%	5	0.2%
Totals	114036	100.00%	2469	100.0%

Table 3.1: Comparison between proportion of aircraft types between all approaches and trial approaches.

28. Table 3.2 below compares the Heathrow fleet mix as a percentage of all movements to the numbers of 3.2° RNAV approaches flown during the 2nd trial period.

	All Approaches		2nd Trial 3.2° Approaches	
Aircraft	**Count**	**%**	**Count**	**%**
A320	50939	55.00%	1125	61.98%
A330	2820	3.04%	9	0.50%
A340	1195	1.29%	6	0.33%
A380	3535	3.82%	125	6.89%
B737 Next Gen	2575	2.78%	21	1.16%
B747	3971	4.29%	90	4.96%
B767	4680	5.05%	8	0.44%
B777	11839	12.78%	131	7.22%
B787	7150	7.72%	272	14.99%
Others[6]	585	0.63%	16	0.88%
Executive Jet	3335	3.60%	12	0.66%
Totals	92624	100.00%	1815	100.00%

Table 3.2: Comparison between proportion of aircraft types between all approaches and trial approaches.

[6] ‘Others’ include: A300, A310, A350, RJ100, B737 Classic, B757, Dash-8, E-Jet & Fokker Types.

Aircraft Participation

29. During the 1st trial the A320 family[7] accounted for 69% of all 3.2° RNAV Approaches with the B777 accounting for c.13%.

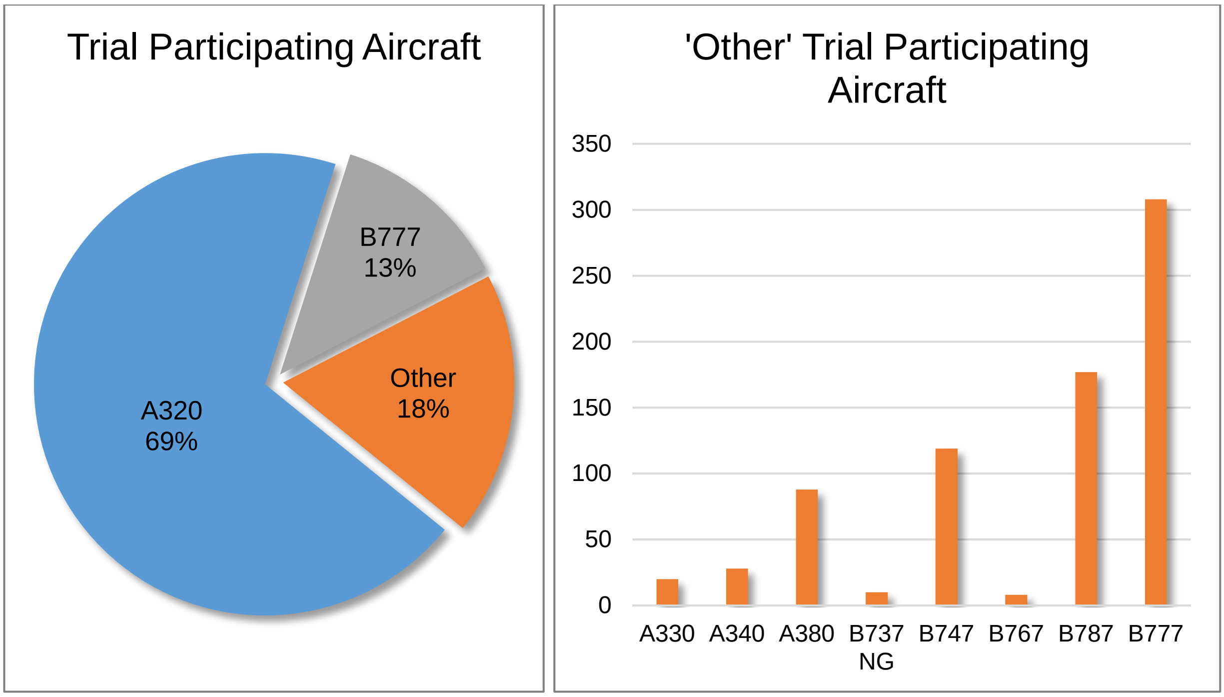


Figure 4.1: 1st Trial – Breakdown of aircraft participation

30. During the 2nd trial the A320 family accounted for 62% of all 3.2° RNAV Approaches with the B777 only accounting for c.7%. However, the B787 accounted for 15% of all 3.2° RNAV Approaches during the 2nd trial, an increase of over 10%.

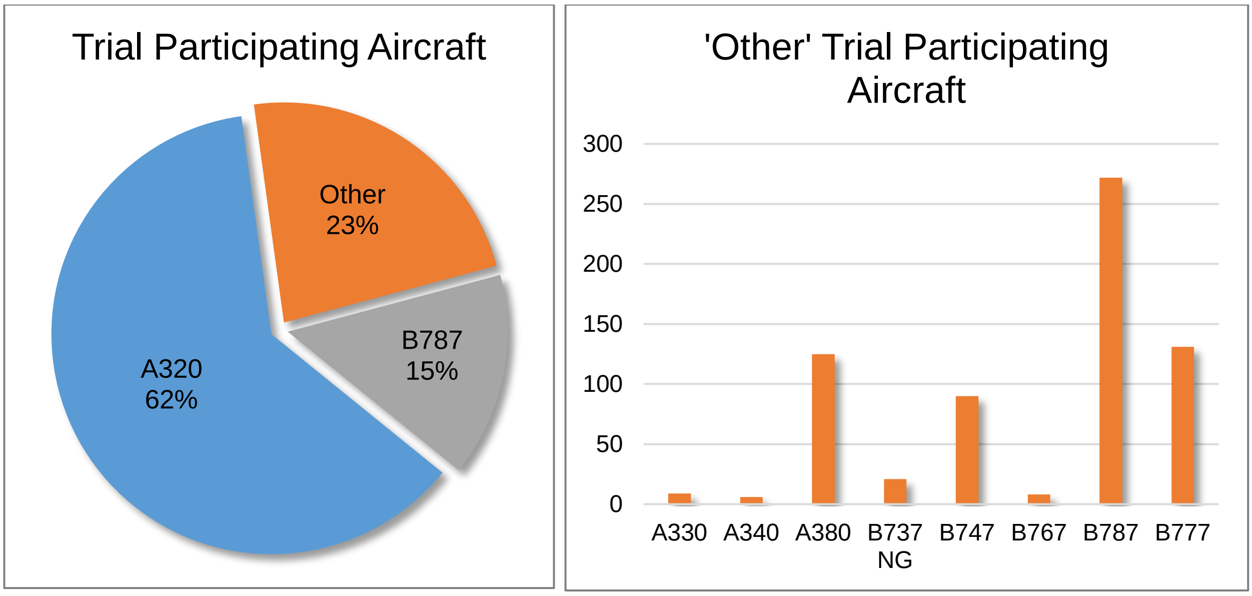


Figure 4.2: 2nd Trial – Breakdown of aircraft participation

[7] For this report, the A320 family refers to the A318, A319, A320 and A321 aircraft

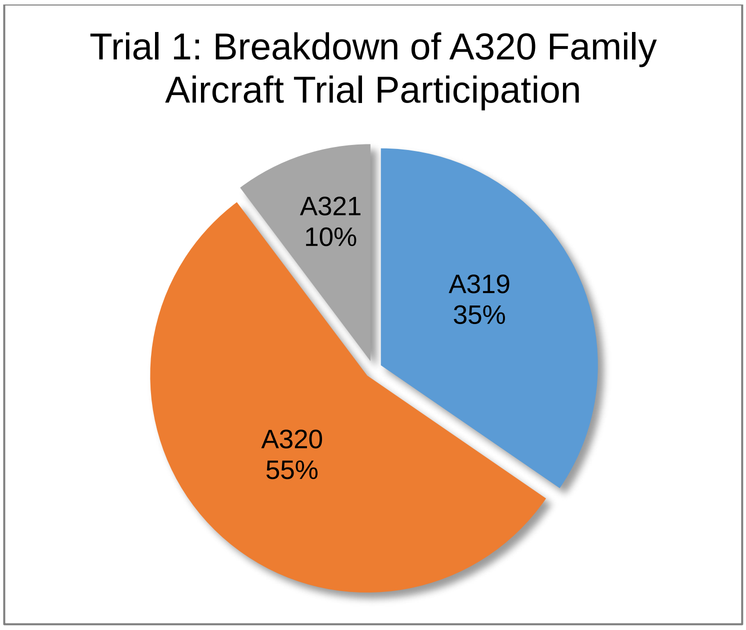


Figure 5.1: 1st Trial A320 family participation

Type	Count	Percentage
A319	632	35%
A320	999	55%
A321	184	10%

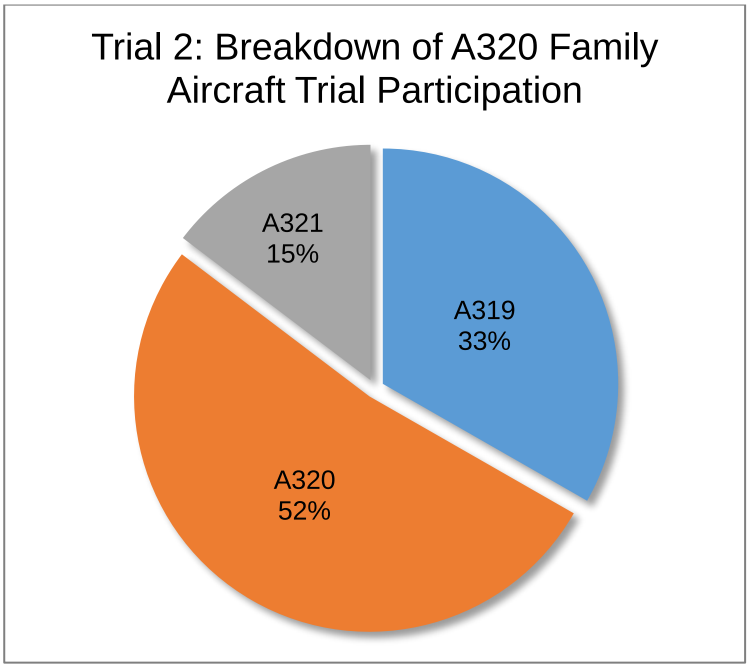


Figure 5.2: 2nd Trial A320 family participation

Type	Count	Percentage
A318	1	0%
A319	374	33%
A320	585	52%
A321	165	15%

31. Seven A380 Airlines participated in the trials: British Airways, Singapore Airlines, Emirates, Etihad Airways, Qantas, Qatar Airways and Malaysian Airlines.

32. 91 of all 3.2° RNAV Approaches during the 1st trial were undertaken by the A380 accounting for c.4% of the RNAV data set.

33. 123 of all 3.2° RNAV Approaches during the 2nd trial were undertaken by the A380 accounting for c.3.6% of the RNAV data set.

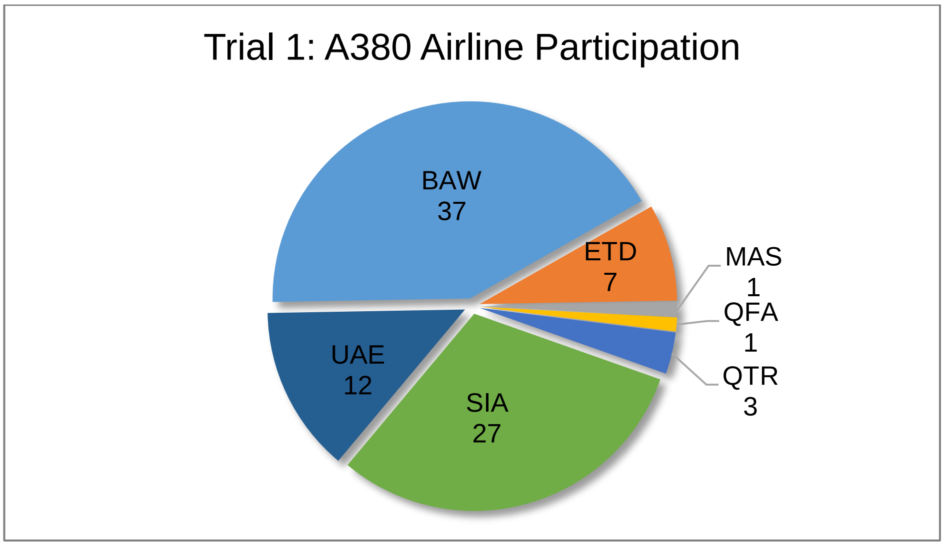


Figure 6.1: 1st A380 airline participation

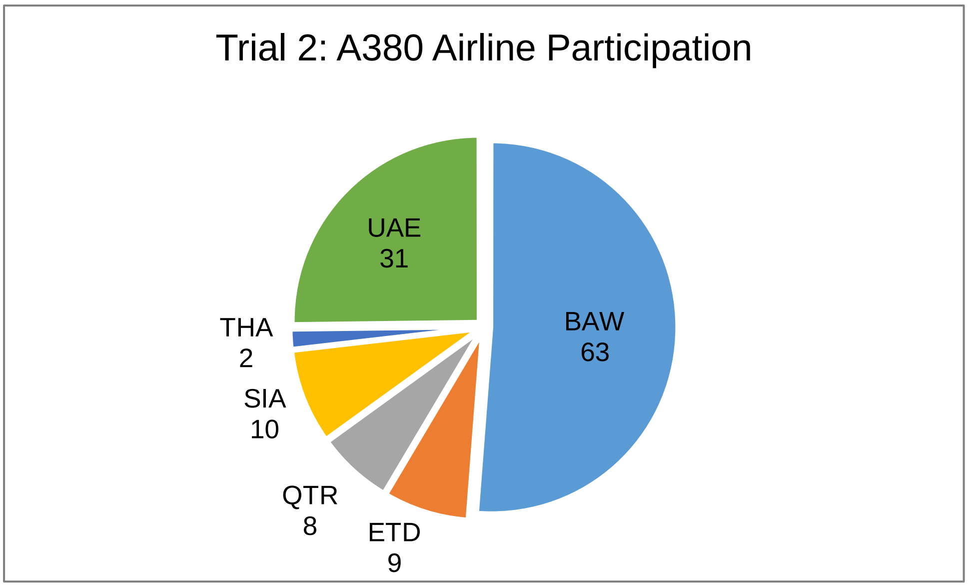


Figure 6.2: 2nd A380 airline participation

Continuous Descent Arrival (CDA) Performance

34. The 2nd trial data shows that CDA compliance for the 3.2° RNAV arrivals is slightly lower than the overall CDA compliance for all approaches (overall includes both 3.2° RNAV and 3° ILS approaches); although there has been an overall improvement in CDA performance for both ILS and RNAV approaches between the 1st and 2nd trial.

35. The slightly lower CDA performance for the 3.2° arrivals could be a difference between comparing RNAV arrivals to ILS arrivals, not necessarily 3.2° approaches to 3.0° approaches. Data to compare CDA performance between RNAV and ILS for another comparative, non-trial, period was not available.

36. Figure 7.1 shows an improving trend in CDA performance over the duration of the 1st trial for 3.2° RNAV approaches with 3.2° becoming significantly greater than 3.0° CDA performance by the end of the trial. This was possibly as a result of the experience gained by crews in flying the approaches. This trend was not repeated during the 2nd trial.

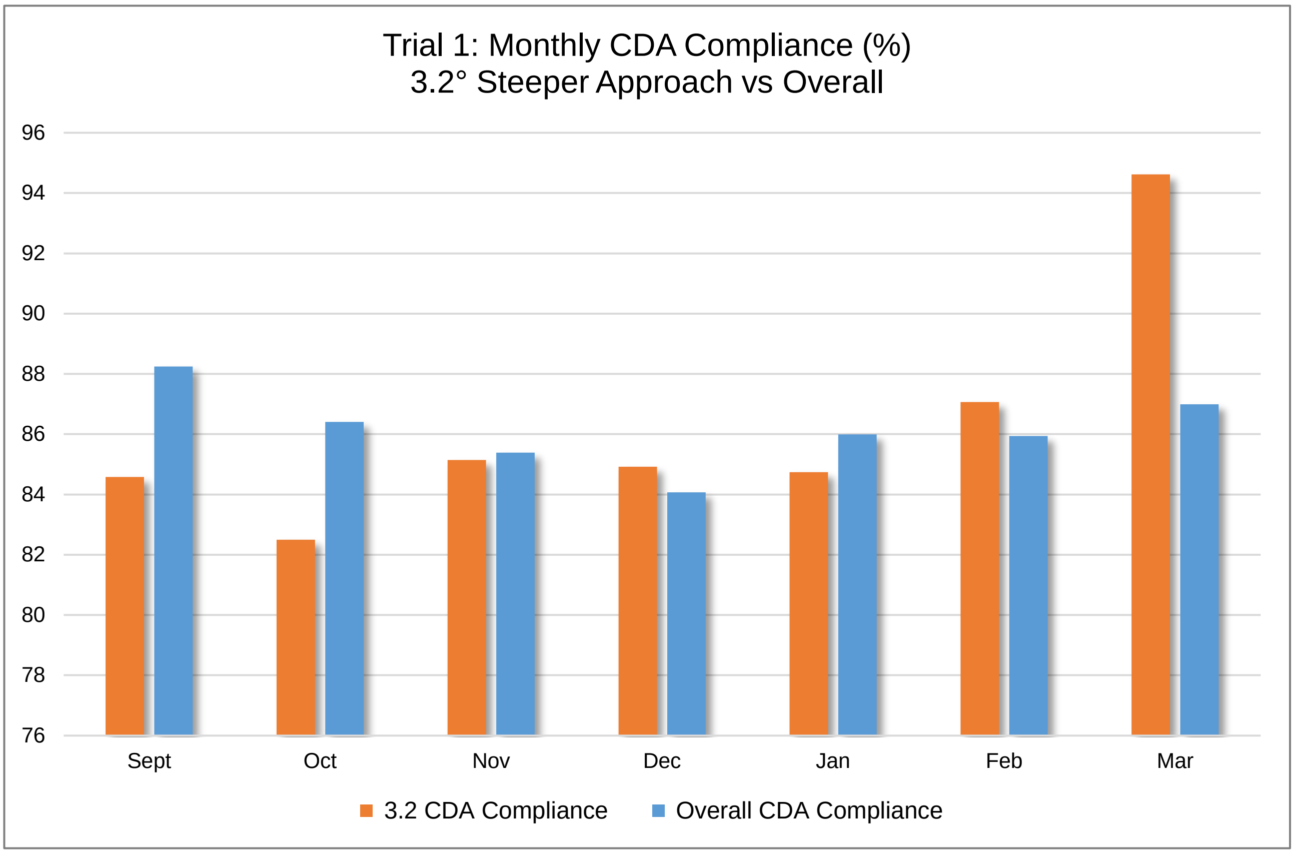


Figure 7.1: 1st Trial monthly comparison of 3.2˚ CDA performance

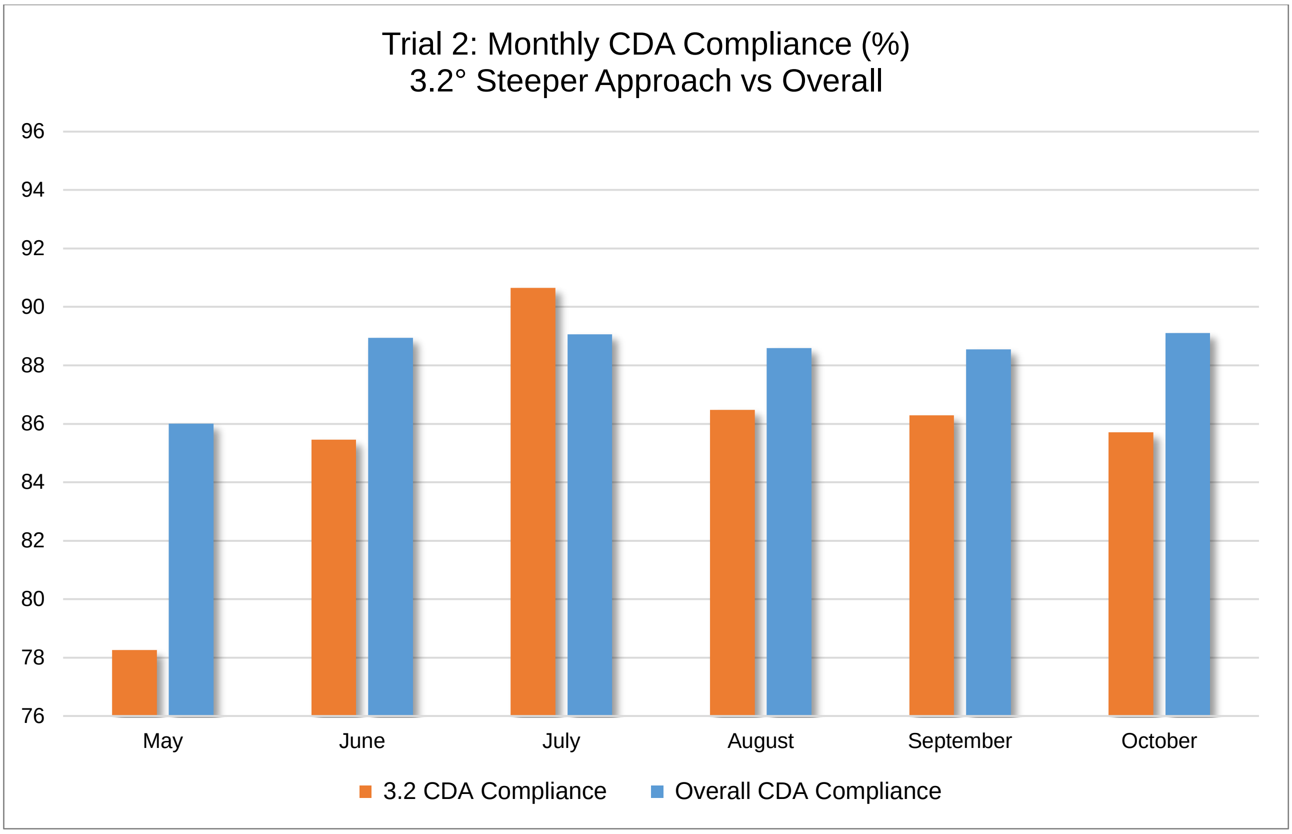


Figure 7.2: 2nd Trial monthly comparison of 3.2˚ CDA performance

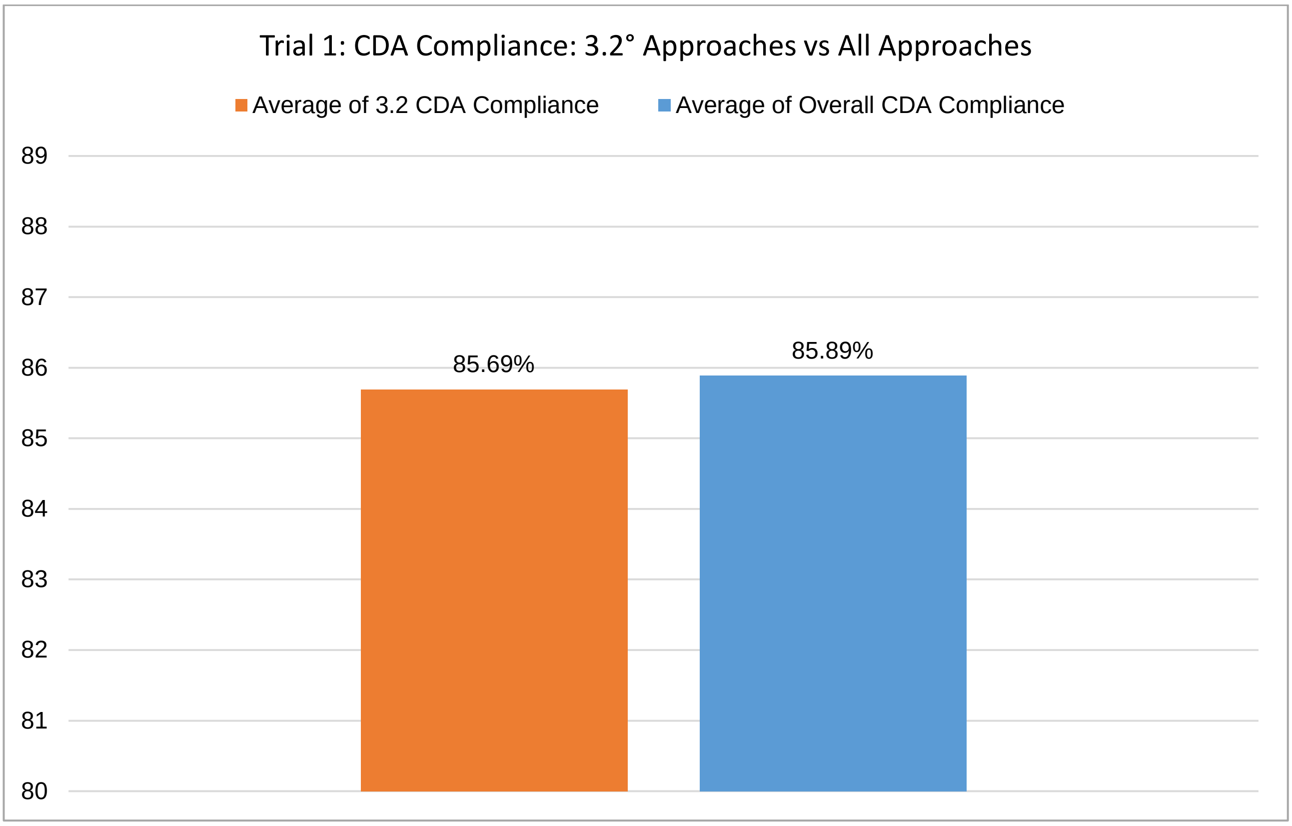


Figure 8.1: 1st Trial Overall comparison of 3.2˚ approach CDA performance

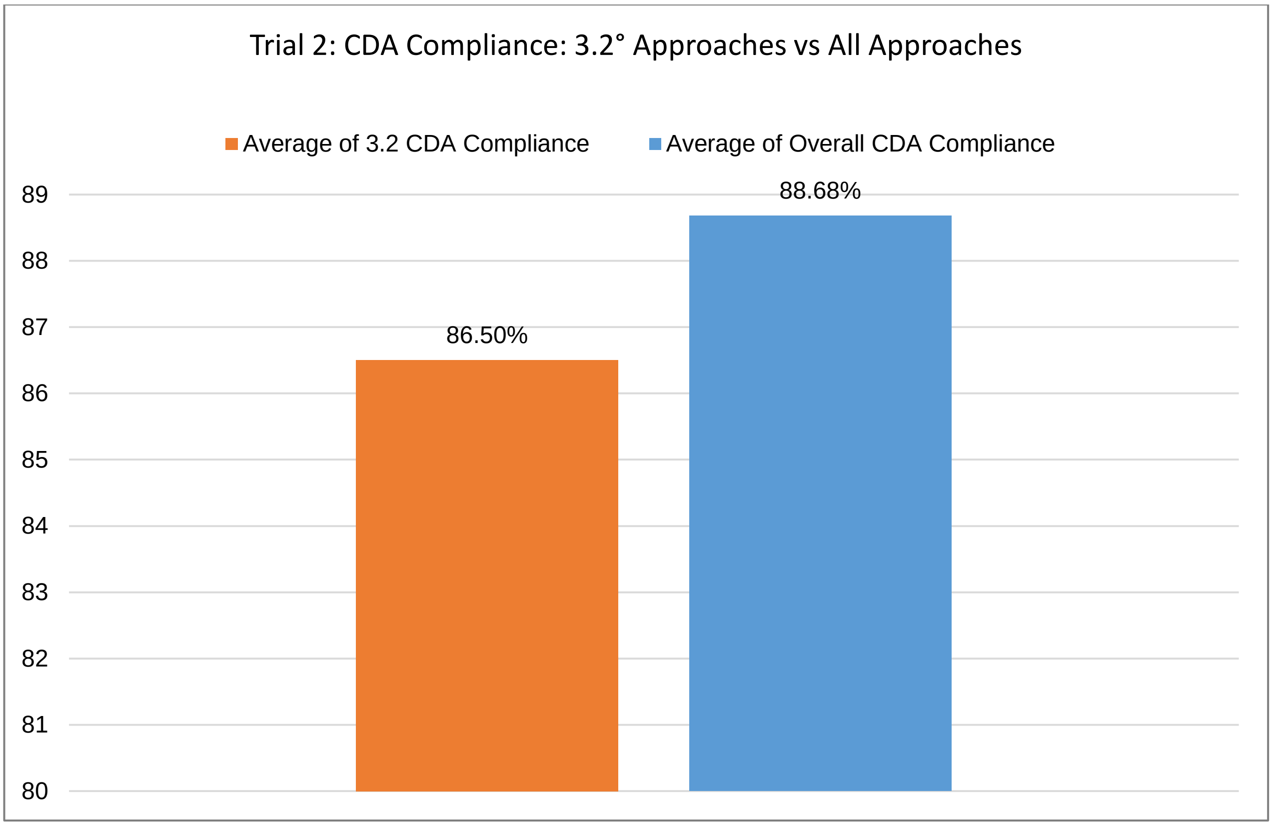


Figure 8.2: 2nd Trial Overall comparison of 3.2˚ approach CDA performance

37. When comparing CDA performance of westerly versus easterly operations, it can be seen that there is a poorer CDA performance with the 3.2° approaches on easterly operations compared to on westerly operations. This reflects the current situation with CDA performance on easterly operations.

Orientation	3.2°RNAV CDA Compliance	Overall CDA Compliance
Easterly	81%	84%
Westerly	87%	86%

Table 4.1: 1st Trial CDA performance by Runway Direction

Orientation	3.2°RNAV CDA Compliance	Overall CDA Compliance
Easterly	80%	85%
Westerly	88%	89%

Table 4.2: 2nd Trial CDA performance by Runway Direction

Speed adherence on final approach – 1st trial

38. In order to provide accurate and consistent final approach spacing, all Heathrow arrivals, with the exception of the A380 are instructed to maintain 160Kts until 4nm (4DME) from touchdown. The A380 is instructed to maintain 160Kts until 5nm (5DME). Figure 9 shows that speed adherence at these distances from touchdown was actually slightly closer to optimal on the 3.2° than on the 3° approaches.

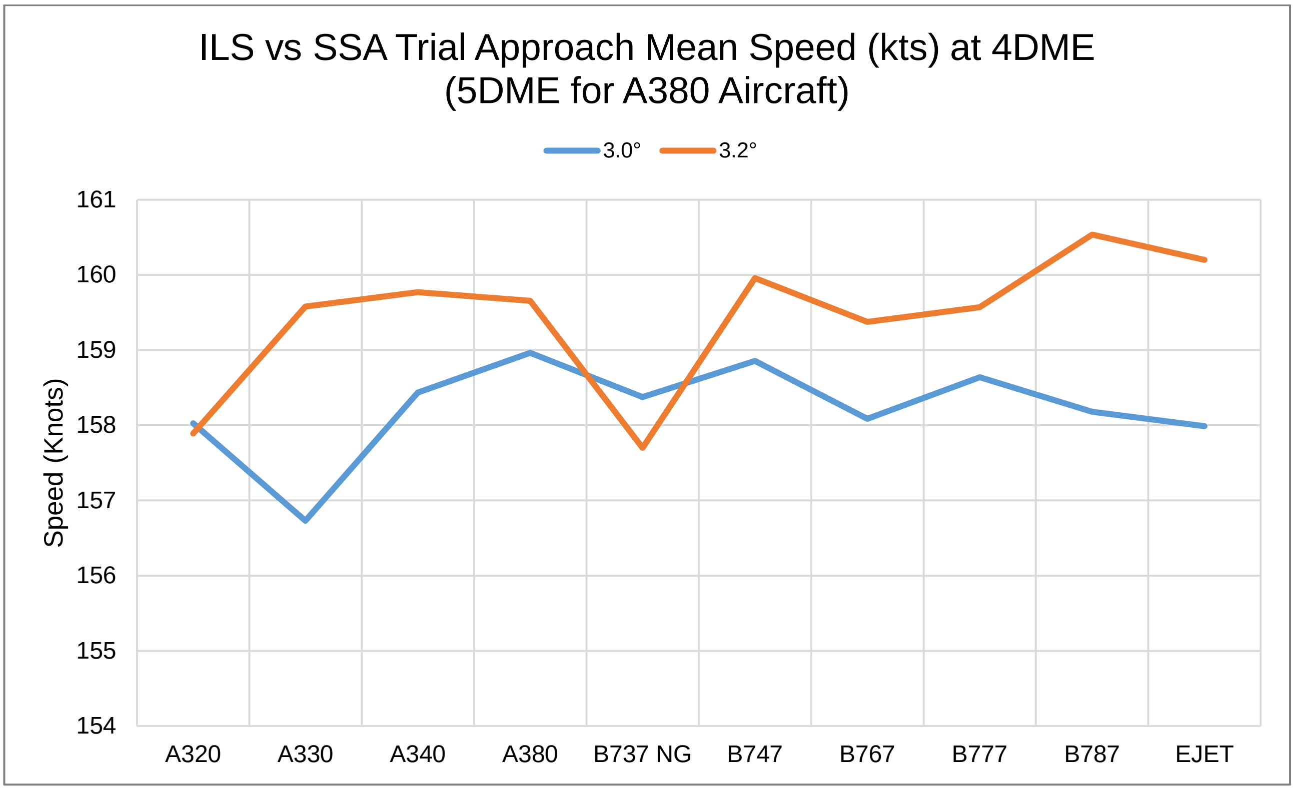


Figure 9: Speed adherence at 4DME all aircraft

39. There is very little difference in the mean speeds at 4DME (5DME for A380s) between the different aircraft types. A 3kt difference for A330 aircraft is the largest difference observed.

40. With the exception of the B737, the 3.2° RNAV arrivals were able to achieve closer to the ideal 160Kts until 4DME than the 3° ILS arrivals.

41. Looking at the mean speeds at 4DME of just the A320 family (Figure 10) there is very little, less than a ¼ of a knot, between the 3° ILS and 3.2° RNAV approaches. The distribution of the 3.2° approaches sits comfortably within and about a similar mean to the 3.0° ILS approach's distribution, suggesting that the difference in type of approach has a negligible effect on adhering to the 4DME speed restriction.

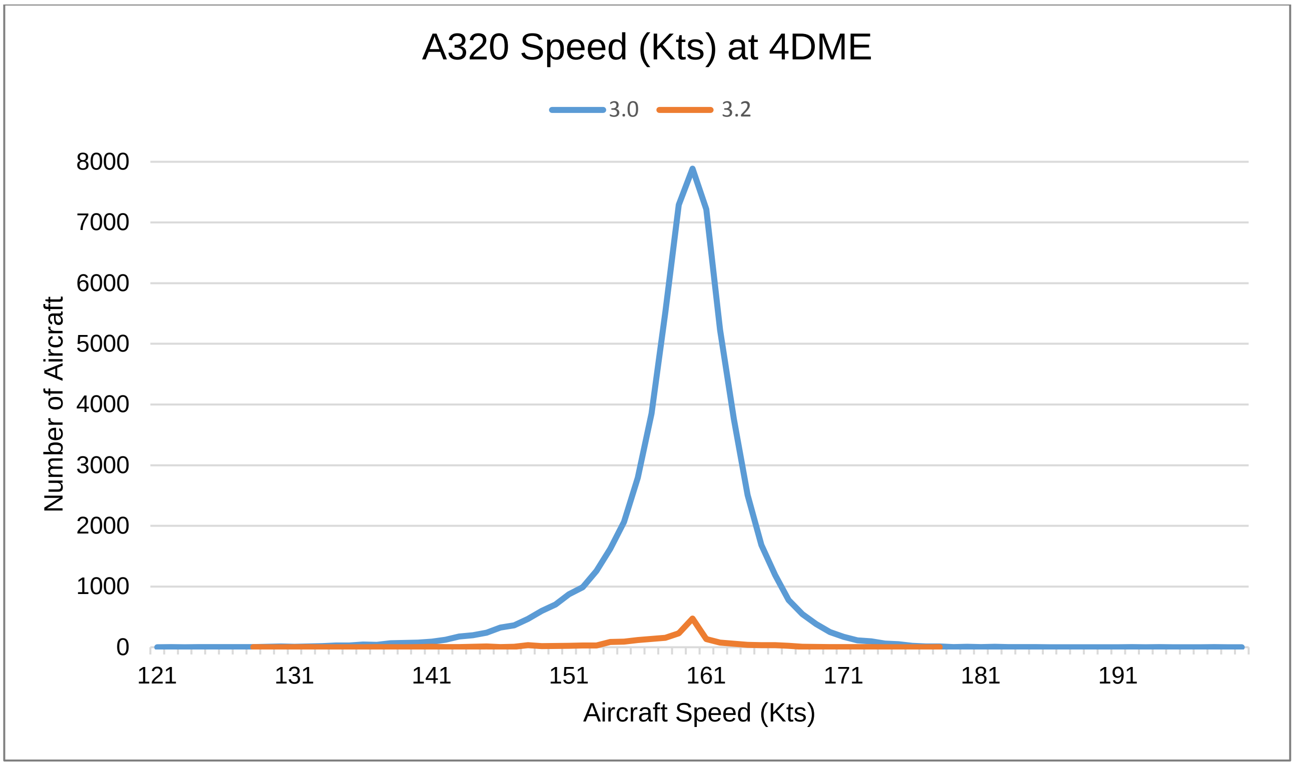


Figure 10: Speed adherence at 4DME for A320 family

42. The impact of poor speed adherence on final approach could be linked to either a drop in landing rates achieved during the trial or an increase in the number of go-arounds, neither of which were observed during the trial.

Speed adherence on final approach – 2nd trial[8]

43. There is an overall improvement in speed compliance of 1.4%[9] for flights operating a 3.2° RNAV approach compared to the standard approach.

44. The largest difference is for Heavy wake turbulence category aircraft, which is 8% higher for aircraft operating a 3.2° RNAV approach.

45. Super and Medium wake turbulence category aircraft were both slightly reduced for those flying the 3.2° RNAV approach.

46. Note that speed compliance varies by airline, and the airlines to have used the 3.2° RNAV approach with any regularity only forms a subset of all airlines operating at Heathrow. This may have influenced the overall result.

Approach Angle	Speed Compliance
3.0°	80.3%
3.2°	81.7%
Change	1.4%

Table 5: Speed compliance of all approaches

	3.0° RNAV Approach	3.2° RNAV Approach	
Wake Category	Speed Compliance	Speed Compliance	Change
HEAVY	82.5%	90.5%	8.0%
MEDIUM	78.7%	77.2%	-1.5%
SUPER	84.1%	82.9%	-1.2%

Table 6: Speed compliance by Wake Vortex Category.

47. Within the Medium wake turbulence category, all airlines see an improvement in speed adherence except from BA who experienced a 4.6% decrease. The reduction of 4.6% for BA indicates that more aircraft were flying outside of this speed window at 4DME. The heavy weighting of BA flights within the Medium wake turbulence category cause the overall significant decrease in speed adherence of 1.5% for the Medium wake turbulence category.

48. Conversely, within the Heavy wake category, BA experience a 6.2% increase leading to an overall significant increase in speed adherence of 8% for the heavy wake turbulence category.

---

[8] Data for the 2nd trial was supplied by NATS, already analysed as opposed to in its raw format. For this reason, the Speed Adherence data is presented in a different manner to in the 1st trial

[9] This percentage is the proportion of flights that are flying a speed between 155 and 165 knots at 4DME (5 DME for A380s)

49. Significant increases for the B744, B77W, B788 and B789 further indicate an improvement in speed compliance for aircraft types with a Heavy wake turbulence category.

50. Significant decreases for the A320 and A321 support the decrease speed compliance for aircraft types with a Medium wake turbulence category.

51. A decrease of 1% for the A388 supports the slight reduction in the Super wake turbulence category.

Heavy Wake Cat	3.0° RNAV Approach	3.2° RNAV Approach	
Airline	Speed Compliance	Speed Compliance	Change
BAW	86.5%	92.7%	6.2%
VIR	88.5%	87.8%	-0.7%
Medium Wake Cat	3.0° RNAV Approach	3.2° RNAV Approach	
Airline	Speed Compliance	Speed Compliance	Change
EIN	86.1%	91.5%	5.4%
BAW	78.4%	73.8%	-4.6%
SHT	77.9%	79.9%	2.0%
DLH	77.7%	84.6%	6.9%
SAS	81.9%	87.2%	5.3%

Table 7: Speed compliance by Wake Vortex Category & Airline.

	3.0° RNAV Approach	3.2° RNAV Approach	
Aircraft Type	Speed Compliance	Speed Compliance	Change
A319	74.8%	74.3%	-0.5%
A320	81.1%	78.1%	-3.0%
A321	77.9%	76.4%	-1.5%
B744	84.2%	95.5%	11.3%
B772	85.4%	84.5%	-0.9%
B77W	78.5%	84.8%	6.3%
B788	75.9%	93.5%	17.6%
B789	89.0%	91.8%	2.8%
A388	84.2%	83.2%	-1.0%

Table 8: Speed compliance by Aircraft type.

52. In summary, speed adherence for aircraft using the 3.2° RNAV approach was 1.4% higher than for aircraft using the 3.0° approach. Variation by airline and aircraft type was observed, with a trend of improved speed compliance for Heavy aircraft and a slightly reduced speed compliance for Medium and Super aircraft.

Runway Occupancy Times – 1st trial

53. The average Runway Occupancy Time (RoT) is extremely similar between 3° and 3.2° approaches (Figure 11).

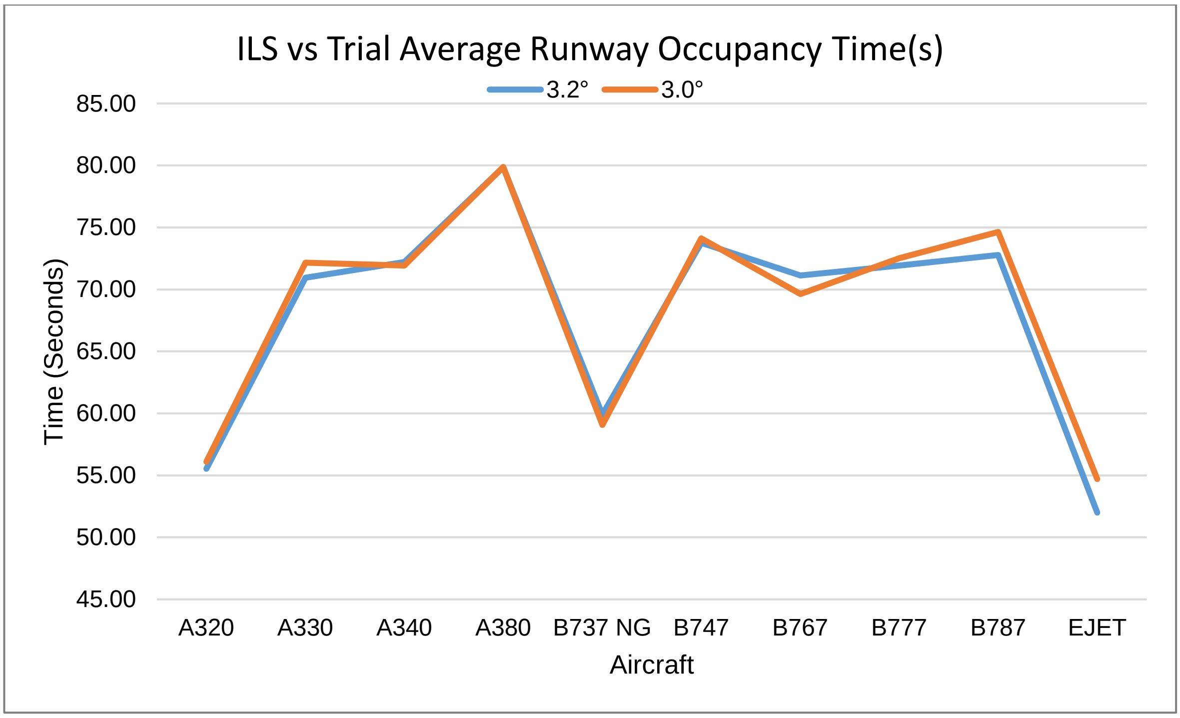


Figure 11: 1st Trial average RoT all aircraft

54. Looking at the RoTs of just the A320 family (Figure 12) there is very little difference in the means for the respective approaches, approximately ½ of a second, with the distribution of the 3.2° RNAV approaches sitting within the ILS approach distribution. This suggests that the difference in type of approach has negligible effect on the runway occupancy time.

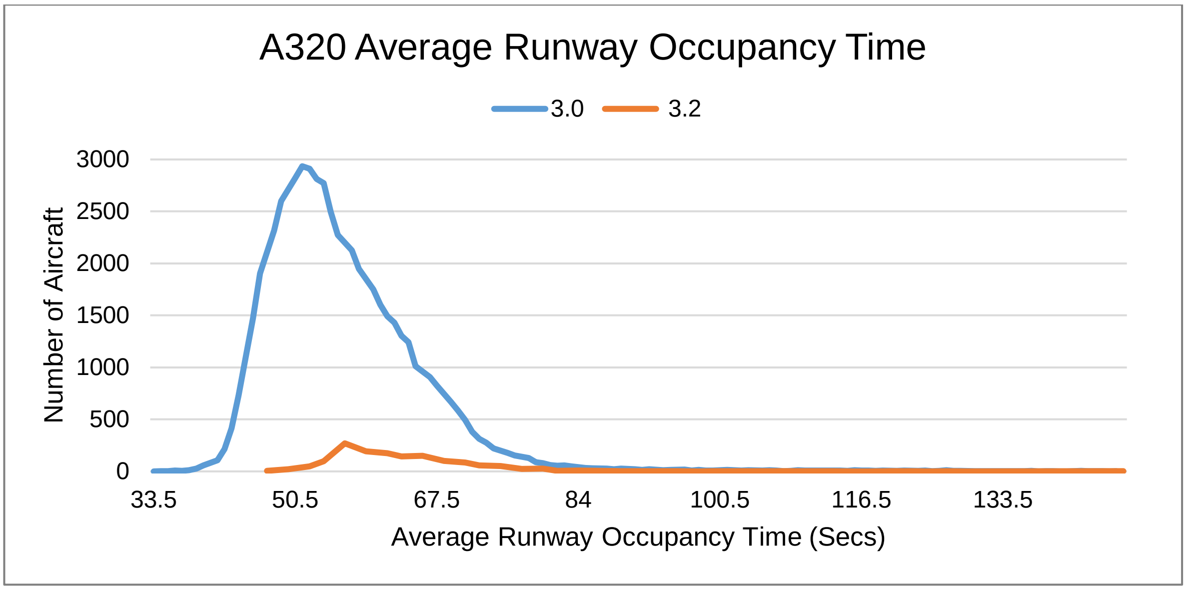


Figure 12: 1st Trial average RoT of the A320 family

Runway Occupancy Times – 2nd trial (NATS[10])

55. The overall distribution of ROT shows an increased proportion of flights with average ROT (aROT) of 45-50 seconds, with a reduced proportion of flights in the 55-70 seconds range. (See Figure 13)

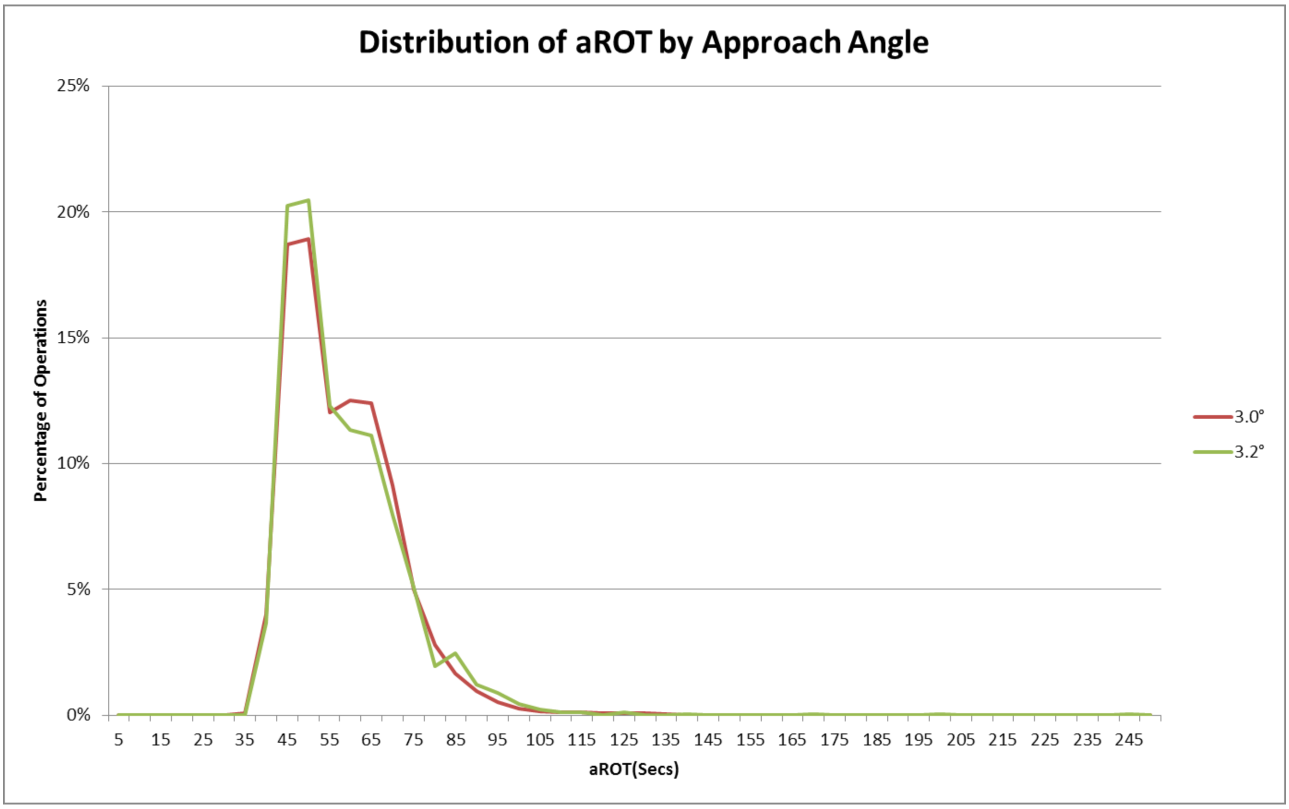


Figure 13: 2nd Trial – Distribution of aROT by Approach Angle.

56. Mean aROT for all aircraft using the 3.2° RNAV approach was 59.8 seconds, compared to 60.0 seconds for the 3.0° approach.

57. Analysis of individual airlines and aircraft types shows some variation in performance. For example, mean aROT has reduced for Emirates (UAE), but increased for Scandinavian (SAS). See figure 14.

[10] Data for the 2nd trial was supplied by NATS, already analysed as opposed to in its raw format. For this reason, the RoT data is presented in a different manner to in the 1st trial

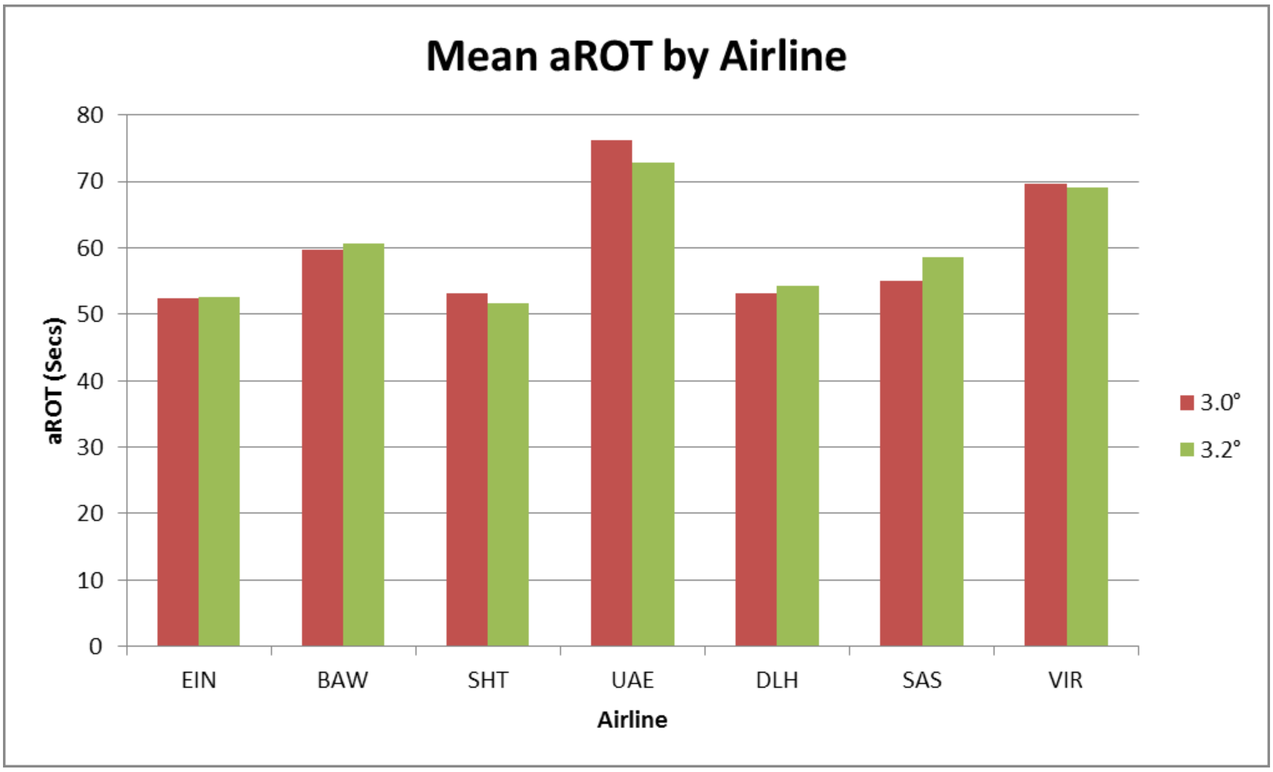


Figure 14: 2nd Trial – Mean aROT by Airline.

58. For most aircraft types, there were no significant differences in mean aROT. The largest difference for a single aircraft type was for the B788, with an increase of 3 seconds. See figure 15.

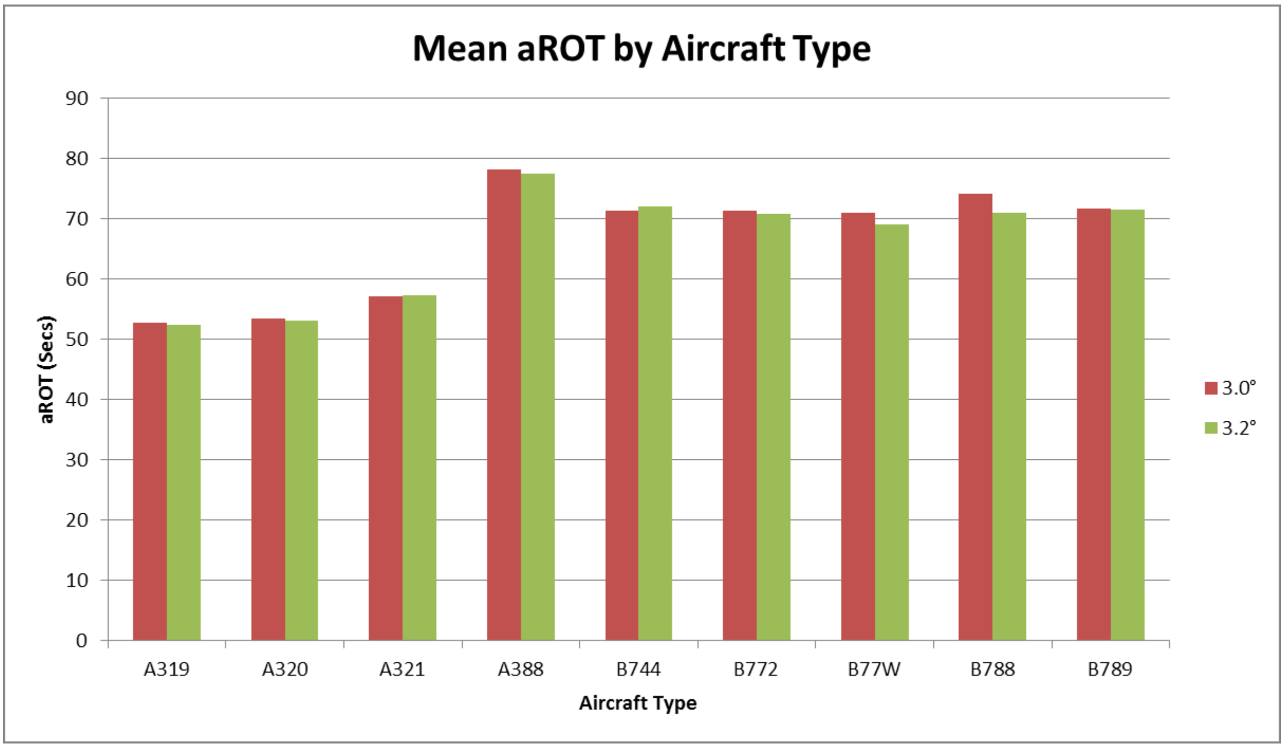


Figure 15: 2nd Trial – Mean aROT by Aircraft Type.

59. In summary, during the 2nd trial, mean aROT for aircraft using the 3.2° RNAV approach was consistent with those using the 3.0° approach.

Number of Go-Arounds

60. During the 1st trial period, there were 351 Go-arounds (approximately 2 per day) at Heathrow. Of these, only 3 were performed by aircraft arriving on a 3.2° RNAV approach. None of these were due to the RNAV procedure itself; one was due to a Flight Management Computer issue, one due to the previous landing aircraft was slow to vacate the runway and the other was due to windshear[11].

61. Of the 348 remaining go-arounds, none were reported to have been due to an effect from a preceding 3.2° RNAV arrival.

62. During the 2nd trial period, there were 237 Go-arounds (under 2 per day) at Heathrow. Of these, 5 were performed by aircraft arriving on a 3.2° RNAV approach. None of these were reported to be due to the RNAV procedure and of the 232 remaining go-arounds, none were reported to have been due to an effect from a preceding 3.2° RNAV arrival.

[11] Windshear is a change in wind speed and/or direction over a relatively short distance. This can cause sudden fluctuations in an aircraft's airspeed and destabilise the final approach requiring the pilot to initiate a go-around.

Landing Gear Deployment

63. Landing Gear deployment is associated with an airline's Standard Operating Procedure (SOP), which for most airlines, including British Airways (BA), is on passing a certain height. Therefore, with a slightly steeper approach, that height is reached slightly closer to the runway. However, commencing the lowering of the landing gear is not an automated process and the height differential between 3° and 3.2° is relatively small.

64. From data supplied by BA for the 1st trial; Table 9 and Figure 15 compare the differences in average distances from touchdown and height across BA's fleet on 3° ILS and the 3.2° RNAV approaches. Note that data for the B747, B767 and B777 fleets was only available from the 1st month of the trial period.

Type	No.3.0°ILS Approaches	No.3.2°RNAV Approaches	3.0°ILS Mean Heights (ft)	3.2°RNAV Mean Heights (ft)	Distance Closer to THR. (m)	Height Diff. (ft)
A319	13,702	441	1525	1564	28	+39
A320	19,177	590	1487	1523	6	+36
A321	5,141	104	1471	1484	201	+13
A380	470	17	2161	2004	1404	-157
B747	873	24	1958	1973	362	+15
B777	1,121	56	2090	2135	495	+45
B787	151	19	2104	2127	109	+23

Table 9: BA Landing Gear Selection average heights and distances. A319. A320, A321 & A380 data was available for the entire trial period of 6 months. Data for the B747, B767 & B777 fleets was only available from the 1st month of the trial period.

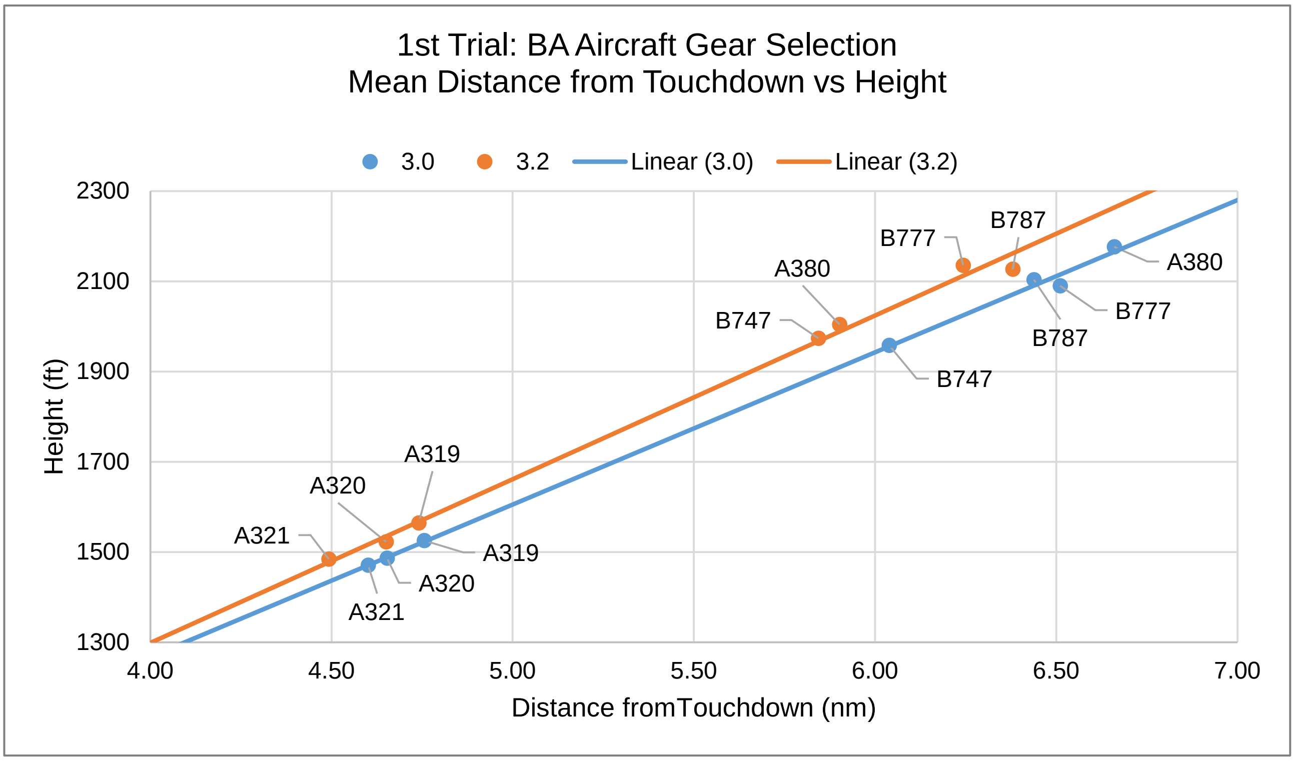


Figure 15: 1st Trial, BA Landing Gear Selection average heights and distances. A319. A320, A321 & A380 data was available for the entire trial period of 6 months. Data for the B747, B767 & B777 fleets were only available from the 1st month of the 1st trial period.

65. The medium sized jets were deploying landing gear at almost the same distance, but the larger, heavy aircraft were clearly deploying their landing gear slightly closer in to the runway at the same approximate height. The most significant difference between 3° and 3.2° landing gear deployment occurred on the A380 with it being, on average, 0.75nm closer to the runway (on the 3.2°approach). The A380 self-corrects for the effect of temperature on baro-VNAV approaches. Therefore, as the actual height differential was greater, one would expect the landing gear selection point to move closer to the runway, but keep the height of deployment the same. However, although the A380 was one of the aircraft offering the greatest noise reduction on the ground during the 1st trial, the height of landing gear deployment was actually slightly lower.

66. Due to the effect of temperature on baro-VNAV approaches, the average RNAV approach angle was actually less than 3.2°. With a fixed 3.2° ILS approach it could be expected that the average landing gear deployment could be slightly closer to the runway.

67. For the 2nd trial the same dataset was not available however, landing gear deployment altitude data has been made available from British Airways. This data shows the altitude at which the landing gear is down and locked, whereas the data supplied for the 1st trial is the point at which the landing gear is selected for deployment. A summary of the average landing gear deployment altitude for each type may be seen in Figure 16.

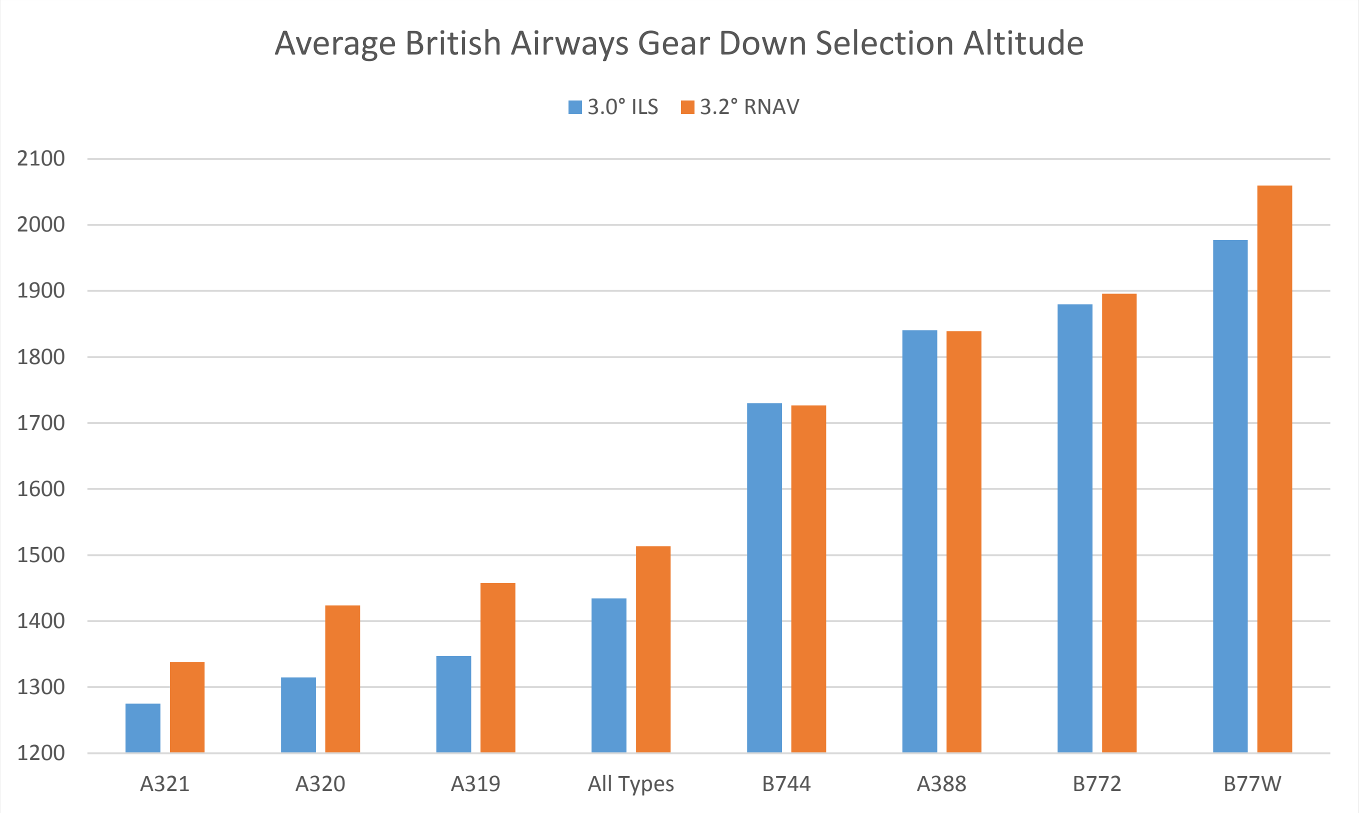


Figure 16: 2nd Trial, average BA Landing Gear deployment altitude across the BA fleet.

68. It can be seen, for the 2nd trial, that the RNAV landing gear deployment altitude is as expected, similar or higher than the ILS approaches landing gear deployment altitude. This confirms the general premise of the 1st trial, in that the landing gear deployment is very slightly higher for an RNAV versus an ILS approach.

Aircraft height on Final Approach

69. Figure 17 shows the available height improvement between a 3° and a 3.2° glide slope based on the trigonometric difference at 2nm intervals.

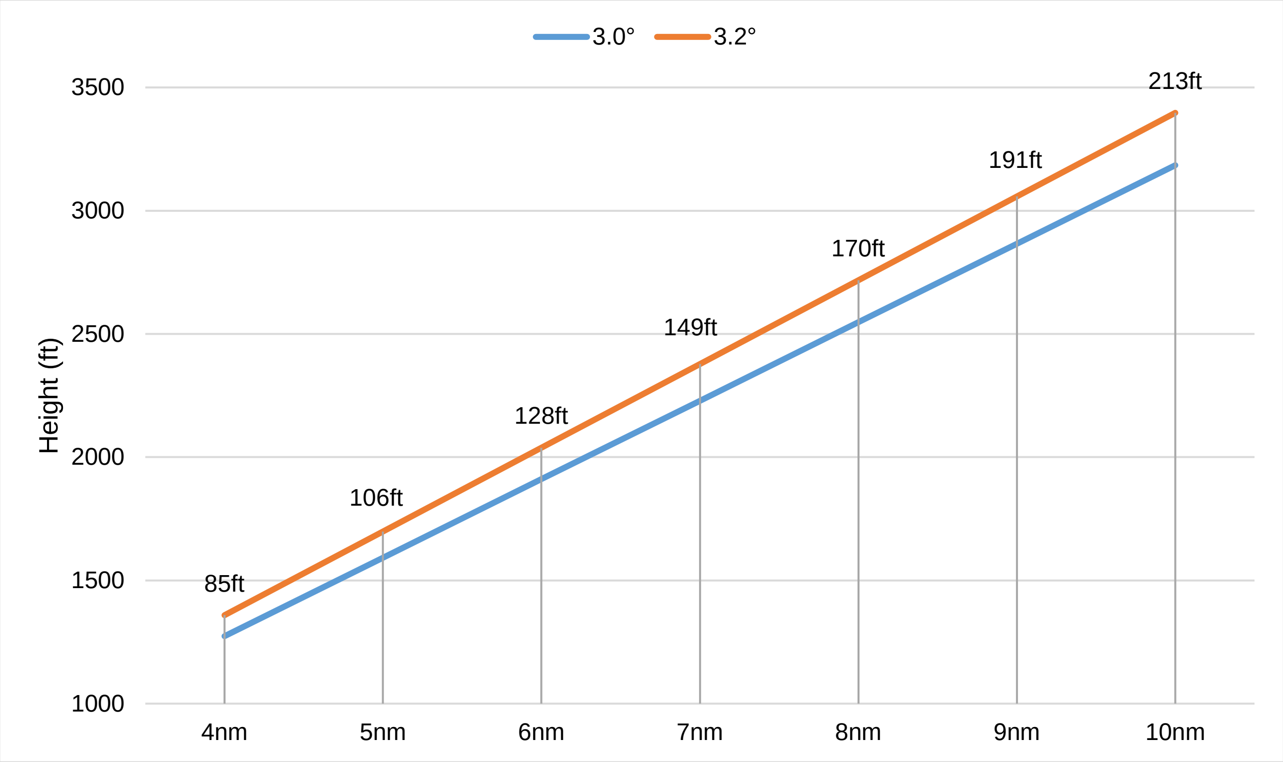


Figure 17: Trigonometric Height differential at 2nm intervals

70. When looking at the average actual height improvement at 4nm, 6nm and 8nm across all 3.2° RNAV Approaches on all aircraft types across the first 6-month trial period, the height improvement was lower than the trigonometry would expect. See Figure 18.1.

71. Conversely, during the 2nd trial, actual height improvement was higher than the trigonometry would expect. See Figure 18.2.

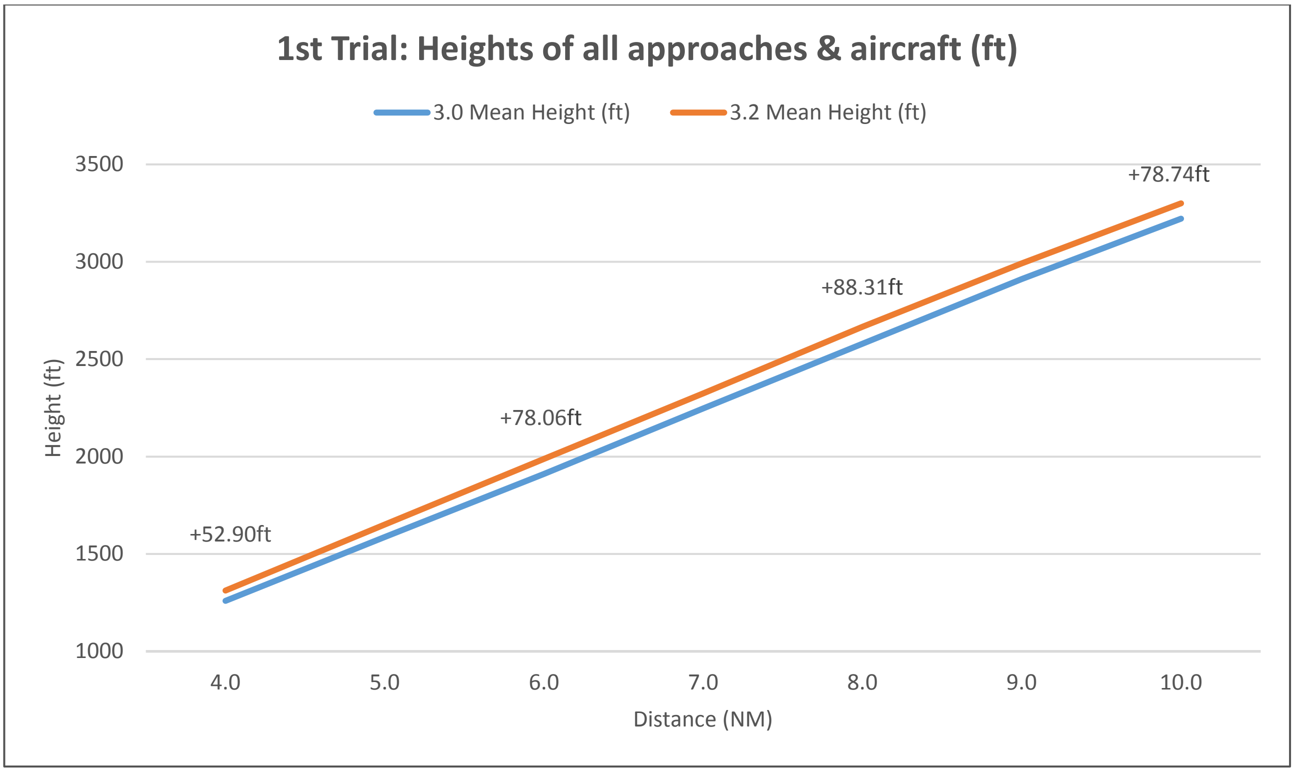


Figure 18.1: Average height improvement achieved. All runways, all aircraft types.

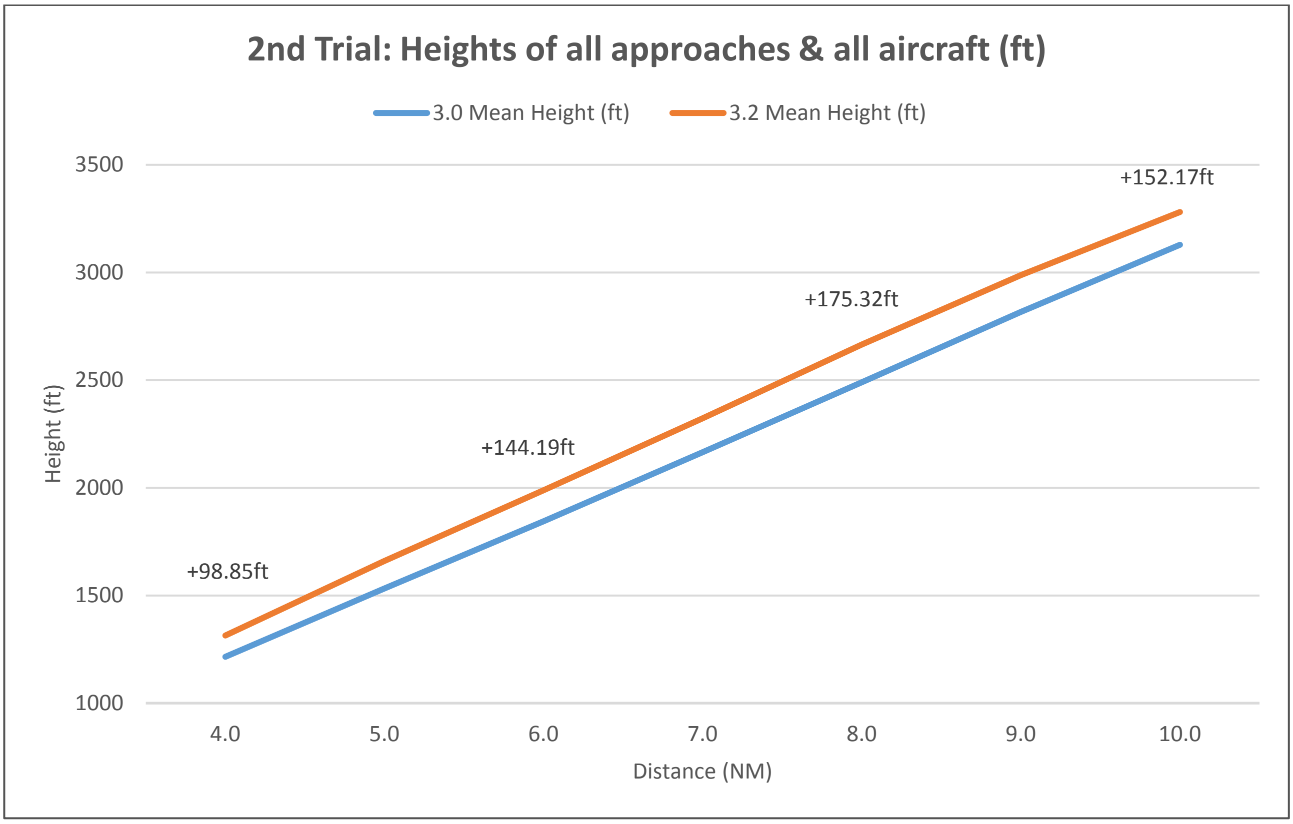


Figure 18.2: Average height improvement achieved. All runways, all aircraft types during 2nd trial

Westerly V Easterly height differential

72. Comparing separate Westerly (Figures 20.1 & 20.2) and Easterly (Figure 21.1 & 21.2) approaches for both trials across all aircraft types, there was a much ‘better’ 3.2°

height performance for the 2nd trial, with a similar performance on westerlies and easterlies that was not experienced during the 1st trial.

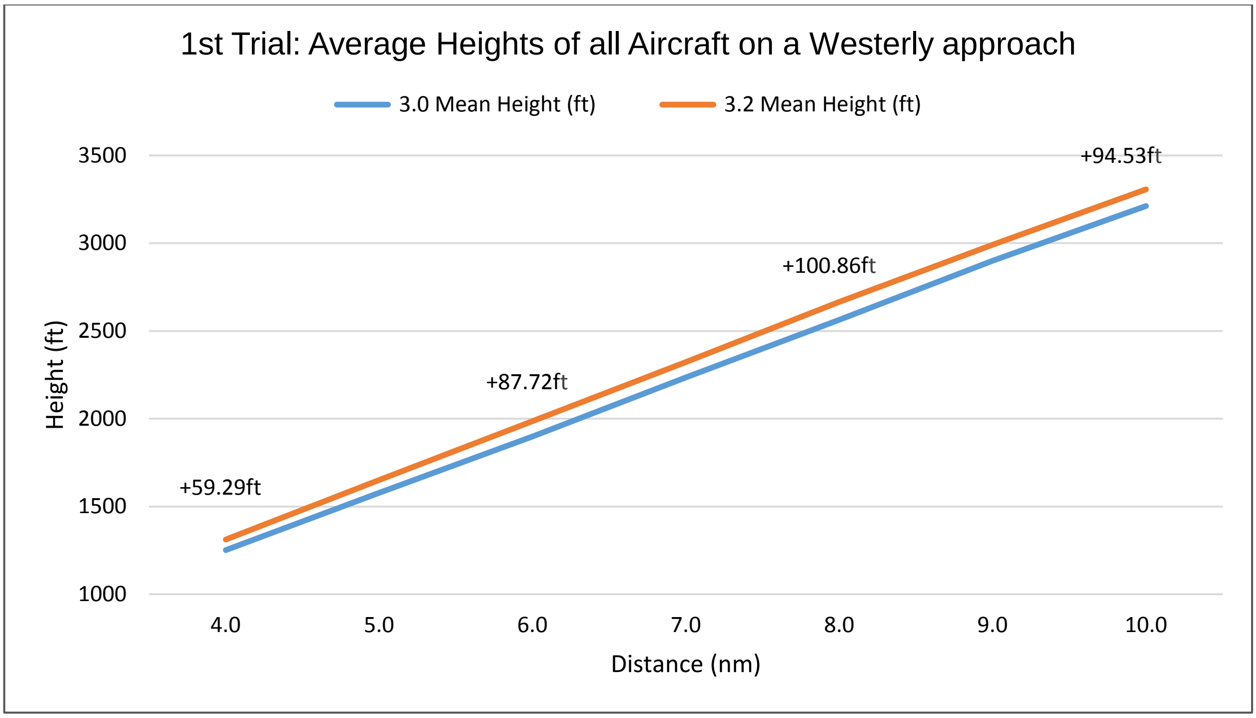


Figure 20.1: 1st Trial Average height improvement achieved. Westerly approaches all aircraft

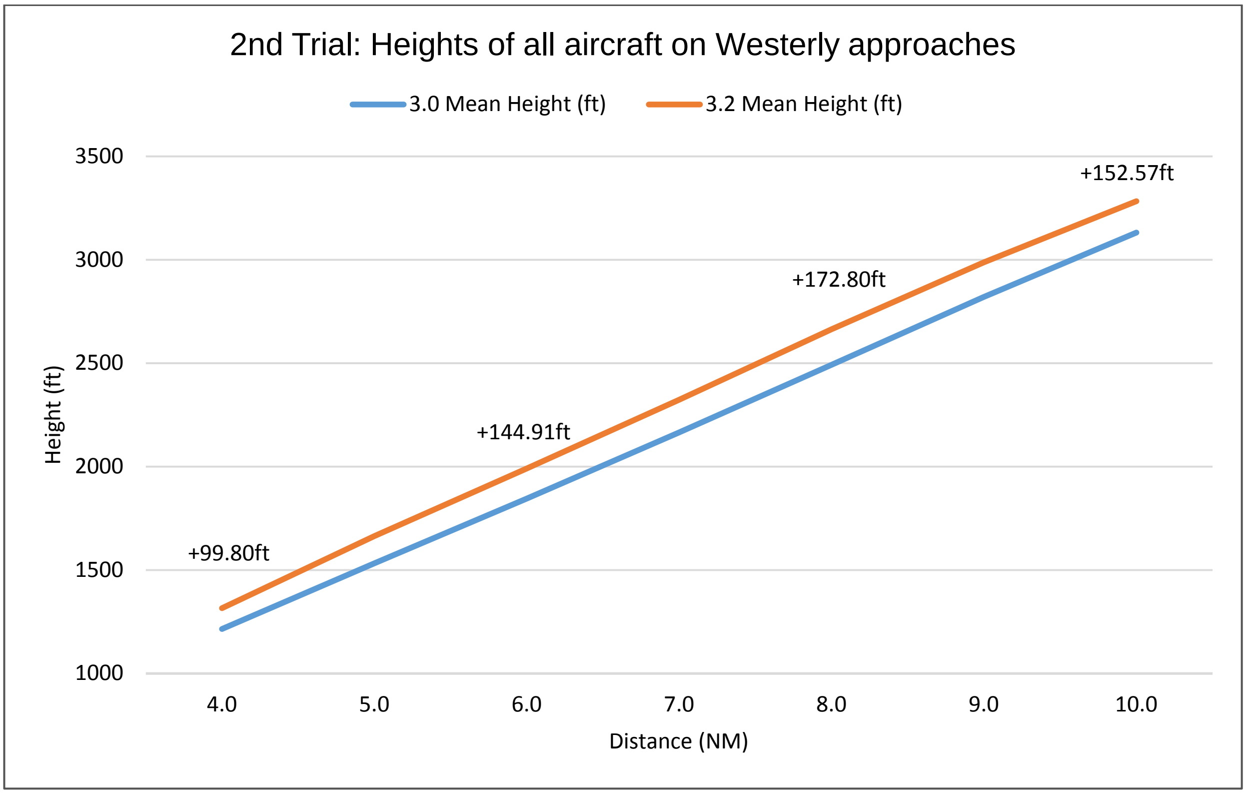


Figure 20.2: 2nd Trial Average height improvement achieved. Westerly approaches all aircraft

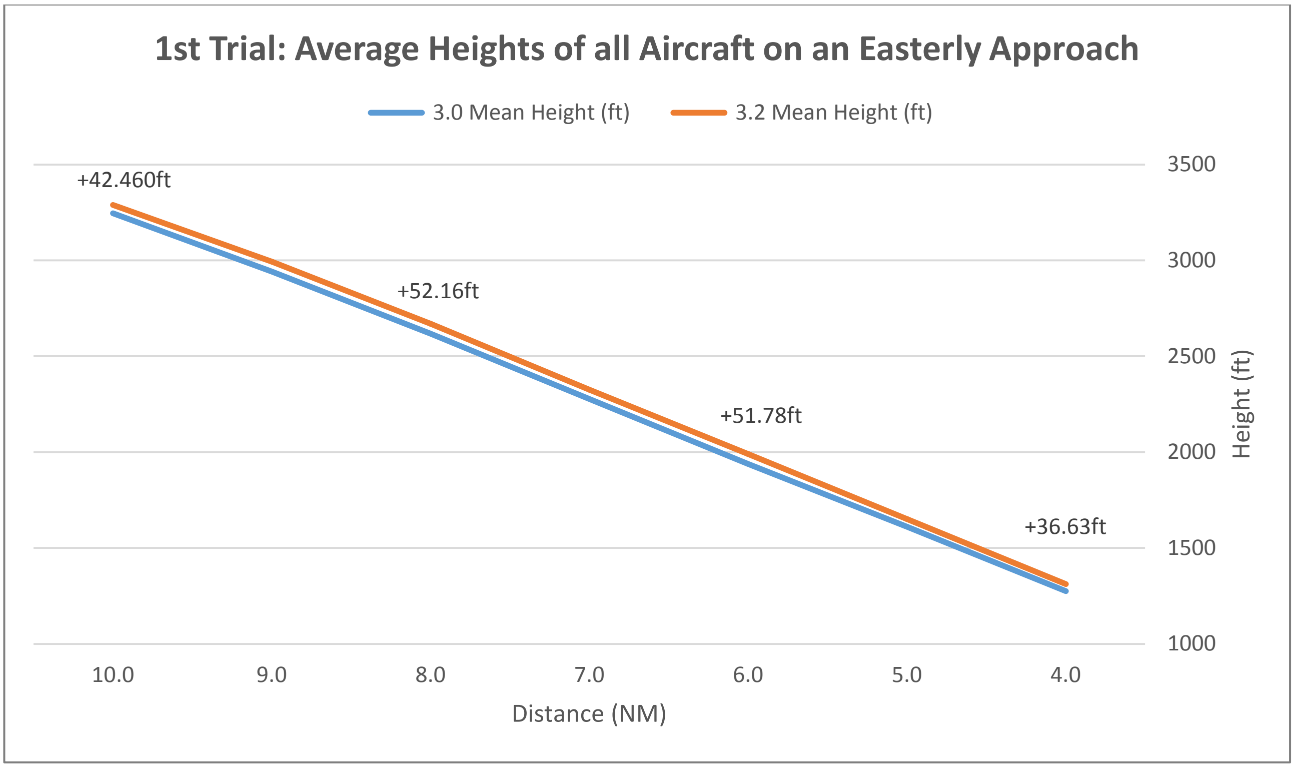


Figure 21.1: 1st Trial average height improvement achieved on Easterly approaches. 09L approaches excluded due insufficient data

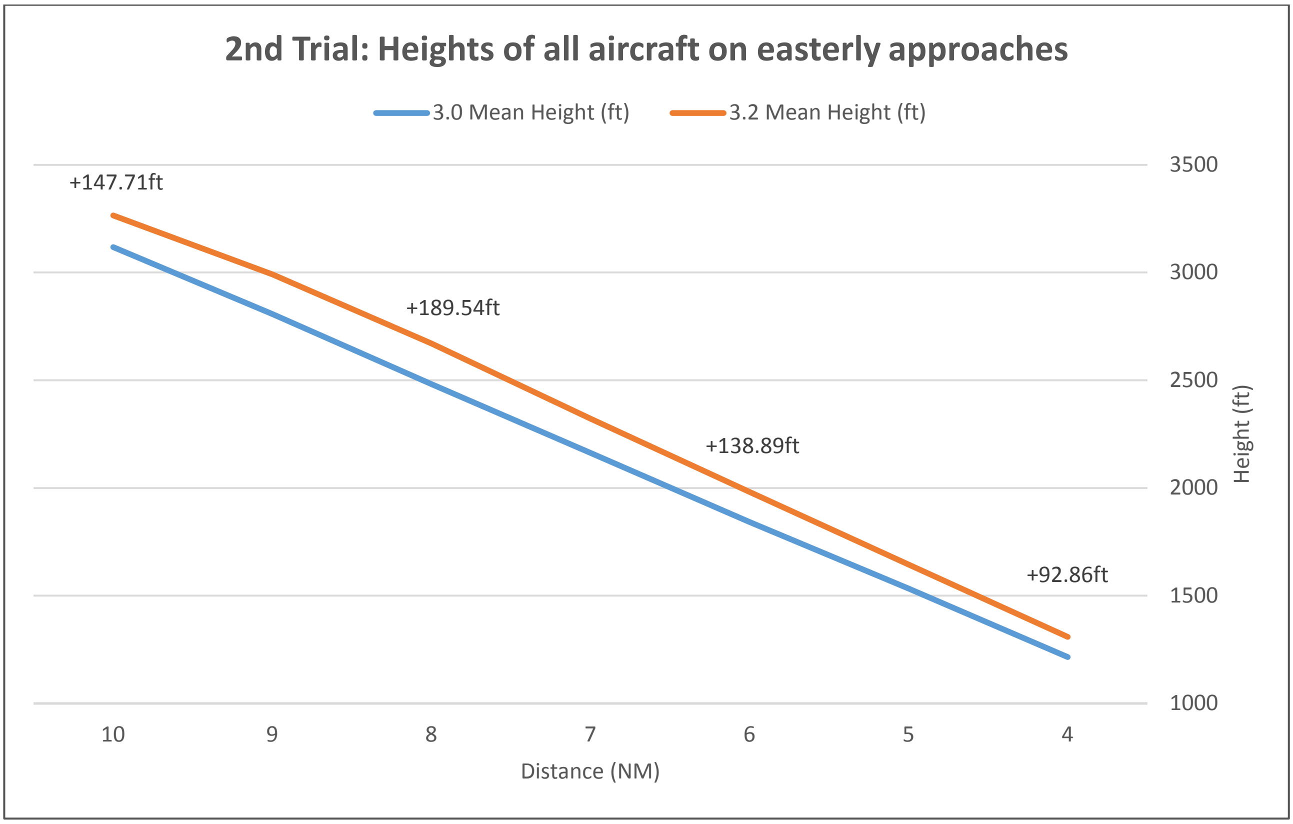


Figure 21.2: 2nd Trial average height improvement achieved on Easterly approaches. 09L approaches excluded due insufficient data

The Temperature Effect

73. An RNAV Approach's descent angle is based on the angle at the International Standard Atmosphere (ISA) temperature at mean sea level which is 15°C. When the temperature is not precisely 15°C, the barometric approach angle starts to alter slightly. The colder the temperature, the shallower the approach angle. The warmer it gets, the steeper the approach angle.

74. Data analysed from METARs[12] for Heathrow during the 2nd trial period confirm the average temperature (0600-2230) was 18.41°C. This had the effect of producing an average RNAV approach angle of approximately 3.24°.

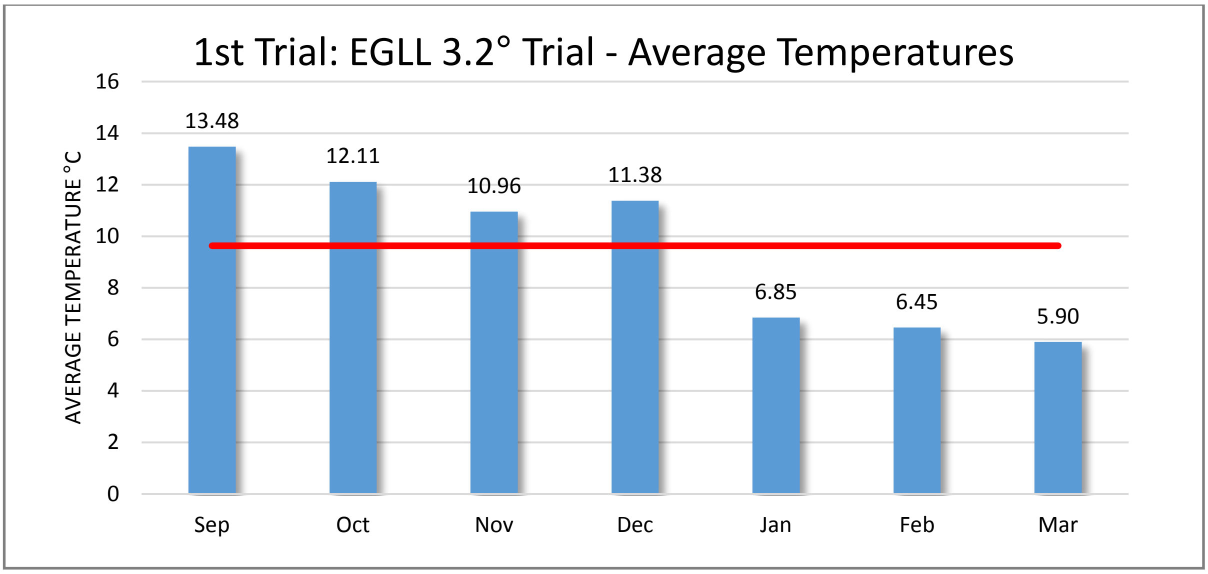


Figure 22.1: Average temperature of 9.63°C at Heathrow during the 1st trial period (H24)

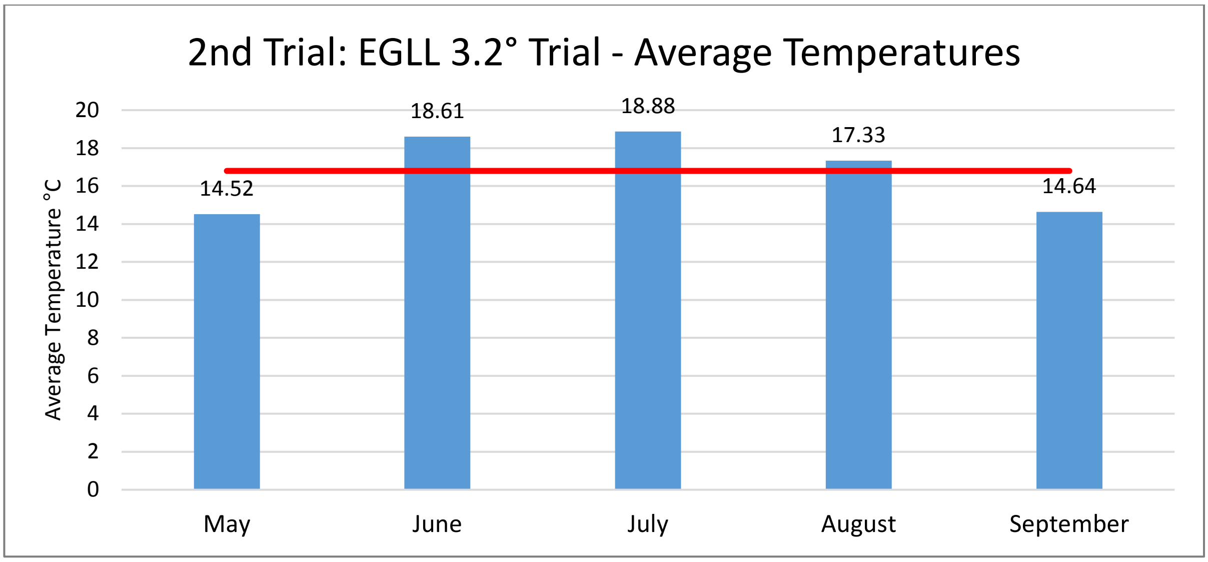
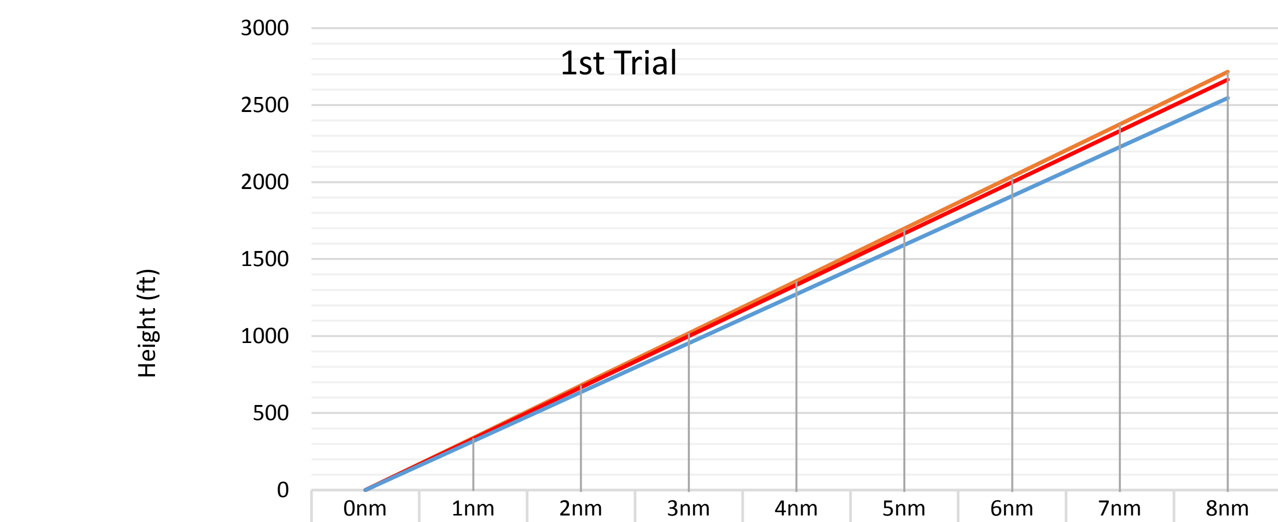


Figure 22.2: Average temperature of 16.80°C at Heathrow during the 2nd trial period (H24)

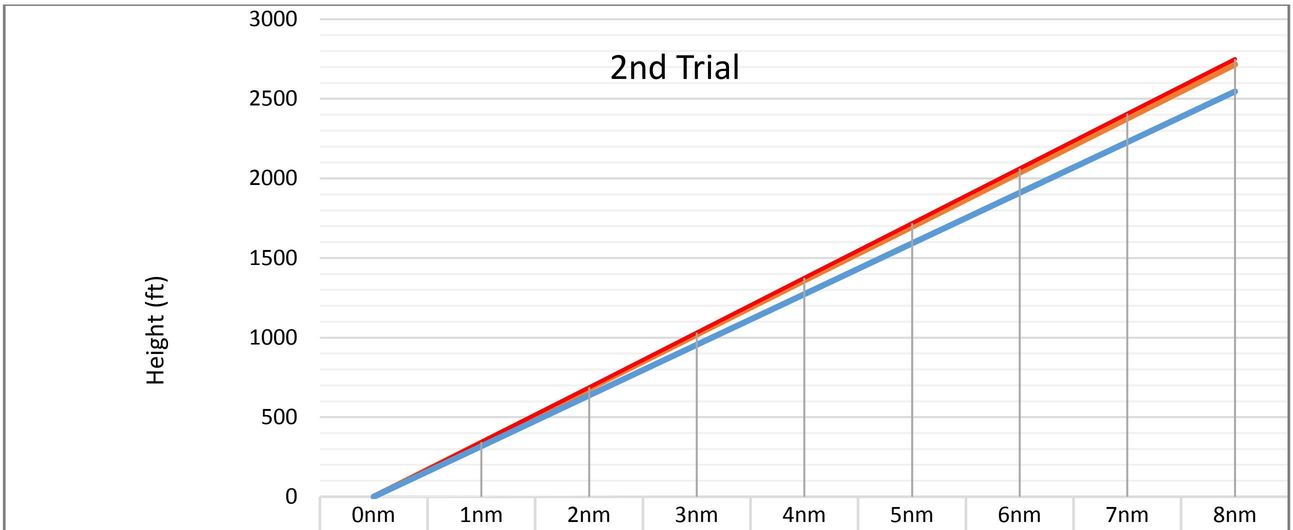
[12] A METAR, METeorological Actual Report, is a format for reporting weather information to the aviation sector.

75. Figures 23.1 & 23.2 below shows the effect that this average temperature reduction alone would have on the height of aircraft along the 3.2° final approach track.



	0nm	1nm	2nm	3nm	4nm	5nm	6nm	7nm	8nm
3.2°	0	339.53	679.06	1018.59	1358.12	1697.65	2037.19	2376.72	2716.25
3.2 ° +/- Temperature	0	333.26	666.50	999.73	1332.94	1666.14	1999.33	2332.49	2665.65
Difference	0	-6.27	-12.56	-18.86	-25.18	-31.51	-37.86	-44.22	-50.60
3°	0	318.27	636.54	954.81	1273.08	1591.35	1909.62	2227.89	2546.16

Figure 23.1: 1st Trial – Effect of an average 9.63°C air temperature on a 3.2° Baro-VNAV approach



	0nm	1nm	2nm	3nm	4nm	5nm	6nm	7nm	8nm
3.2°	0	339.53	679.06	1018.59	1358.12	1697.65	2037.19	2376.72	2716.25
3.2 ° +/- Temperature	0	343.68	687.37	1031.07	1374.79	1718.51	2062.24	2405.98	2749.73
Difference	0	4.15	8.31	12.48	16.66	20.85	25.05	29.26	33.48
3.0°	0	318.27	636.54	954.81	1273.08	1591.35	1909.62	2227.89	2546.16

Figure 23.2: 2nd Trial – Effect of an average 16.80°C air temperature on a 3.2° Baro-VNAV approach

76. The warmest day during the 2nd trial was 34°C which gave an RNAV approach angle of 3.34° and the coldest day during the 1st trial was 20/01/2016 -4°C which gave an RNAV approach angle of 3.07°.

A380 performance

77. The A380 automatically corrects its height for temperature. Figure 25.1 & 25.2 shows that the height improvement of the A380 performing 3.2° RNAV approaches during the 1st trial is considerably better than the average, and very close to the height improvement expected of a 3.2° final approach angle.

78. It is also worth considering this data when looking at the noise analysis from the 3 Remote Monitoring Terminals (RMTs), as the A380 is one of the aircraft offering the best noise reduction as a result of the 3.2° approach.

79. During the 2nd trial, A380 aircraft are higher on the 3.2° approach than other aircraft. However, as the A380 self corrects for temperature, the reason for this cannot be determined and is worthy of more investigation.

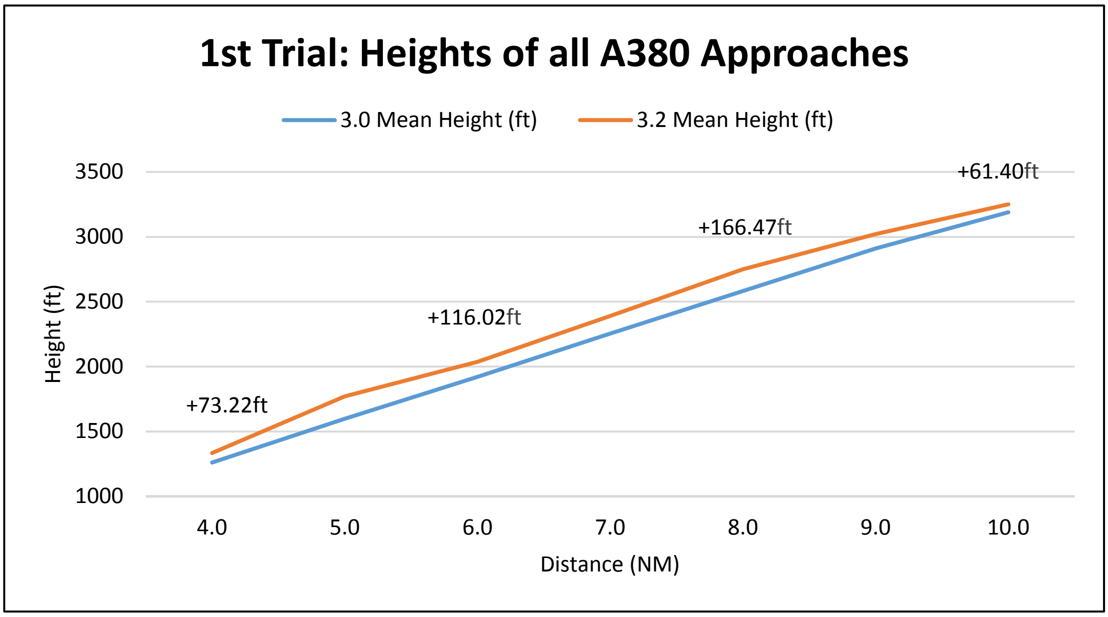


Figure 25.1: 1st Trial average height improvement achieved. All runways for A380.

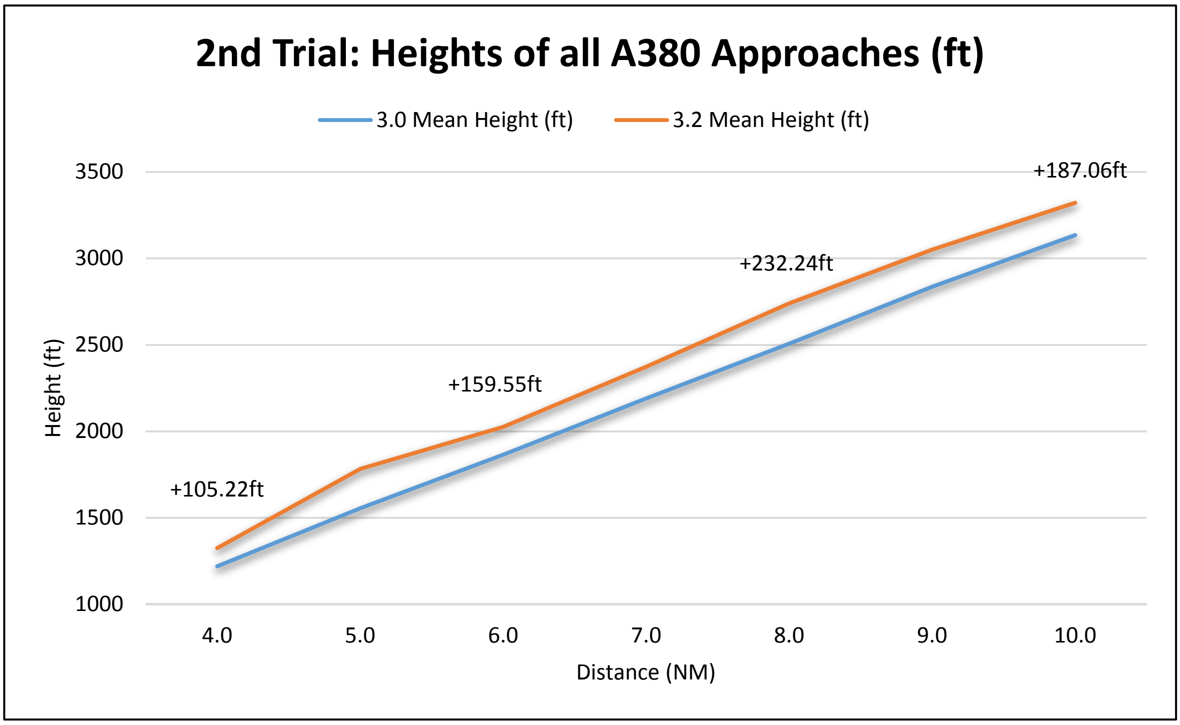


Figure 25.2: 2nd Trial average height improvement achieved. All runways for A380.

80. Figures 26.1 and 26.2 compare A320 performance across both trials

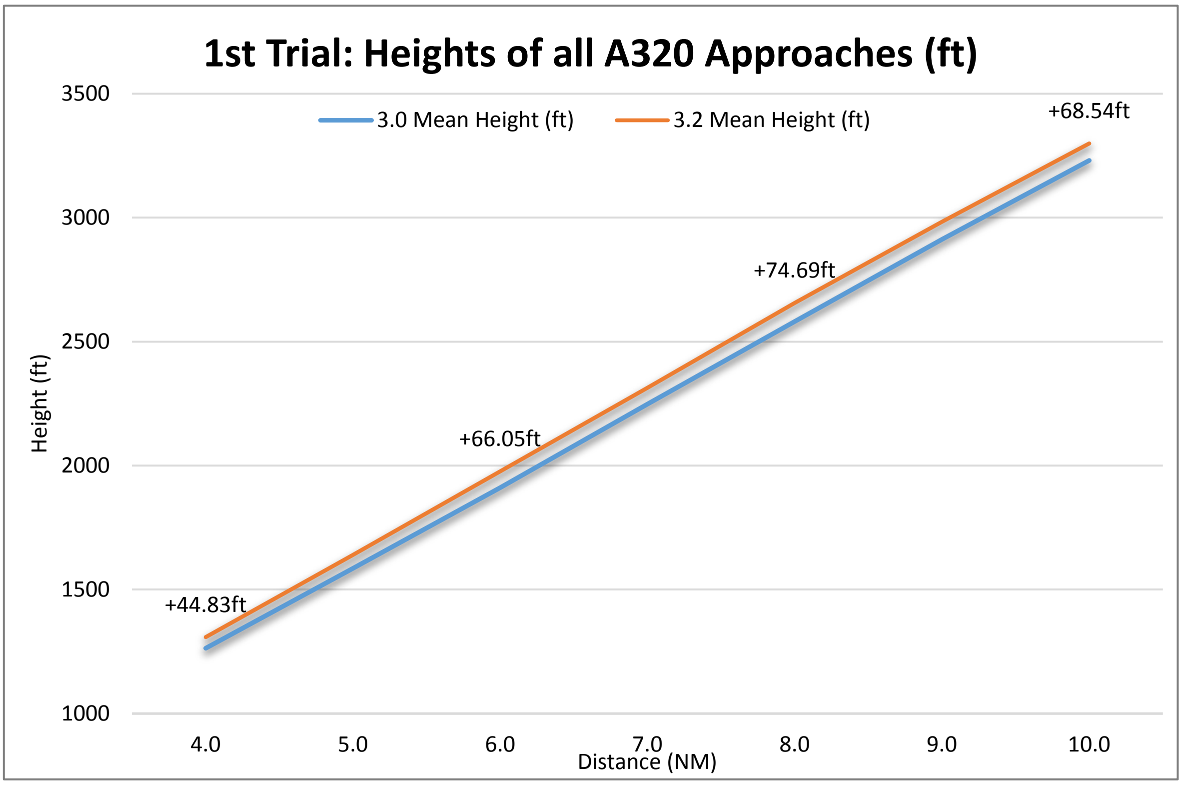


Figure 26.1: 1st Trial average height improvement achieved, all runways for A320.

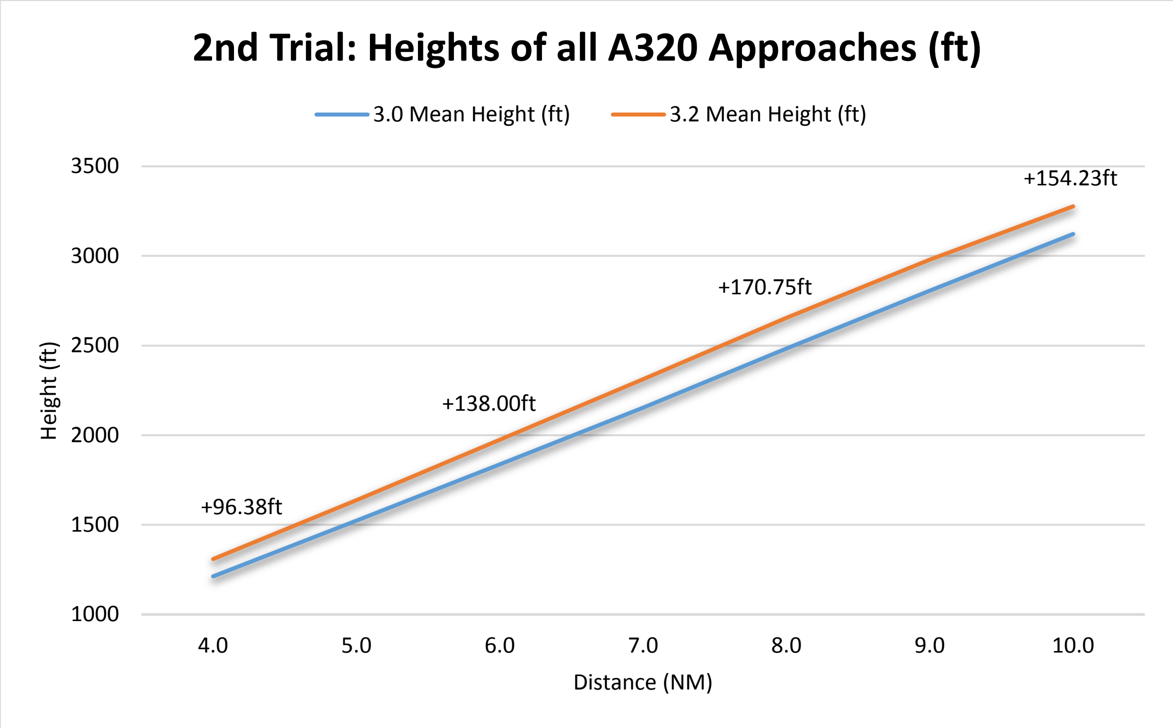


Figure 26.2: 2nd Trial average height improvement achieved, all runways for A320.

Summary

81. As expected, the height improvement achieved on final approach during the 2nd trial was much improved compared to the 1st trial. This was due to the effect of the warmer temperatures on the Baro-VNAV approaches during the 2nd trial.

82. Looking only at average temperatures between 0600 and 2230 throughout the 2nd trial period, the average RNAV approach angle was 3.24° compared to 3.14° during the 1st trial.

Final Approach joining point

83. On average, across all runways, aircraft types and both trials, the 3.2° RNAV arrivals are joining final approach 1.25 NM closer to the threshold than the 3.0° ILS arrivals (Figure 27.1 & 27.2). The analysis most likely compares RNAV arrivals to ILS arrivals, rather than 3.2° to 3.0° approaches specifically. The change is therefore a symptom of RNAV approaches being put on their own navigation to the Initial Fix, instead of being positioned by ATC vectors onto the ILS localiser.

84. Behaviour is fairly consistent across all runways with average differences being 1.29nm on 27L, 1.48nm on 27R, 0.97nm on 09L and 0.9nm on 09R.

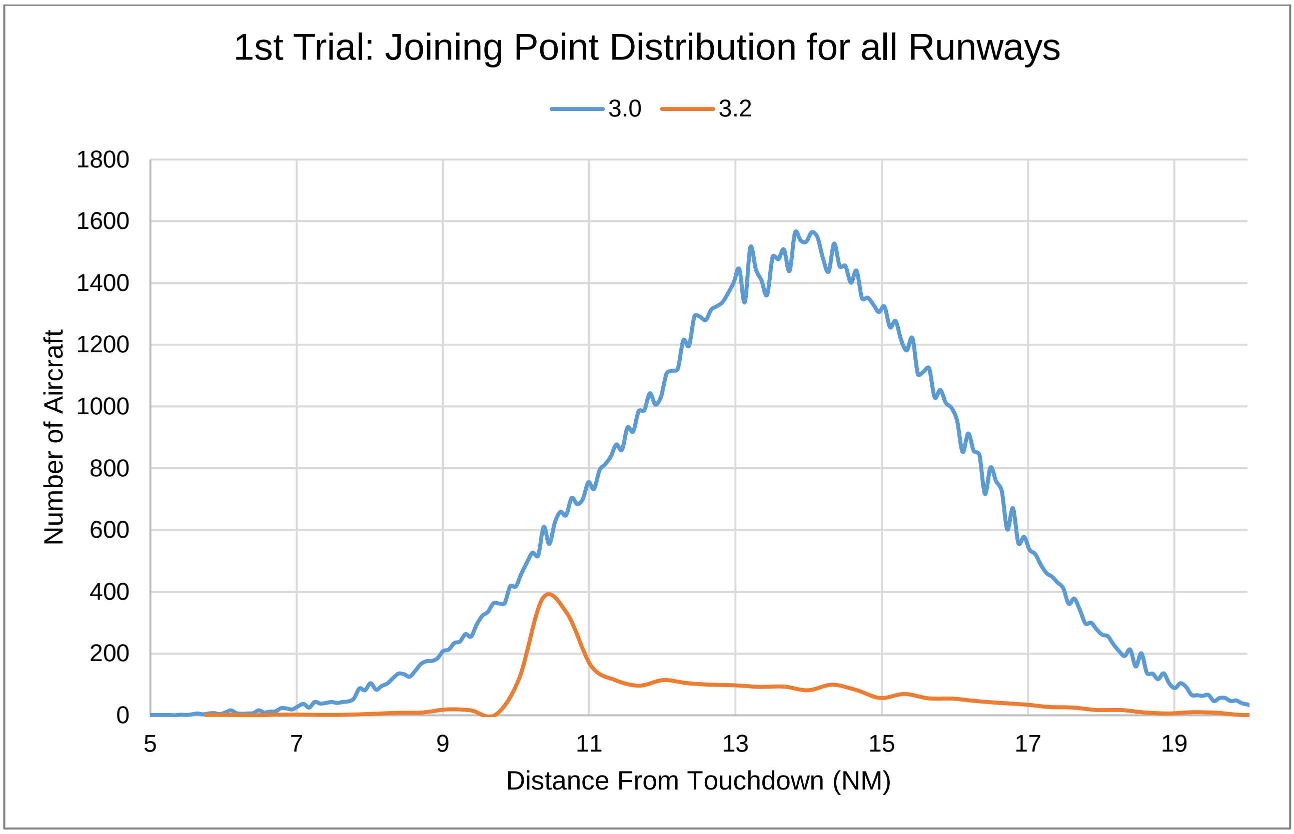


Figure 27.1: Final approach joining point distribution. All runways, all types.

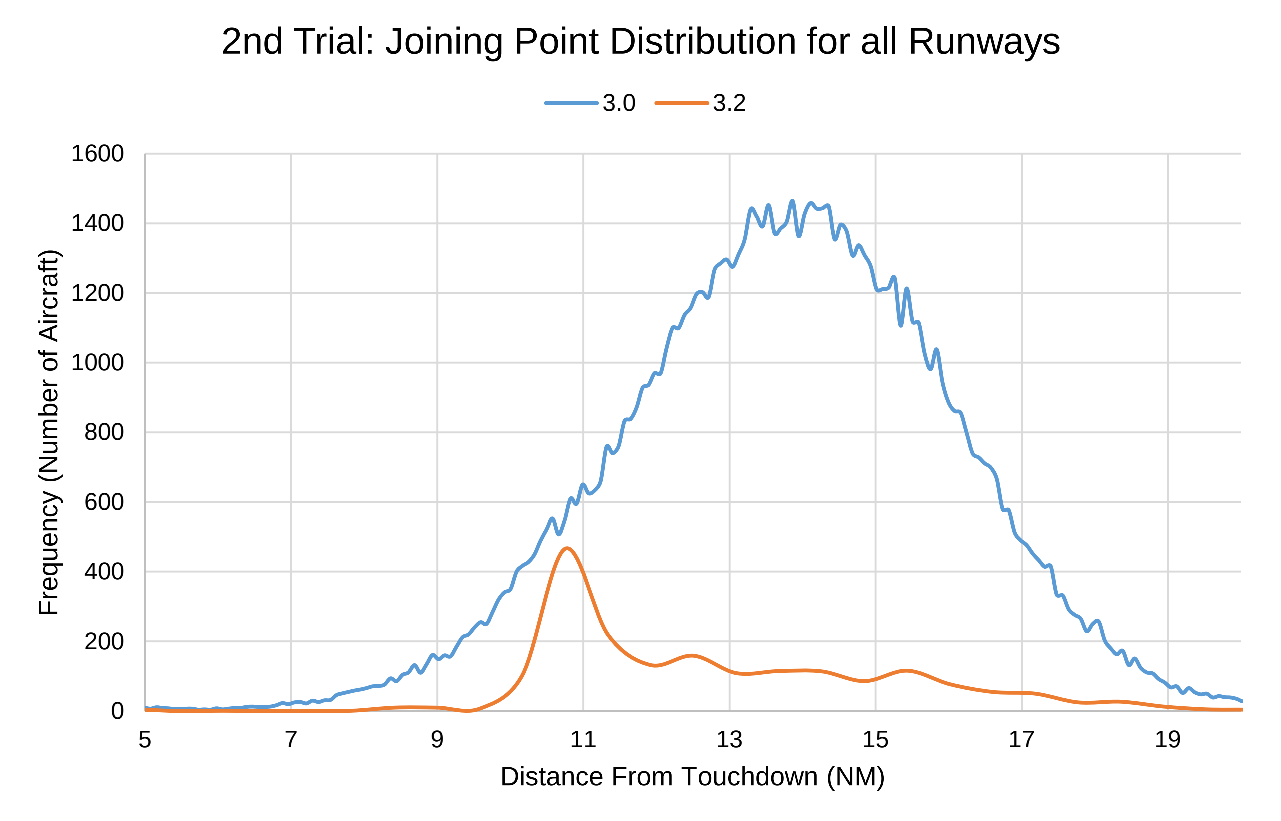


Figure 27.2: 2nd Trial, Final approach joining point distribution. All runways, all types.

	1st Trial, Final Approach Joining Point Differential (closer to threshold)	2nd Trial, Final Approach Joining Point Differential (closer to threshold)
27L	1.26nm	1.32nm
27R	1.52nm	1.44nm
09L	1.09nm	0.85nm
09R	0.76nm	1.04nm

Table 11: Final Approach joining point differential.

Tracks of aircraft over the ground

85. Figures 28.1, 28.2, 29.1 & 29.2 show the tracks of the 3° ILS (red) and 3.2° RNAV (purple) arrivals, below 6000ft for both easterly and westerly configurations. The 3° ILS tracks are for 6 days of traffic only[13], compared to the 6-month dataset for the 3.2° RNAV arrivals.

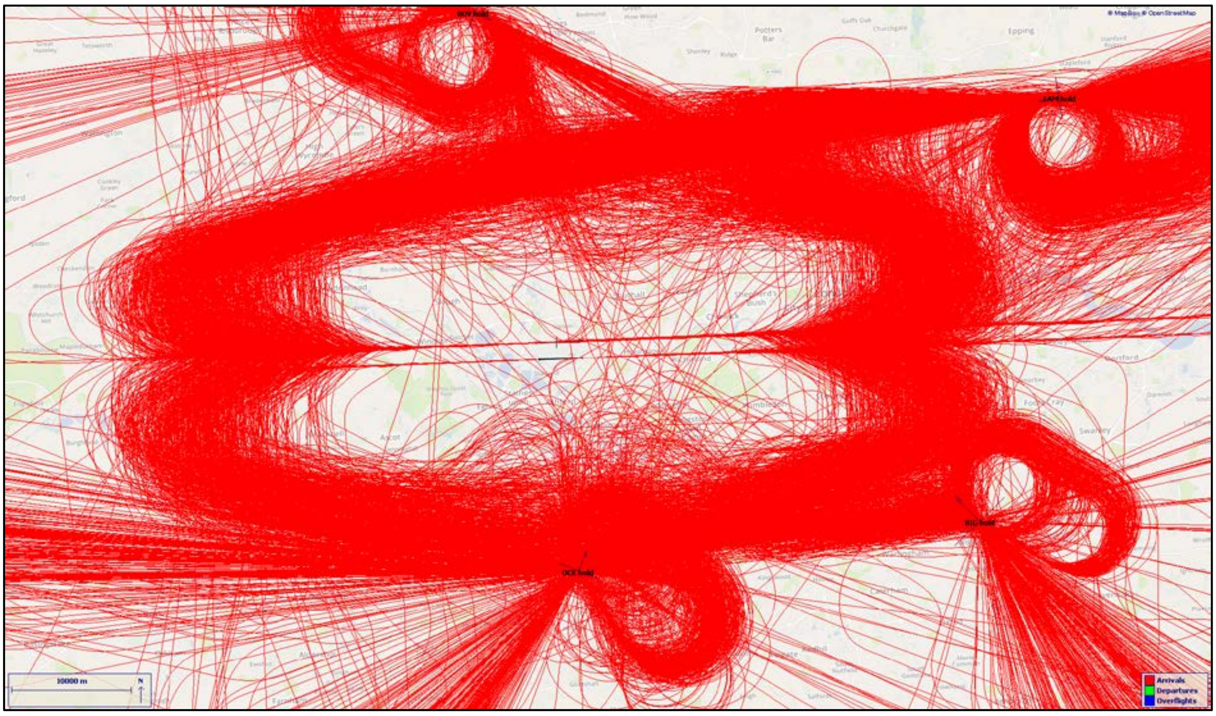
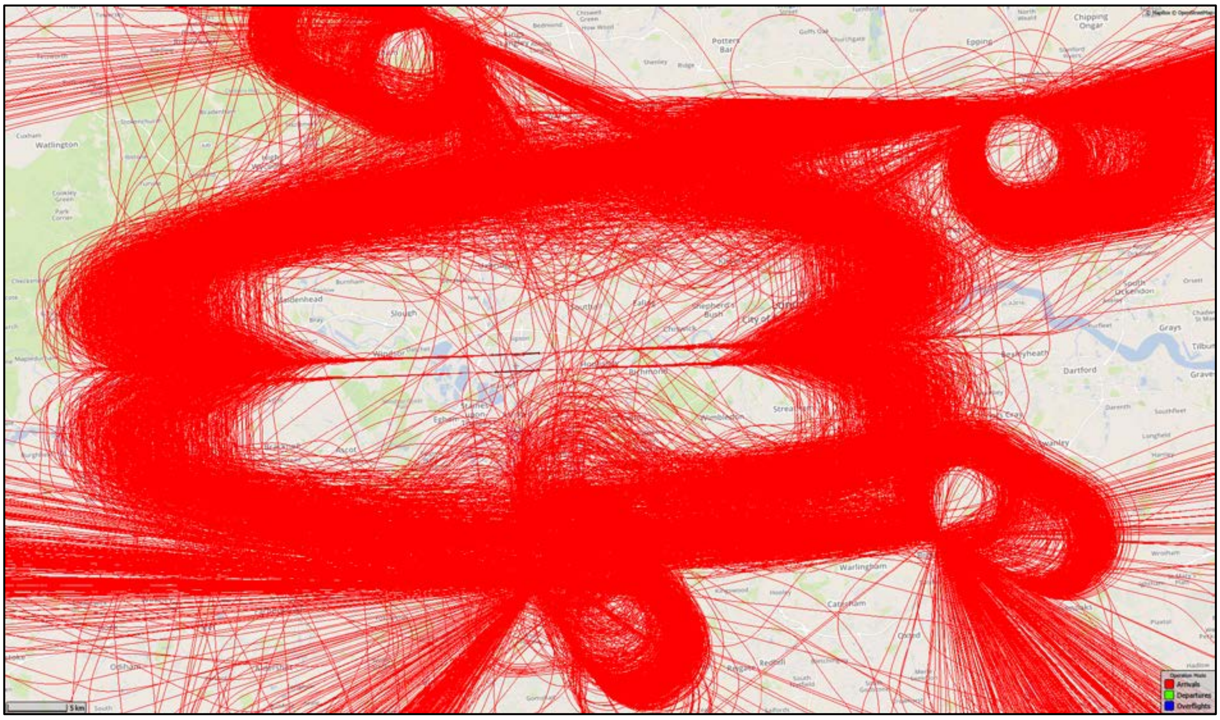


Figure 28.1: 1st Trial – Final approach arrival swathes 3° ILS arrivals only. 6-day sample.



[13] 6 days of ILS traffic provides a more balanced illustration in terms of comparing similar numbers of movements

Figure 28.2: 2nd Trial – Final approach arrival swathes 3° ILS arrivals only. 6-day sample.

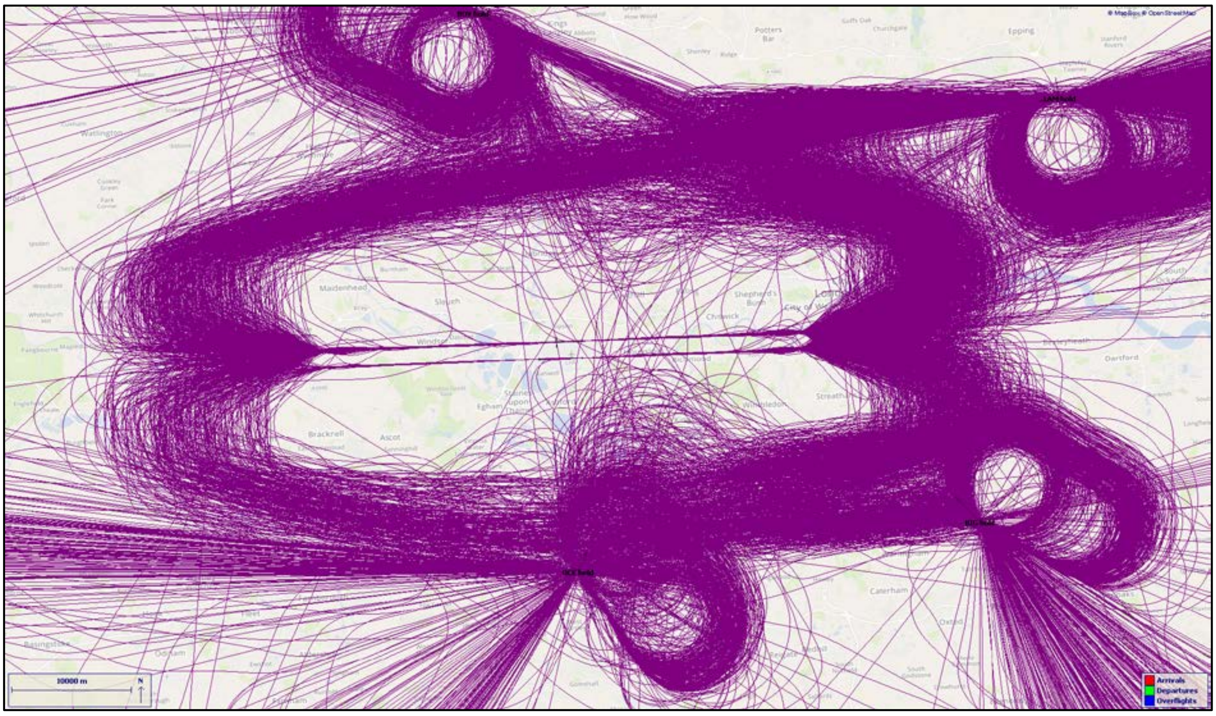


Figure 29.1: 1st Trial – Final approach arrival swathes 3.2° RNAV only. 6-month sample

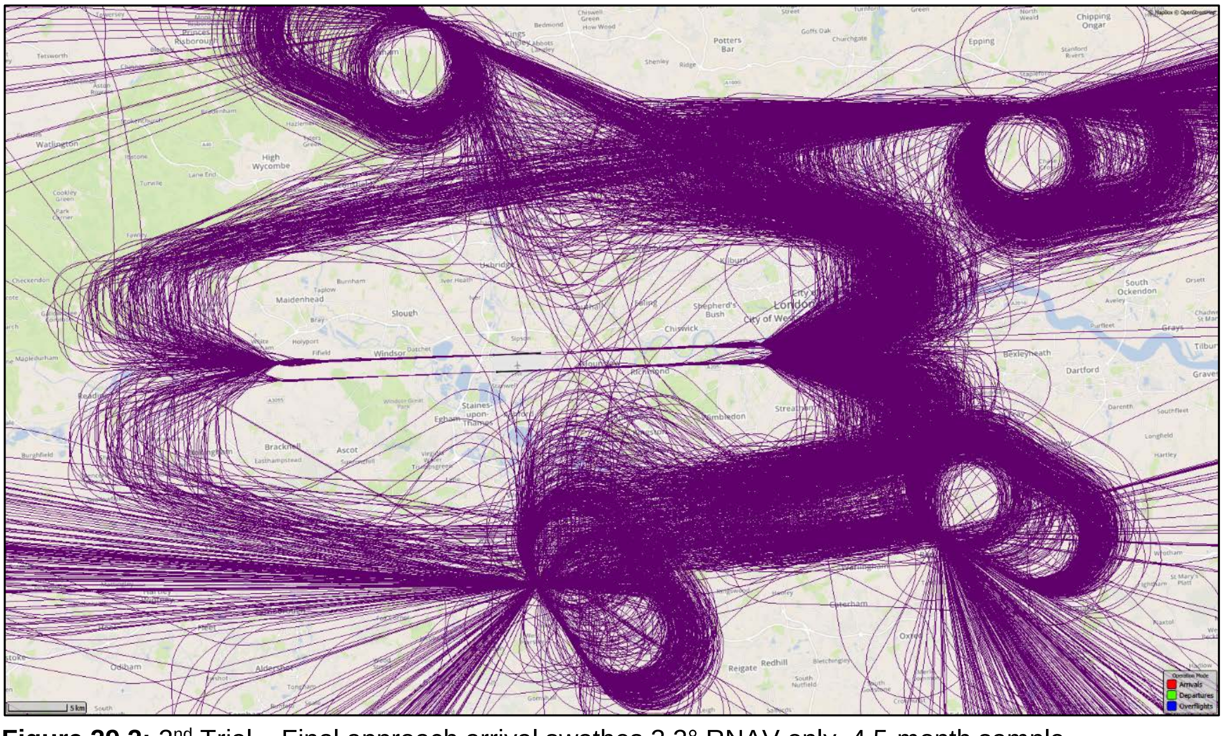


Figure 29.2: 2nd Trial – Final approach arrival swathes 3.2° RNAV only. 4.5-month sample

86. The variation in the arrival tracks is created by the vectoring of the aircraft by ATC until they are established on final approach; creating a broad 'swathe' of tracks over the ground.

87. Figure 30.1 & 30.2 shows all Heathrow arrivals for the trial periods with the darker swathe representing the 3.2° arrivals. It can be seen that the tracks of the darker 3.2° arrivals are fully encompassed within the 3° ILS arrival swathe.

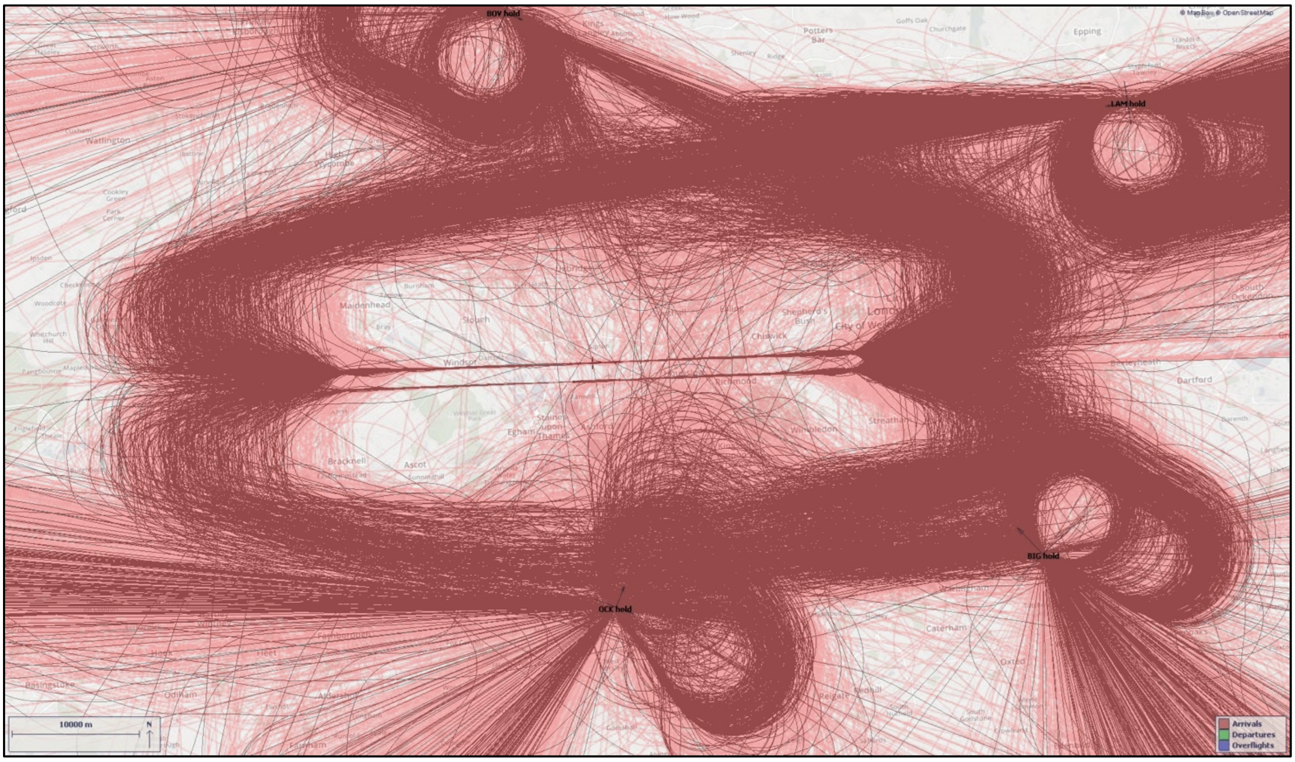


Figure 30.1: 1st Trial – Final approach arrival swathes ILS and RNAV combined

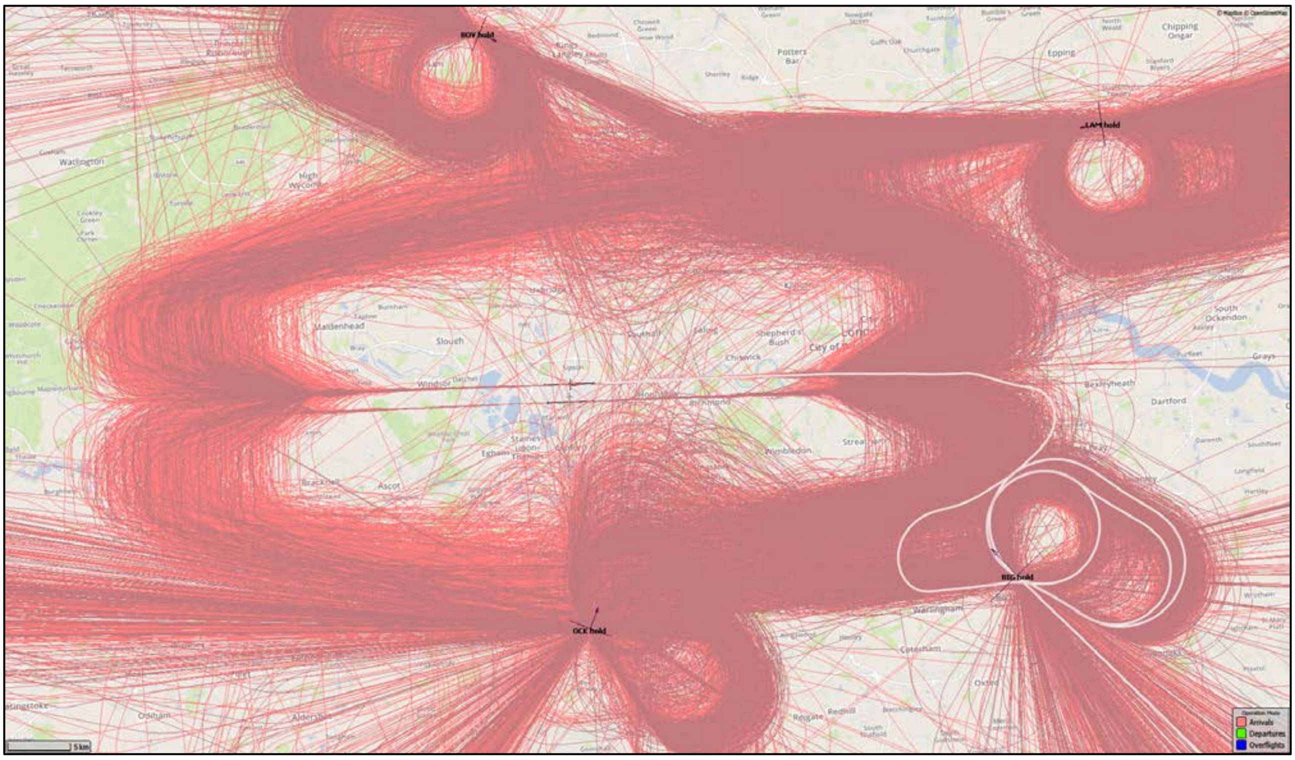


Figure 30.2: 2nd Trial – Final approach arrival swathes ILS and RNAV combined

88. There is no noticeable difference in tracks over the ground between the 3° and 3.2° arrivals or between the 1st and 2nd trial.

ATC feedback

89. After the 1st trial a workshop was held with representatives from Scandinavian Airlines, Heathrow Airport Limited (HAL) Heathrow ATC, LTC Heathrow Approach Controllers, NATS R&D, Eurocontrol and Airbus to share any operational issues from the ATC perspective which had not been raised during the trial or were not covered via the data captured.

90. The main issue from ATC was the integration of a higher number of RNAV approaches in with the ILS approaches, particularly during the 1st 2 months of the trial. ATC felt the issue was less to do with the slightly steeper approach angle but more the issue of RNAV approaches and their integration with the ILS approaches.

91. There was no ATC feedback received during the 2nd trial, indicating that no issues were encountered.

Safety Observations

92. During the 1st trial there was one instance where an aircraft on a 3.2° RNAV approach reported a vortex wake encounter whilst following an aircraft on a 3° ILS approach. ATC felt this was unlikely to be due to the trial.

93. There was one report of an aircraft following an 3.2° RNAV approach which was cleared to route to the Initial Fix via a left turn, but the aircraft turned right. The pilot at the time said this was crew error and was therefore not linked to the 3.2° approach. It is however, potentially another highlight of the extra workload associated with RNAV approaches, both in the cockpit and by ATC and is therefore included here for completeness.

94. No safety observations were submitted relating to the 2nd Slightly Steeper Approach trial.

General airline feedback

95. Heathrow's 3.2° approaches did not require a change to pilot behaviour. The stabilisation of the aircraft, landing gear deployment, energy management and the flare[14] prior to touchdown were not affected. However, all the crews agreed that an approach angle above 3.2° could start to create issues.

96. Airline representatives had no other issues with 3.2° RNAV approaches at Heathrow but all agreed that a standardised Heathrow approach angle would be the preferred option.

97. When discussing the potential next steps, it was highlighted that whilst most aircraft can perform an ILS CAT III autoland with approach angles of up to 3.25° there are still aircraft in operation at Heathrow, including the older A320, which are limited to 3.15°. This is an important consideration for Heathrow if they were to consider an introduction of 3.2° ILS Approaches. In addition, there are global design criteria which currently limit CAT II/III approaches to a maximum of 3.0°.

[14] The flare follows the final approach phase and precedes the touchdown and roll-out phases of landing. In the flare, the nose of the plane is raised, slowing the descent rate, and the proper attitude is set for touchdown.

Noise Measurements

98. Noise measurements were taken from the specific monitoring terminals (RMT129 at Mogden Sewage Works, 130 at Mid Surrey Golf Course and 131 at Roehampton Golf Club. See Figure 31) along the arrival route on runway 27L.

Figure 31: RMT Locations under 27L Final Approach

99. The metric used for analysis and comparison is the logarithmic average Sound Exposure Level, SEL (dBA), measured per aircraft type, for each navigational method (ILS and RNAV) and at each monitoring terminal. The minimum, maximum, standard deviation and size of sample were calculated to inform the level of confidence in the results generated from the noise data gathered.

Numerical Analysis of trial data

100. The additional altitude on a 3.2° approach means a greater noise propagation distance between the aircraft noise source and receptors on the ground. Consequently, for ideal trajectories under standard atmospheric conditions, there would be a constant noise reduction at every point directly beneath the approach path for the 3.2° slightly steeper approaches compared with standard 3° approaches.

101. Figures 32, 33 & 34, and associated tables, show the logarithmic average Sound Exposure Level (SEL) per aircraft type compared between 3° ILS arrivals and 3.2° RNAV arrivals for each noise monitor. They also show additional statistical parameters to assist in the interpretation of results. These parameters are the minimum and maximum SEL values, the standard deviation, and the number of noise events per aircraft type and noise monitor.

102. Since the analysis of the 1st trial noise data, additional versions of aircraft/engine ANCON types are evident.

103. Data from the noise monitors during the 2nd trial was analysed by Heathrow Airport and supplied to Trax for inclusion in this report.

RMT129 Mogden Sewage Works

ANCON Aircraft Type	ILS SEL (dBA)	RNAV SEL (dBA)	Noise change (dBA)
B744R (B747)	90.3	90.1	-0.2
B772G# (B777)	86.8	86.7	-0.2
B772R (B777)	87.8	87.5	-0.2
B787	86.0	85.9	-0.1
EA319V (A319)	83.0	82.9	-0.1
EA320C (A320)	84.7	84.3	-0.4
EA320V (A320)	83.6	83.3	-0.2
EA321V (A321)	83.9	83.7	-0.2
EA38R (A380)	88.8	88.2	-0.6

Figure 32.1: 1st Trial RMT129. Average reduction across all types -0.25dBA

ANCON Aircraft Type	ILS SEL (dBA)	RNAV SEL (dBA)	Noise change (dBA)
B744R (B747)	89.2	88.9	-0.3
B772G (B777)	86.4	86.1	-0.4
B772R (B777)	87.2	87.0	-0.2
B773G (B737)	87.9	87.4	-0.5
B788 (B787)	85.2	85.1	-0.1
B789 (B787)	85.7	85.4	-0.3
EA319C (A319)	83.5	83.2	-0.3
EA319V (A319)	82.5	82.1	-0.4
EA320C	84.0	83.4	-0.6
EA320NEO	82.8	82.8	0.0
EA320V	82.9	82.4	-0.5
EA321V	83.1	82.8	-0.3
EA38GP	86.7	86.6	-0.2
EA38R	88.0	87.5	-0.5

Figure 32.2: 2nd Trial RMT129. Average reduction across all types -0.32dBA

ANCON aircraft type	3° ILS				3.2° RNAV			
	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events
B744R	88.3	92.4	0.8	1,300	88.7	91.6	0.8	23
B772G	84.9	88.9	0.7	845	85.5	87.9	0.6	40
B772R	85.5	90.5	1.0	825	86.3	89.0	0.7	28
B787	84.0	87.8	0.8	1,306	84.7	86.9	0.5	42
EA319V	81.1	85.1	0.8	3,994	81.1	84.6	0.8	153
EA320C	82.3	87.4	1.1	3,015	81.6	85.8	1.0	38
EA320V	81.3	86.3	1.1	5,739	81.3	85.9	1.1	233
EA321V	81.4	86.9	1.2	2,049	81.9	86.5	1.2	43
EA38R	86.6	90.7	0.9	593	86.7	89.4	0.9	19

Table12.1: 1st Trial – RMT129 – Statistical analysis

ANCON aircraft type	3° ILS				3.2° RNAV			
	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events
B744R	87.20	89.70	0.41	829	87.80	89.70	0.53	37
B772G	84.10	89.40	0.76	909	84.80	87.60	0.71	31
B772R	82.10	89.70	0.95	962	84.80	88.70	0.95	18
B773G	84.80	89.70	0.85	2530	86.10	88.90	0.87	21
B788	81.70	89.60	0.81	1326	83.80	86.40	0.65	36
B789	82.50	88.80	0.73	1510	84.00	87.50	0.64	86
EA319C	81.30	89.30	1.04	1239	81.30	85.00	1.17	14
EA319V	81.30	87.20	0.66	4471	81.30	84.30	0.55	145
EA320C	81.30	89.40	0.92	3991	81.30	85.50	0.84	60
EA320NEO	81.30	84.90	0.62	156	81.60	83.90	0.78	11
EA320V	81.30	89.50	0.86	6805	81.30	85.00	0.74	162
EA321V	81.30	88.60	0.93	2233	81.30	85.70	1.05	59
EA38GP	84.40	89.70	0.89	714	84.90	88.90	0.97	34
EA38R	86.00	89.70	0.77	692	85.40	89.40	0.87	31

Table 12.2: 2nd Trial – RMT129 – Statistical analysis

RMT130 Mid Surrey Golf Course

ANCON Aircraft Type	ILS SEL (dBA)	RNAV SEL (dBA)	Noise change (dBA)
B744R (B747)	88.8	88.5	-0.2
B772G (B777)	85.3	84.9	-0.4
B772R (B777)	86.4	86.0	-0.5
B787	84.8	84.5	-0.2
EA319V (A319)	80.2	79.8	-0.4
EA320C (A320)	82.8	82.1	-0.7
EA320V (A320)	80.0	79.6	-0.4
EA321V (A321)	81.0	80.2	-0.8
EA38R (A380)	87.9	87.1	-0.8

Figure 33.1: 1st Trial RMT130. Average reduction across all types -0.49dBA

ANCON Aircraft Type	ILS SEL (dBA)	RNAV SEL (dBA)	Noise change (dBA)
B744R (B747)	87.7	87.4	-0.3
B772G (B777)	84.8	84.1	-0.7
B772R (B777)	85.8	84.6	-1.2
B773G (B737)	86.3	85.9	-0.5
B788 (B787)	84.0	83.7	-0.3
B789 (B787)	84.3	83.8	-0.5
EA319C (A319)	81.9	80.8	-1.1
EA319V (A319)	78.9	78.8	-0.1
EA320C	82.2	81.5	-0.7
EA320NEO	81.6	80.8	-0.8
EA320V	79.5	79.0	-0.5
EA321V	79.7	79.1	-0.6
EA38GP	85.8	85.6	-0.2
EA38R	87.1	86.7	-0.4

Figure 33.2: 2nd Trial RMT130. Average reduction across all types -0.55dBA

ANCON aircraft type	3° ILS				3.2° RNAV			
	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events
B744R	85.9	90.8	1.0	1,124	85.7	90.7	1.2	20
B772G	80.7	87.3	1.1	726	83.5	85.9	0.6	35
B772R	83.1	89.7	1.2	722	84.1	87.7	1.2	24
B787	80.6	86.9	1.0	1,159	81.4	85.9	0.9	38
EA319V	77.6	83.4	1.3	3,429	77.8	82.6	1.2	131
EA320C	79.2	85.6	1.4	2,558	78.8	84.1	1.5	36
EA320V	77.4	83.7	1.3	4,945	77.4	82.4	1.1	208
EA321V	77.9	84.7	1.7	1,733	78.0	83.1	1.3	35
EA38R	85.4	89.7	0.9	511	85.5	88.6	0.9	17

Table 13.1: 1st Trial – RMT130 – Statistical analysis

ANCON aircraft type	3° ILS				3.2° RNAV			
	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events	SEL_{min} (dBA)	SEL_{max} (dBA)	StDev	Number of Events
B744R	79.50	88.60	1.15	1025	86.30	88.60	0.58	39
B772G	76.80	88.50	1.39	904	82.70	86.20	0.88	30
B772R	78.20	88.60	1.43	901	78.80	86.40	1.65	18
B773G	76.90	88.60	1.65	2399	81.60	88.40	1.55	21
B788	77.00	88.60	1.32	1305	82.00	86.00	0.81	36
B789	76.80	88.50	1.31	1492	81.30	87.00	0.85	83
EA319C	76.70	87.20	1.79	1240	78.10	83.40	1.54	14
EA319V	76.70	88.60	1.38	4525	76.70	84.70	1.42	150
EA320C	76.70	87.70	1.64	3928	78.20	84.10	1.31	59
EA320NEO	77.10	85.10	1.25	157	78.00	82.40	1.63	11
EA320V	76.70	88.30	1.74	6600	76.70	84.70	1.58	170
EA321V	76.70	88.60	1.76	2189	76.80	82.70	1.46	54
EA38GP	77.60	88.50	1.27	706	83.40	87.20	0.93	34
EA38R	76.80	88.60	1.21	691	85.00	87.50	0.57	31

Table 13.2: 2nd Trial – RMT130 – Statistical analysis

RMT131 Roehampton Golf Club

ANCON Aircraft Type	ILS SEL (dBA)	RNAV SEL (dBA)	Noise change (dBA)
B744R (B747)	82.6	82.7	+0.1
B772G (B777)	78.0	77.3	-0.8
B772R (B777)	79.7	78.4	-1.4
B787	79.8	78.4	-1.3
EA319V (A319)	77.3	77.4	+0.1
EA320C (A320)	78.5	77.4	-1.1
EA320V (A320)	77.1	76.6	-0.5
EA321V (A321)	76.9	76.2	-0.8
EA38R (A380)	83.2	82.2	-1.0

Figure 34.1: 1st Trial RMT131. Average reduction across all types -0.74dBA

ANCON Aircraft Type	ILS SEL (dBA)	RNAV SEL (dBA)	Noise change (dBA)
B744R (B747)	82.0	81.3	-0.7
B772G (B777)	78.1	77.3	-0.8
B772R (B777)	79.5	78.7	-0.8
B773G (B737)	81.0	81.1	0.1
B788 (B787)	79.3	77.5	-1.9
B789 (B787)	79.6	79.2	-0.3
EA319C (A319)	78.0	76.9	-1.1
EA319V (A319)	75.4	75.2	-0.2
EA320C	77.8	77.5	-0.3
EA320NEO	76.0	74.7	-1.3
EA320V	75.7	75.3	-0.4
EA321V	75.7	75.1	-0.6
EA38GP	82.8	81.9	-0.9
EA38R	82.7	82.4	-0.3

Figure 34.2: 2nd Trial RMT131. Average reduction across all types -0.68dBA

ANCON aircraft type	3° ILS				3.2° RNAV			
	SEL$_{min}$ (dBA)	SEL$_{max}$ (dBA)	StDev	Number of Events	SEL$_{min}$ (dBA)	SEL$_{max}$ (dBA)	StDev	Number of Events
B744R	78.4	86.5	1.2	1,265	80.7	84.9	1.1	23
B772G	74.6	82.7	1.7	807	74.9	82.0	1.5	34
B772R	74.6	84.9	2.5	789	74.7	80.5	1.7	25
B787	74.4	83.4	2.3	1,290	75.2	83.9	2.0	40
EA319V	73.3	81.2	1.8	3,879	73.7	81.5	2.0	153
EA320C	75.0	82.1	1.6	2,953	73.7	79.7	1.5	38
EA320V	73.3	81.0	1.8	5,591	72.9	80.3	1.7	223
EA321V	73.6	80.7	1.5	2,001	73.6	78.5	1.0	40
EA38R	79.8	86.4	1.3	585	78.9	84.6	1.3	18

Table 14.1: 1st Trial RMT131 – Statistical analysis

ANCON aircraft type	3° ILS				3.2° RNAV			
	SEL$_{min}$ (dBA)	SEL$_{max}$ (dBA)	StDev	Number of Events	SEL$_{min}$ (dBA)	SEL$_{max}$ (dBA)	StDev	Number of Events
B744R	73.80	84.50	1.10	1231	79.30	83.80	0.99	38
B772G	72.80	84.40	2.08	781	73.90	80.40	1.75	26
B772R	72.80	84.50	2.56	829	75.60	81.80	1.92	16
B773G	72.90	84.50	2.56	2161	75.60	84.10	2.66	18
B788	72.90	84.50	2.41	1158	73.90	81.00	1.80	33
B789	72.90	84.00	2.22	1303	74.20	84.00	2.15	74
EA319C	72.80	84.40	1.84	1176	74.60	79.30	1.49	13
EA319V	72.80	84.20	1.48	4202	72.80	82.10	1.59	132
EA320C	72.80	84.10	1.70	3679	74.00	80.80	1.60	56
EA320NEO	72.90	84.40	1.71	146	72.90	77.20	1.26	10
EA320V	72.80	84.10	1.70	6144	72.80	81.20	1.67	152
EA321V	72.80	83.90	1.56	2037	72.80	78.00	1.36	51
EA38GP	73.50	84.50	1.37	569	79.10	84.00	1.62	30
EA38R	73.40	84.50	1.26	592	79.90	84.30	1.08	24

Table 14.2: 2nd Trial RMT131 – Statistical analysis

Analysis of trial data

104. The results in Figures 32, 33 & 34, and associated tables, suggest that, in the majority of cases and across both trials, 3.2° approaches do indeed provide noise reductions compared to 3° approaches. However, despite the theoretical analysis, these reductions are not constant at each of the monitoring points considered in this study. Instead, noise attenuation appears to be greater at receptors further away from the airport.

105. Across both trials, the SELs reductions vary between:

	RMT129	RMT130	RMT131
1st Trial	-0.1 dBA and -0.6 dBA	-0.2 dBA and -0.8 dBA	+0.1dBA and -1.4 dBA
2nd Trial	-0.1 dBA and -0.6 dBA	-0.1 dBA and -1.2 dBA	+0.1 dBA and -1.9 dBA

Table 15: SEL Variation by RMT

106. Across both trials, the average SELs reductions across all aircraft types are:

	RMT129	RMT130	RMT131
1st Trial	-0.25 dBA	-0.49 dBA	-0.74 dBA
2nd Trial	-0.32 dBA	-0.55 dBA	-0.68 dBA

Table 16: Average SEL Variation by RMT

107. Whilst there was an improved height benefit experienced during the 2nd trial, the data recorded on the noise monitors showed average SEL noise reductions of c. 0.5 dBA for both trials across all aircraft types performing 3.2° RNAV Approaches. It should be noted that, as per the 1st trial, noise data was only collected for arrivals for 27L.

Community Feedback during the trial

108. During the 1st trial, Heathrow received 50,274 pieces of feedback made by 2,718 people. Of these, there were only 29 (0.06%) comments, queries and complaints received from approximately 23 people in respect of the 3.2° slightly steeper approach trial.

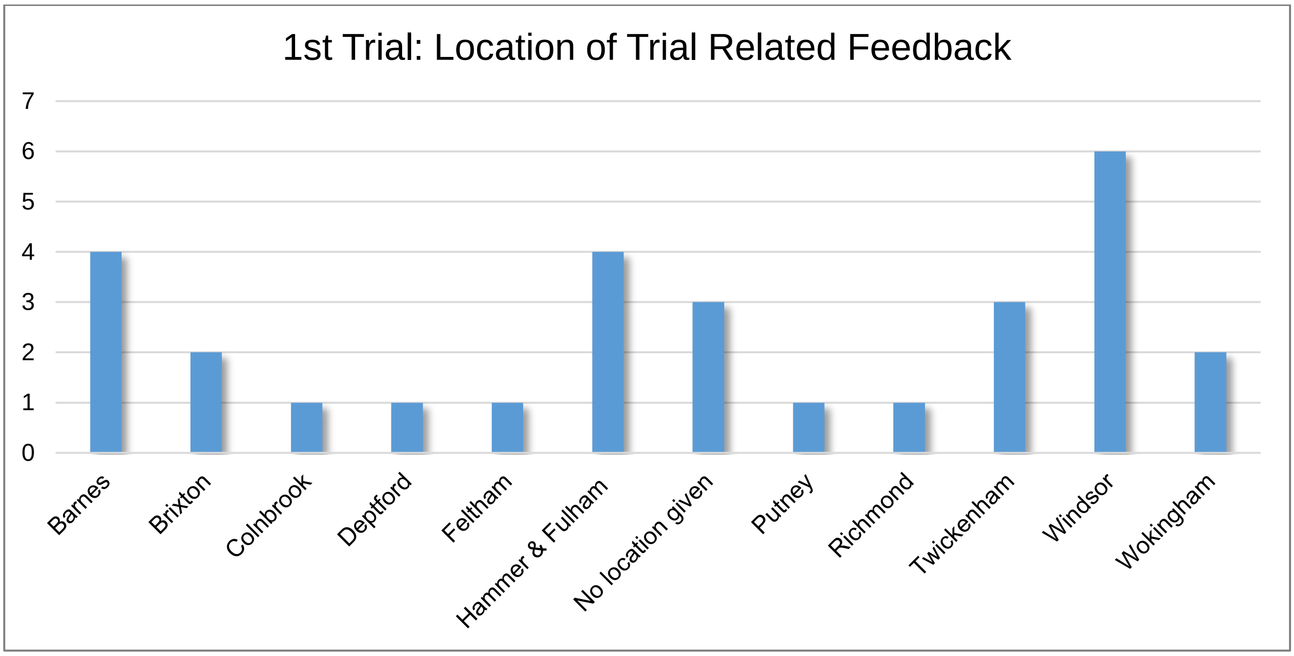


Figure 35.1: 1st Trial Feedback by location.

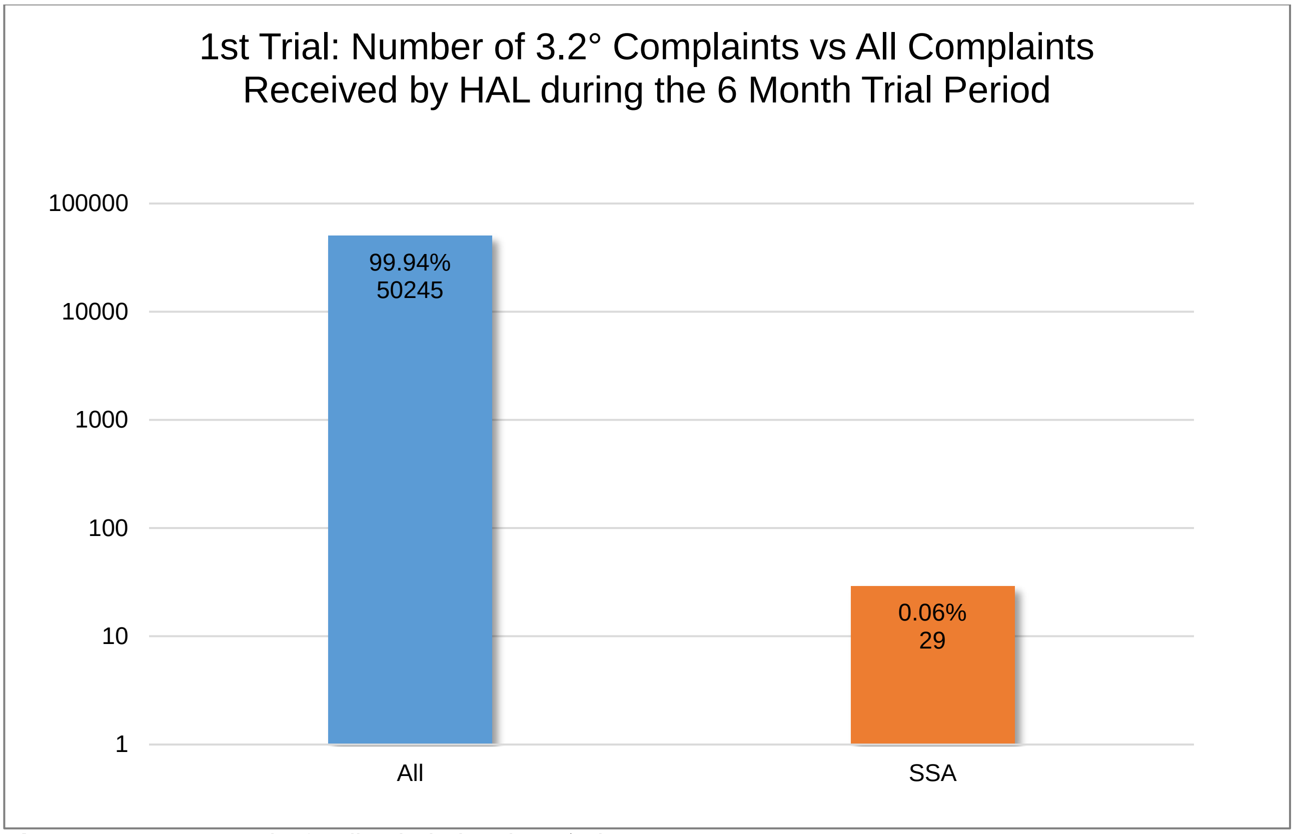


Figure 36.1: Community feedback during the 1st trial.

109. During the 2nd trial, Heathrow received 32,050 pieces of feedback, made by 1,693 people. Of these, only 9 (0.03%) were related to the 2nd slightly steeper approach trial.

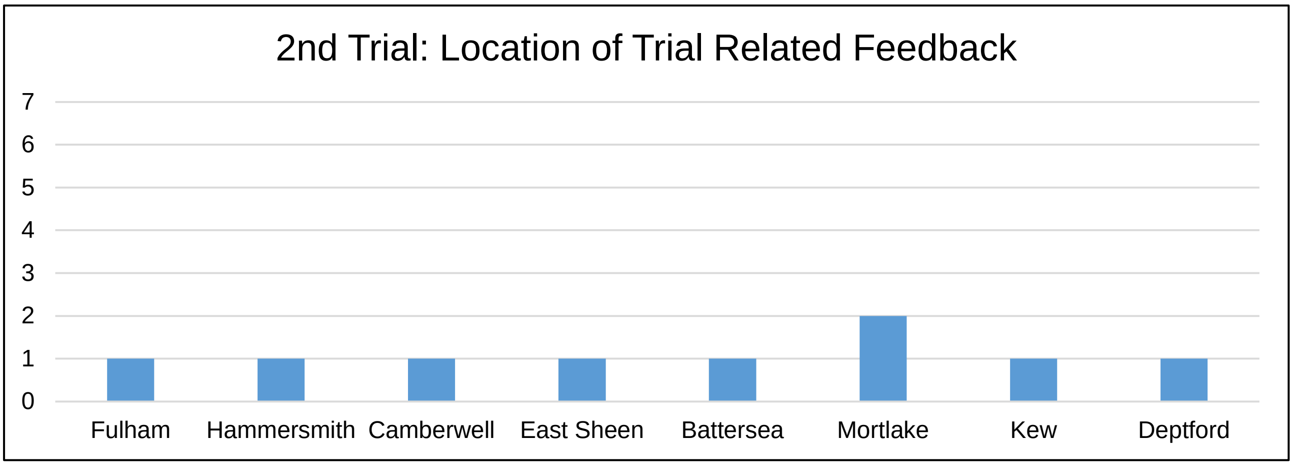


Figure 35.2: 2nd Trial Feedback by location.

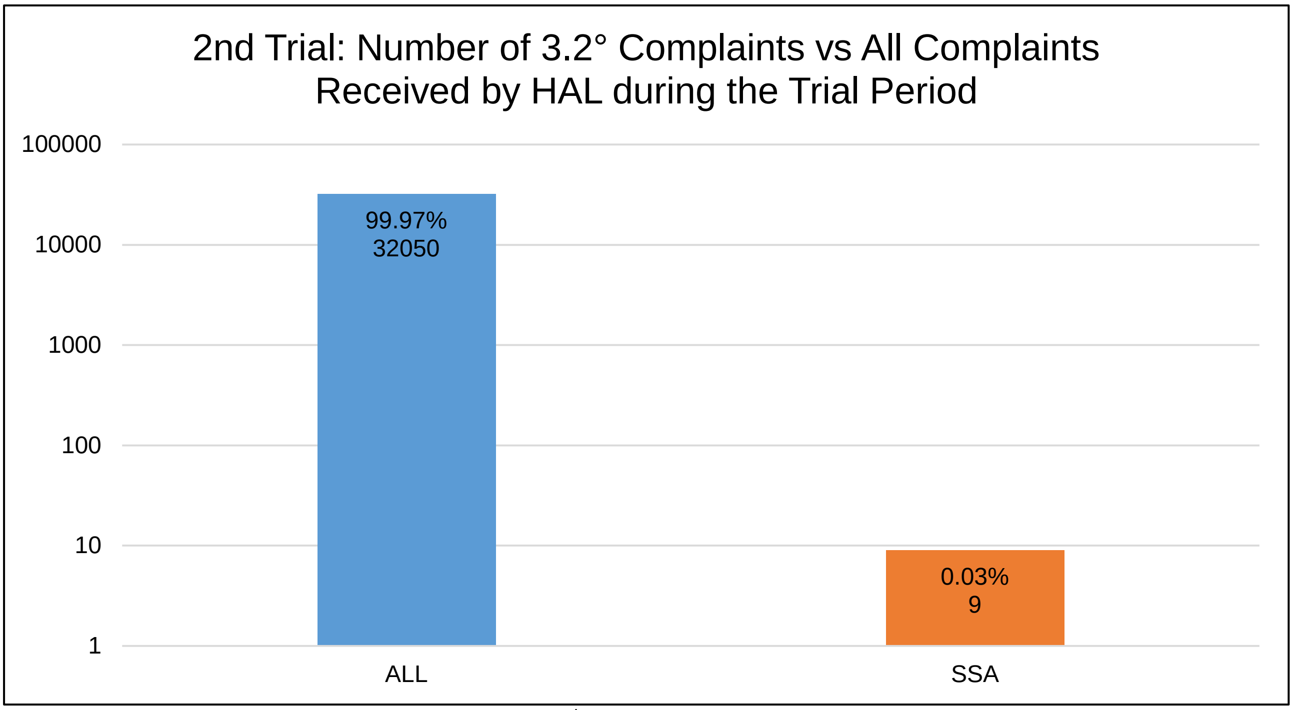


Figure 36.2: Community feedback during the 2nd trial.

Unintended Consequences

110. There did not appear to be any unintended consequences as a result of the 3.2° slightly steeper approaches however, a marked increase in the numbers of RNAV approaches would have a direct impact on ATC workload (1st trial finding).

Trial conclusions and next steps

111. Heathrow declared that a successful outcome from the trials would be to have gathered sufficient data with no adverse impact to safety or operational performance. Specifically, Heathrow set out to measure the impact of a slightly steeper approach on CDA performance, speed adherence on final approach, landing rates, runway occupancy time, numbers of go-arounds, landing gear deployment, aircraft tracks over the ground and to quantify the re-distribution of noise associated with the slightly steeper approach.

112. The 2nd trial established that the warmer temperatures did not have any adverse operational or environmental impact. The improved vertical benefit gained during the warmer 2nd trial did not translate into a measurable increased average noise benefit compared to the 1st trial. However, noise data was only collected for arrivals to 27L.

113. With this in mind, the trial met all objectives with no adverse impact on the daily operation. It is evident that 3.2° approaches would have no negative effect on Heathrow's operation, does not change the track of Heathrow arrivals over the ground and local residents would be exposed to less aircraft noise.

Objective		1st Trial Outcome	2nd Trial Outcome
CDA		3.2º compliance of 85.7% versus 85.9% overall compliance	3.2º CDA compliance of 86.5% versus 88.7% overall compliance
TBS		No detrimental impact	No detrimental impact
RoT		No detrimental impact	No detrimental impact
Go-around		No detrimental impact (3 out of 351 were on a 3.2º approach)	No detrimental impact (5 out of 237 were on a 3.2º approach)
Speed		Slightly improved speed adherence on final approach	Slightly improved speed adherence on final approach
Joining point		1.27nm closer to threshold (due to RNAV, not the 3.2º approach angle)	1.2nm closer to threshold (due to RNAV, not the 3.2º approach angle)
Landing Gear		Medium jets: Same but higher / Heavies: Later similar height	Medium jets: Same but higher / Heavies: Later similar height
Landing Rate		No impact	No impact
Height		Low temperature reduced average angle to 3.14º but height benefit as expected	Average angle 3.24º saw improved height benefit
Community		29 out of 50,274 comments, queries and complaints related to trial	9 out of 32,050 comments, queries and complaints related to trial
Airline		No issues with 3.2º approach angle	No issues with 3.2º approach angle
ATC		No detrimental impact due to 3.2º approach	No detrimental impact due to 3.2º approach
Environment		Min: +0.1dBA / Average: -0.5dBA / Max: -1.4dBA (SEL)	Min: +0.1dBA / Average: -0.5dBA / Max: -1.9dBA (SEL)

Table 17: Trial Objective Summary Table

114. The noise analysis and modelling confirms that 3.2° approaches do provide a small noise benefit to local communities. It should be noted that the magnitude of that average benefit is small (c.-0.5dBA) and unlikely to be perceptible on the ground[15]. However, 3.2° approaches would actively progress a reduction in Heathrow's noise footprint and could be seen as a necessary incremental step towards even steeper approaches or a standardised 3.2° approach for all of Heathrow's arrivals in the future.

115. Heathrow have commenced the Airspace Change Process to retain their 3.2° RNAV approaches as a permanent feature.

[15] A reduction in the order of 3 dBA is widely considered to be required in order to be 'just perceptible'. See CAP1378 Page 99 and Planning Policy Guidance 24 (Glossary)

Appendix A: Technical Glossary

ACP	Airspace Change Proposal
AIP	Aeronautical Information Publication
ANCON	Aircraft Noise Contour model
ANOMS	Airport Noise Monitoring and Management System
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
Baro-VNAV	Barometric Vertical Navigation
CAA	Civil Aviation Authority
CAVOK	Cloud and Visibility OK
CDA	Continuous Decent Arrival
dB	Decibel
dBA	A-weighted decibel units
DfT	Department for Transport
ERCD	Environmental Research and Consultancy Department
FAS	Future Airspace Strategy
HAL	Heathrow Airport Limited
HCNF	Heathrow Community Noise Forum
ICAO	International Civil Aviation Organization
IF	Initial Fix
ILS	Instrument Landing System
ISA	International Standard Atmosphere
Kts	Knots
LEQ	Equivalent Sound Level
LHR	London Heathrow
LTC	London Terminal Control
NM	Nautical Mile
PBN	Performance-based Navigation
R&D	Research and Development
RMT	Remote Monitoring Terminal
RNAV	Area Navigation
RoT	Runway Occupancy Time
RVR	Runway Visual Range
SEL	Sound Exposure Level
SESAR	Single European Sky ATM Research
SOP	Standard Operating Procedure
STAR	Standard Terminal Arrival Route
TBS	Time Based Spacing