



Aircraft Approach Noise Trials

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ABSTRACT

This article presents the results from a series of aircraft approach trials that were conducted with the aim to investigate noise reduction procedures within the boundaries of a normal ILS approach. The significant decline in air traffic at Stockholm Arlanda, that occurred during the pandemic meant that the empty airspace and the availability of grounded aircrafts could be utilized to perform controlled flights - something that would have been difficult to achieve during normal traffic conditions. The approach trials were performed by two Airbus A321, which alternately carried out interrupted landing procedures starting 17 nautical miles (nm) from the runway threshold. During the trials, the aircraft speed and configuration (high lift devices and landing gear) were varied according to a predetermined schedule. To capture these variations, flight data (FDR) were recorded while the noise on ground was measured at positions approximately once every nautical mile along the flight track. Results suggest that speed and configuration recommendations can be effective to reduce noise, especially for the final 7 nautical miles of the flight track. However, whether a low speed is to be advocated during the entire approach is currently unclear.

1. INTRODUCTION

During the pandemic, many of the restrictions that were imposed reduced the mobility of people. This change affected life in many aspects, both good and bad. One of the more positive consequences were lower environmental noise levels, for example reduced road traffic noise in cities [1]. Of the various transport modes, air traffic was perhaps to an even larger extent affected by the restrictions and in Sweden, traffic decreased by 70% to its former levels. As devastating this may have been for aviation and businesses, this sudden change must certainly have been experienced as a relief by many people, especially those living near airports, as noise levels dropped drastically. In addition to provide temporal relief in form of lowered noise levels, this respite also offered opportunities that would be difficult to find under pre-pandemic circumstances. One such opportunity, provided by the empty airspace and the availability of stranded aircraft and crews, was to conduct noise test flights. These types of flights are rare and very valuable because they provide high quality data. Data that can be used to improve source models and noise estimation methods. Such tools that will in come in handy when noise mitigate procedures have to be developed for the current and future aircraft fleets.

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As society recovers from the suites of the pandemic, air traffic is resuming and is likely to converge with pre-pandemic forecasts. Before the pandemic approximately 1.2 million people in Europe were exposed to aviation noise levels above 55 Lden [2]. With a 40% predicted increase in traffic intensity by 2040 [3], this figure is likely to increase. Moreover, this scenario stands in contrast to the WHO environmental noise guidelines from 2018 [4] as recommendations advocate greatly reduced noise levels, up to 10 dB lower than guideline values used in many European countries today, including Sweden [5]. Although great efforts have been made to build quieter aircrafts and develop approach procedures to reduce noise [6], aircraft noise remains an environmental problem and needs to be further addressed.

The result in this article is part of a measurement project performed under the auspices of Center for Sustainable Aviation (CSA), at KTH. During one April morning in 2021, sixteen interrupted landing procedures were conducted with the standard aircraft type Airbus A321. The purpose with these flights was to create a database where noise levels, frequency content and sound direction dependence (directivity) can be described regarding the aircraft's speed through the air, use of leading edge and/or trailing edge flaps and landing gear. The results in this article describe the partial results on how the noise on ground, directly under the flight path, is affected by the; aircraft speed, approach height, and landing gear deployment.

2. Method

2.1. Flight schedule

The test flights were conducted with two Airbus A321-neo operated by Novair airlines. These were each powered by the same engine type high-pass turbofan jet engine the CFM Leap-1A. The interrupted approach procedures were flown as straight approaches starting 17 nautical miles (nm) from the runway threshold. Each approach was flown with either a different speed, approach altitude or configurational setting. The variation of these flight parameters was chosen to represent the natural variations of a normal ILS-approach, regarding maximum and minimum allowed speeds, approach altitude, and configurational setting. The speed profile was determined by the initial speed at 17 nm and was either 230, 220, 210 or 200 knots (kn). Throughout the approach, this speed difference was kept constant, so that there always was a 10 kn difference between the speed profiles. The approach altitude was either 2500 and 4000 feet (ft) to mimic the difference of ILS height for runway 26 and 01R and L at Arlanda airport. The variation of configurational settings was mainly governed by at what distance the landing gears were deployed. Two distances were selected, 5.2 and 6.2 nm, to be representative of a late and early deployment phase. In total 16 interrupted approaches were conducted, which equates to 4 flights for each speed, and 8 flights for the two different approach heights and landing gear positions.

2.2. Measurement locations

A total of 31 microphones were used to capture the noise from the approaching aircrafts. Most of these microphones were placed directly under the flight path, approximately with 1 nm spacing. Each measurement position was carefully selected to offer the most continuous measurement of the aircraft's different configurational stages without too much recording of "transition" between configurations. Care was also taken to find positions with low background noise levels and avoid proximity to busy roads or agricultural activity. Beside the positions directly under the flight path, three "legs" of microphones were positioned lateral to the ground track. These legs consisted of 3-4 microphones each and were positioned at the beginning (15 nm), midsection (6 nm) and end (1.6 nm) of the flight



path. Each of these “legs” extended an equivalent distance (depending on flyover height) to cover lateral overflight angles up to 60 degrees.

2.3. Data acquisition system

The noise gathering system consisted of an omni-directional 6 mm electret-condenser microphone with integrated soundcard connected to a Raspberry Pi single board computer powered by a 12V battery. The recorded noise was logged as 1/3-octave levels using a Real Time Analyzer with 125 ms update frequency. For precise synchronization of measurements each system was equipped with a real time clock (RTC). To mitigate wind-induced noise, each microphone was equipped with a Rycote windscreen. Predominantly higher frequencies will be attenuated by the windshield but as the characteristic’s aircraft noise is dominated by frequencies up to 5 kHz, due to the source characteristics and atmospheric attenuation, the disturbance of the windshield is considered negligible. Each microphone was calibrated before, and after the measurements were completed.

Data for position, altitude, speed, and other valuable parameters describing the aircraft's configuration, were gathered from the aircraft’s Flight Data Recorders (FDR). The sample time for FDR-data is 1 sample/second and over 30 different parameters were recorded in addition to the above mentioned. Among these, are data for thrust settings and fuel consumption, allowing analysis of environmental impact of the different approach trails.

3. RESULTS

One of the main questions for this project was to investigate the effects of various flight parameters. Previous studies and observations indicate that the aircraft's speed and configuration are decisive parameters for the aircraft's noise generation [7]. To examine the impact of these parameters the results are therefore presented as averages over: speed, approach height and landing gear deployment distance. An analysis of the engine's impact on noise is not included as this relationship was proven weak for this type of aircraft during the landing procedure.

In examination of the FDR files and flight trajectories, it was concluded that all the 16 performed flights managed to fulfill the predetermined flight schedule. The FDR files delivered from Novair showed no sign of corruption or missing values.

3.1. Impact of Speed

Figure 1 (top) shows the effect of the different approach speeds on the sound level as a function of distance to runway. The curves represent mean values for the groups of four flights that flew with the same approach speed. Figure 1 (bottom) shows the corresponding average speeds of these groups. According to the flight schedule, see section 2.1, the initial speed was either; 230, 220, 210, or 200 kn. Judging by results (bottom), this criterion seems to have been met. Furthermore, we can see that the 10 kn separation is close to constant along the entire flight route, which is an indication of the pilots' ability to fly according to instructions. The effect of the different approach speeds on the noise level is strong, especially for positions within 10 nm from the runway threshold. Within this distance, the separation between the highest and lowest speeds is significant and amount to approximately 3 dB. On average this implies that the noise level increases by about 1 dB per 10 kn. However, this separation is not so evident for the intermediate speeds. It is only at positions within distances 1-5 nm that this separation can be discerned. Outside 5 nm, the uncertainty increases. At distances beyond 10 nm there is no clear separation between any of the groups.

To some extent this result is expected since there are three factors that come into play as the source-to-receiver distance increases. The first, and maybe the most significant, is the composition of the

flight schedule that contains some essential differences within some of the speed-groups. These differences which mainly concern the configuration are less distinctive past the glide slope intercept at 7.3 nm. The second factor concerns the speed dependence for the aircraft noise generation, which increases with a higher configuration as drag increases. The speed relationship should therefore become stronger as the aircraft approaches the runway and uses a higher configuration. The third factor concerns the influence of external variables and adds uncertainty to the measurements in the form of atmospheric attenuation and refraction, which becomes stronger as the source-to-receiver distance increases. Nevertheless, the overall result shows a strong dependence between the aircraft's speed and its noise generation.

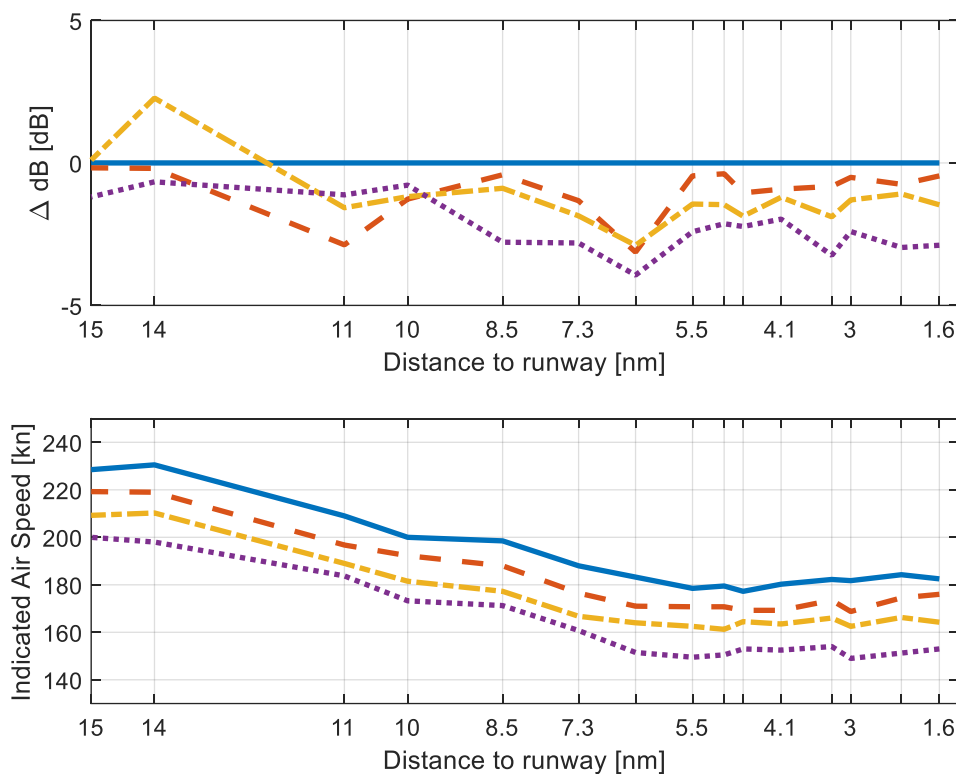


Figure 1: The top figure shows the difference between the mean normalized noise levels for the four approach speeds (bottom figure) as a function of distance to runway. Each curve is the average of four flights. Blue solid line: 230 kn, red dashed line: 220 kn, yellow dash-dotted line: 210 kn, purple dotted line: 200 kn.

3.2. Impact of Approach Height

Figure 2 (top) shows the differences in noise level for the two approach heights, 2500 and 4000 feet. As expected, the differences are significant between the two altitudes and amounts to about 5 dB, calculated as a mean value. This figure is very close to the theoretical value obtained for the propagation difference, if a spherical source and a homogeneous atmospheric attenuation (5.1 dB), is assumed. In addition to this more expected result, the approach height also appears to affect the noise level difference after the glide slope intercept at 7.2 nm. It would not be a hasty conclusion to assume that this elevated level is due an excess in kinetic energy resulting from a higher approach altitude,

with the consequent need to slow the aircraft down using a higher configuration or speed brake. This is also what partly occurs. If we look at the individual flight profiles (not shown) four of the flights from 4000 ft have an early deployment of the landing gears, starting at 7.3 nm. It is these flights that contribute to the overshoot at around 6 nm. However, if these two flights are removed the effect disappears and there is no longer a difference between the approach altitudes beyond the glide slope intercept. The two remaining flights do in fact have almost identical configuration profiles (neither not shown) but with different approach heights.

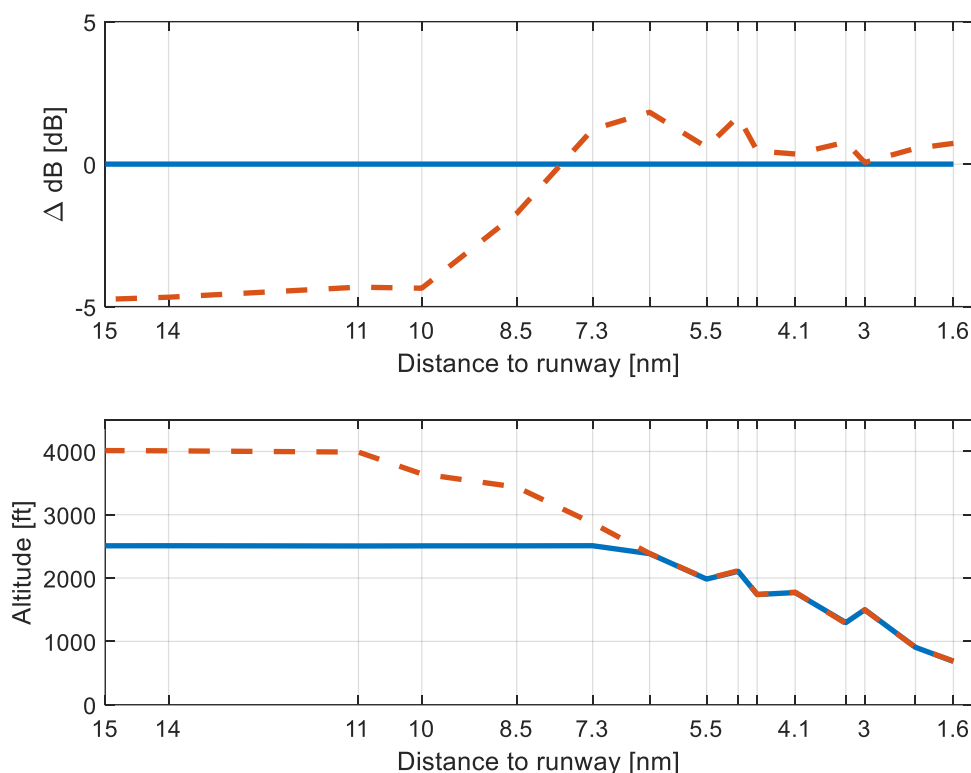


Figure 2: The top figure shows the mean noise levels for the two different approach altitudes (bottom figure) as a function of distance to runway. Blue solid line represents approach altitude 2500 ft and red dashed line represents 4000 ft. The bottom shows the corresponding mean approach altitude. Each curve is the average of eight flights. The noise levels are normalized (top figure).

3.3. Impact of Landing Gear

Figure 3 shows the mean difference in noise level for landing gear deployment at 5.2 nm in relation to deployment at 6.2 nm. As can be seen a delayed deployment of the landing gears is beneficial as it lowers the noise by approximately 2.5 dB in a limited section of the ground track. A figure which is in range with estimates of the landing gear deployment effect from similar types of aircrafts [8]. As with previous averaging the two means include flights with different speeds and approach heights, which means that each mean consists of eight flights. Therefore, a more nuanced picture of the landing gear impact can be provided if the flights are studied individually. If the averaging is performed partially (not shown) it is for example possible to see that the difference is about 3 dB for the two faster flights and just under 2 dB for the slower flights. However, weak the statistical basis is for such

comparison the results indicate that the overall noise generation is speed dependent, which corresponds with previous assumptions and observations [7].

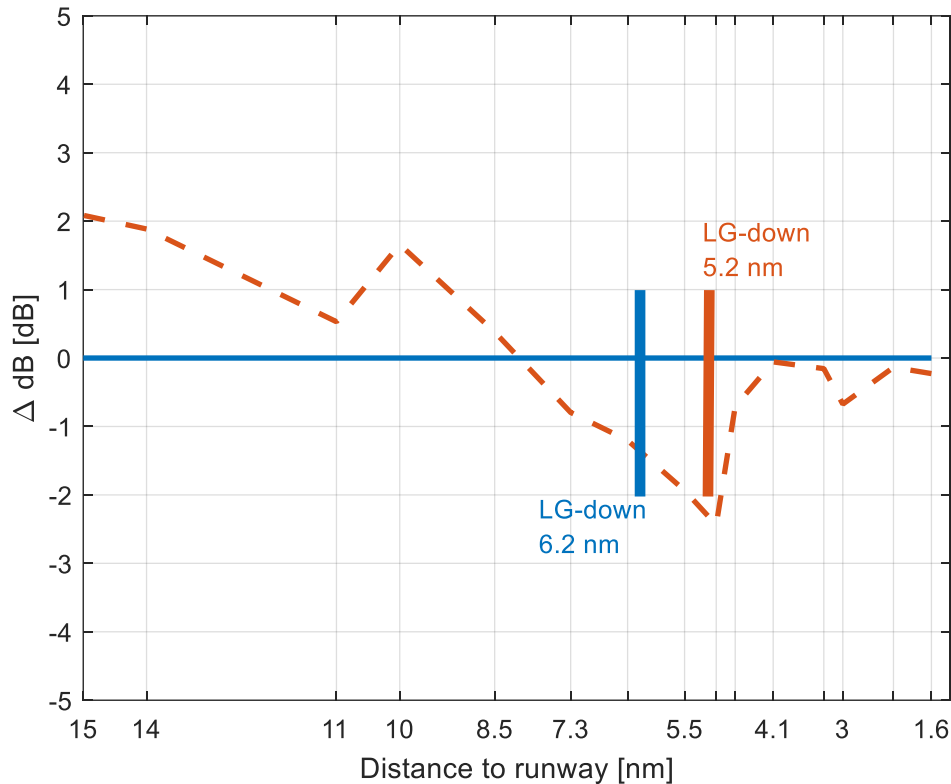


Figure 3: The figure shows the difference between mean normalized noise levels for the two landing gear deployment distances as a function of distance to runway. Blue solid line represents deployment at 6.2 nm and red dotted represent deployment at 5.2 nm. The thick vertical lines show the landing gear (LG) deployment position.

4. Discussion and Conclusions

The combination of noise measurements made along the 17 nm long approach path while two Airbus A321 carried out 16 interrupted landing procedures, show that; the noise level increase by 1 dB for every 10 kn speed increase, the noise level decreases by 5 dB 7 nm outside the runway threshold if a higher approach height (from 2500 to 4000 ft) is used, while a later deployment of the landing gear may reduce the noise (over a limited geographical distance) with up to 3 dB.

The flight schedule, with detailed instructions for the landing procedure, was designed to represent the range of variations seen under normal traffic conditions, regarding flight parameters such as speed, configuration, and approach altitude. It should be noted, however, that the limited number of flights performed are not fully representative for the variation seen under normal traffic conditions.

Although the results showed the benefits of advocating a lower approach speed, we cannot conclude that the quietest possible landing procedure is achieved by flying slow. The optimal approach is probably found somewhere in-between, with the right speed and the right configuration at the right time. That is, the results in this report do not follow a superposition principle where the various effects can be added independently, as the speed and configural state of the aircraft are interdependent, just



as the noise generation is. What the results show, however, is that the relationship between the aircrafts state and noise generation is strong and produce measurable effects on the noise levels on ground even with this limited number of flights.

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