Using Flight Data Recorder Data to Determine Aircraft Noise Levels in the Vicinity of Airports

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INTRODUCTION

Airport operators, especially those operating airports located close to residential areas, need to evaluate noise levels of individual aircraft in the vicinity of the airport. This information can feed community engagement activities, as well as assess aircraft adherence to noise abatement procedures, such as NADP1 and NADP2.

Land use planning policies and their associated restrictions on the construction of new residential dwellings in the most significantly noise exposed areas around airports are often questioned due to changes in flight intensity, composition of used air fleet and conditions for modeling the noise area for a specific airport. Updating results of calculated analysis and field measurements is a resource intensive activity, which airports must carry out on a regular basis.

Because of this, it is suggested that a simple approach to this would involve the use of flight data recorder (FDR) data to determine aircraft noise levels for individual aircraft at specific points around the aerodrome along the takeoff and landing trajectory. This is done by synchronizing mandatory FDR parameters with aircraft noise levels measured in the field at various reference points around the airport, including during certification testing[1].

This can be achieved by building a database of source data for each type of aircraft operated that would include aircraft noise levels measured at specific flight phases and synchronized with FDR data during the aircraft's flight period. This would include actual engine operating parameters as well as other registered parametric information.

FDR DATA APPLICATION PRACTICE

On-board flight data recorders record specific aircraft performance parameters to enable precise determination of such variables as flight path, speed, attitude, engine thrust, and others.

ICAO documents (Amendment 17 to Annex 6 to the Convention on International Civil Aviation, "International Standards and Recommended Practices"[2]) include recommended lists of between 15 and 32 recorded parameters for various aircraft types.

Aircraft operating parameters recorded second-by-second can be decoded and presented in matrix or graphic form. The matrix view supports automatic processing and precise analysis of all recorded data for each second of the flight. The graphic data view allows one to visually compare changes of certain aircraft parameters over the specified time period.

To find a correlation between measured noise levels around the airport and the aircraft's flight performance characteristics, one has to identify the parameters influencing the area with the specified noise level at its borders and evaluate the contribution of each of them based on instrumental measurement data matched to FDR data. This problem was solved for some aircraft by conducting experimental research that yielded enough unbiased data to establish dependency between noise level at a point on the ground and the aircraft's flight performance characteristics.

There are generally available published environmental studies that use flight data recorder information to examine only certain environmental aspects such as: evaluation of pollutant emissions[3], and validating models of aircraft noise distribution over residential areas[4].

CONDUCTING EXPERIMENTAL RESEARCH

Specialists working at the Civil Aviation Environmental Safety Center in CITY, carried out tens of thousands of noise level measurements for all aircraft types operated in Russia for various scientific studies, upon requests of airports, inhabitants, municipal authorities of populated areas near airports and for various design works. These were conducted without regard for the information obtained from aircraft noise continuous monitoring systems.

To achieve this task, several experimental studies under various operating conditions were prepared and carried out with the assistance of airlines and aircraft operators. Circular circuit test flights were performed using various aircraft types including: Tu-154, Il-76, Sukhoi Superjet, Irkut MS-21, A319, A320, A321, B737.

Using simultaneous noise measurements at various specific points on the ground (from 8 to 24), including data from automated aircraft noise monitoring system sensors, and subsequently gathered FDR data, the aircraft maintenance center was able to build a database of noise observations synchronized with aircraft attitude parameters[5].

Comparison of FDR data and automated aircraft noise monitoring system data showed that the FDR data provided more detailed aircraft information and reduced ambiguity errors inherent to the automated aircraft noise monitoring system. This was mostly due to: limited amount of information transmitted over the radio channel, transmission delay, and frequent loss of accuracy. Additionally, the number of microphones used to collect data for the acoustic noise database was significantly larger than the number of microphones used by the aircraft noise continuous monitoring system.

The completed studies identified dependencies between noise levels and aircraft performance characteristics during aircraft maneuvering, along specified flight paths, and during circular circuit flights.

Research Method

Noise measurements on the ground were conducted using well-known standardized methods, while ensuring the required ambient conditions, and clear visibility of the aircraft's flight path.

Microphones were placed on the ground perpendicular to the takeoff path projection, starting 3 km from the executive start, and then spaced every 1 kilometer to a distance of 8.5 km. For evaluating noise levels during the landing phase, microphones were also placed perpendicular to the landing path projection starting 2 km away from the closest runway end, and every 1.5 km to a distance of 6.5 km.

An aircraft's spatial location was determined using triangulation theodolites during takeoff at the point located on the 6.5km perpendicular and during landing at the point located on the 2.0 km perpendicular, combined with FDR data, and supported by similar data obtained from the air traffic radar control system. Parameters such as acoustic noise measurement, aircraft location, and weather data provided by the automated airport weather station and mobile weather station (e.g., Vaisala WXT520) were synchronized using information about the spatial location of objects including: noise level measurement points, aircraft location on the flight path, as well as the time parameter. Aircraft parametric data were entered into the database at 1-second intervals.

The speed, vector of the wind and crosswind component, temperature, and relative humidity were all monitored for each aerodrome during the entire measurement period.

Experimental Data Analysis

Aircraft noise level measurements on the ground were taken and analyzed at four Russian aerodromes and involved 112 aircraft takeoffs and 78 aircraft landings. This was done during 24 circuit circular test flights of different noise category aircraft, and a linear dependency was established between FDR parametric data and measured noise levels for each aircraft type and flight phase. In total, more than 2,000 noise level values were recorded for various points on the ground.

Out of FDR data array for each flight, various characteristics of a specific aircraftat the moment of measurement were selected including: altitude, speed, engine thrust, aircraft weight, angle of attack, flaps configurations, landing gear position, etc. The following parameters were examined to approximate discrete data:

X, Y – aircraft coordinates,
h - aircraft altitude (m),
V - aircraft speed (m/s),
P - compressor revolutions (% of maximum),
m – aircraft weight (t).

No relevant dependencies were found between: aircraft noise and the angle of attack, flaps configuration, and landing gear position. Because the sample is quite limited, these parameters cannot be declared to have no influence at all, however, at the current stage of research using them was considered to be unreasonable.

As an example, Table 1 shows FDR data for each flight and the measured highest noise level at a point on the ground located X=8.5 km away from the line-up at the Pulkovo aerodrome along the takeoff path projected on the ground and Y=0.8 km sideways of the specified path. The highest noise measurement levels are rounded to integers.

Analysis of the data in Table 1 shows that aircraft with similar parameters of aircraft weight, engine power and close enough values of speed have similar noise levels (VQ-BAU, BQ-BIU, VQ-BAQ). With comparable speed, thrust and takeoff weight, but different flight altitude at the examined plane a 2 dBA difference was discovered (EI-EZD, VQ-BAQ). With two parameters being significantly

TABLE 1: Experimental data observations – Pulkovo Aerodrome

No.	ID	Aircraft type	Noise level L_A, dBA	Aircraft geometric altitude h, m	Aircraft speed V, m/s	Aircraft engine power P, %	Aircraft weight m, t
1	1408	A319 EI-EZD	75	784	103	94.4	57.252
2	1427	A319 EI-ETO	75	532	91	93.1	57.335
3	1458	A319 VQ-BAS	80	611	108	95.3	67.066
4	1514	A319 EI-ETP	75	561	95	93.8	61.000
5	1515	A319 VQ-BAT	75	636	106	94.7	62.676
6	1535	A319 EI-EYM	71	930	99	93.5	53.279
7	1555	A319 VP-BIT	74	589	96	93.0	56.29
8	1620	A319 VQ-BAV	75	530	94	94.5	64.762
9	1621	A319 VQ-BDV	74	505	98	96.1	70.543
10	1637	A319 VQ-BAU	73	633	104	93.8	58.612
11	1647	A319 VP-BIU	73	720	99	94.0	57.843
12	1649	A319 VQ-BAQ	73	624	95	92.9	57.462
13	1717	A319 EI-ETN	75	585	93	93.0	56.327
14	1725	A319 VP-BIQ	74	766	103	93.9	55.039

different – takeoff weight (+14t) and flight altitude (-319m) – a 9 dBA difference in measured acoustic noise was discovered (VQ-BAS, EI-EYM).

The research revealed that when parameters such as aircraft type, aerodrome location, and other external factors are the same; differences in aircraft operational parameters such as aircraft speed and aircraft altitude which may differ twice can have significant impacts on perceived noise levels on the ground.

Figures 1, 2, and 3 show graphical representation of FDR data recorded for the examined aircraft. Observations show that during the research most aircraft failed to follow the stepped departure climb according to NADP 1 or NADP 2 procedure for noise reduction and speed requirements for each climb phase. These are required for estimating equal-loudness contours in the vicinity of an aerodrome, which, basically, allows one to conclude that in this case, that the perceived noise levels did not match the noise contours obtained by calculation.

During training and circular circuit test flights with simulated approach, engine thrust and flight altitude had especially significant influence on the noise level at measurement points. During circular circuit test flights without simulated approach, the decoded FDR data showed that the flight altitude during the initial and final stages of the flight was a significant noise contributor.

Approximation methods were used to process the obtained experimental data in order to identify linear dependencies that give as close as possible representations of operating parameters for each monitored aircraft.

Based on the entire array of sound measurements and parametric data for various flight modes, the noise level expected at the point on the ground within 1 km from the borders of the monitored area was determined with a tolerance equal or less than ΔL_{Amax}= 3 dBA for 88% of measurements.

FIGURE 1: 1 Changes in engine operating mode of monitored aircraft during takeoff

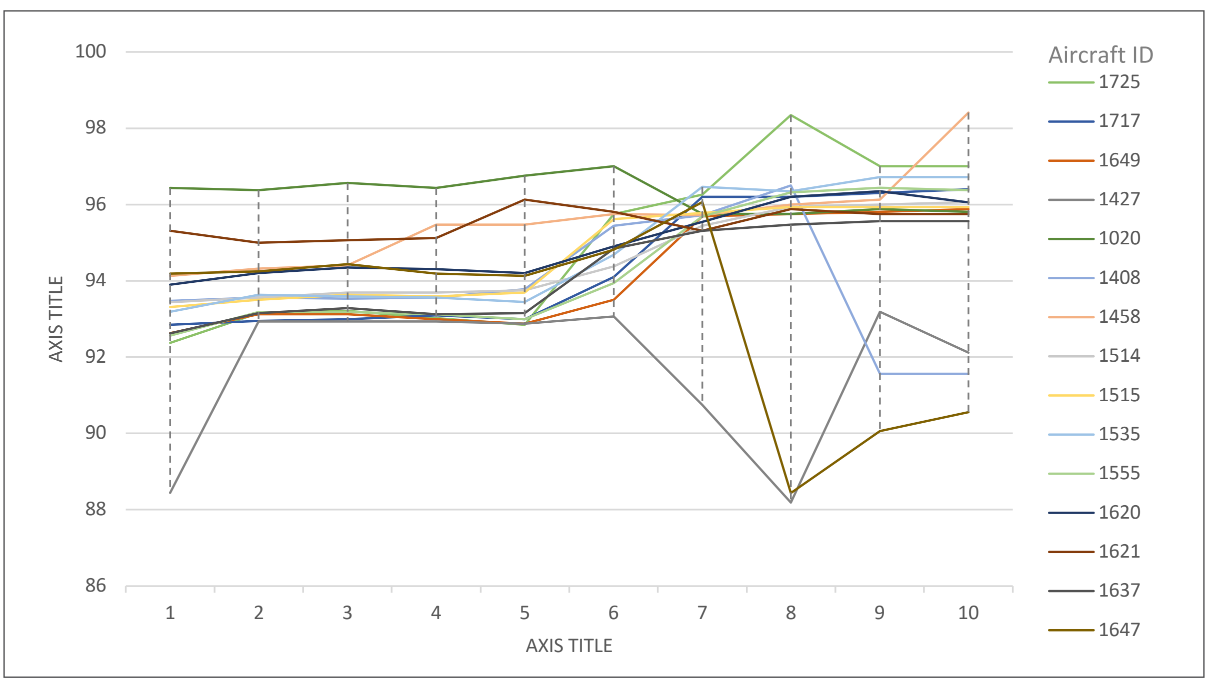


FIGURE 2: Changes in flight speed of monitored aircraft during takeoff

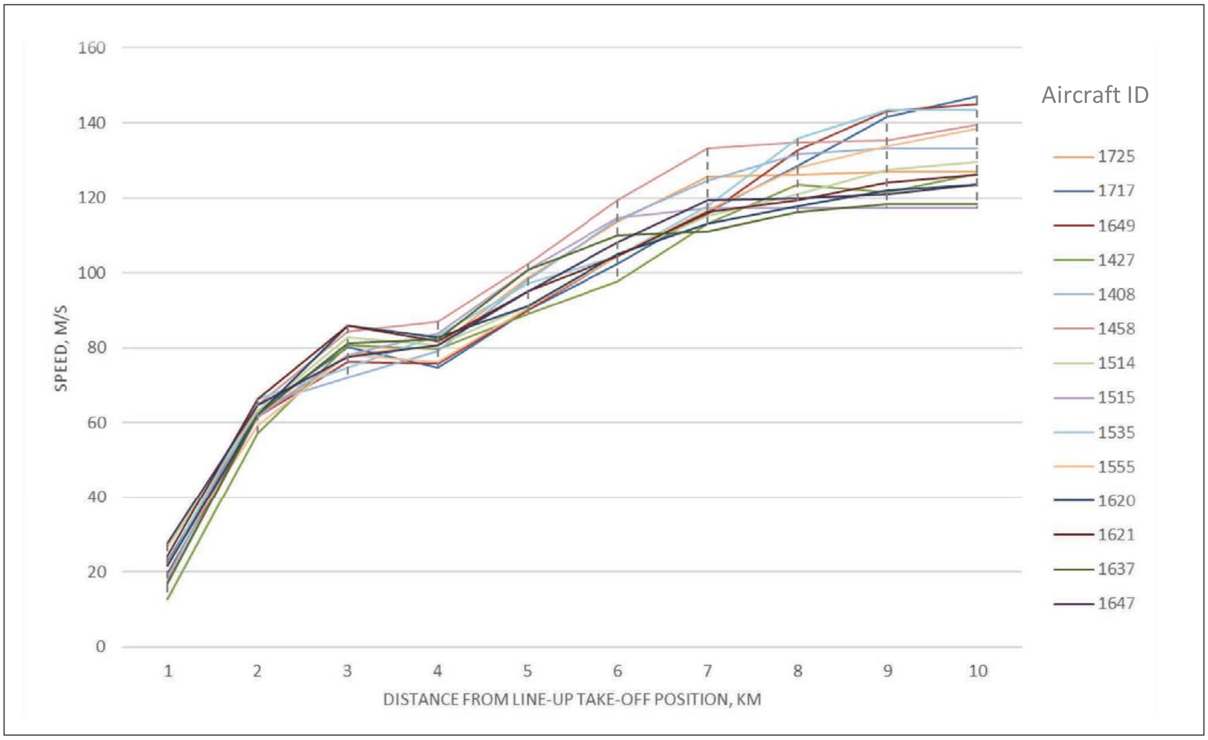
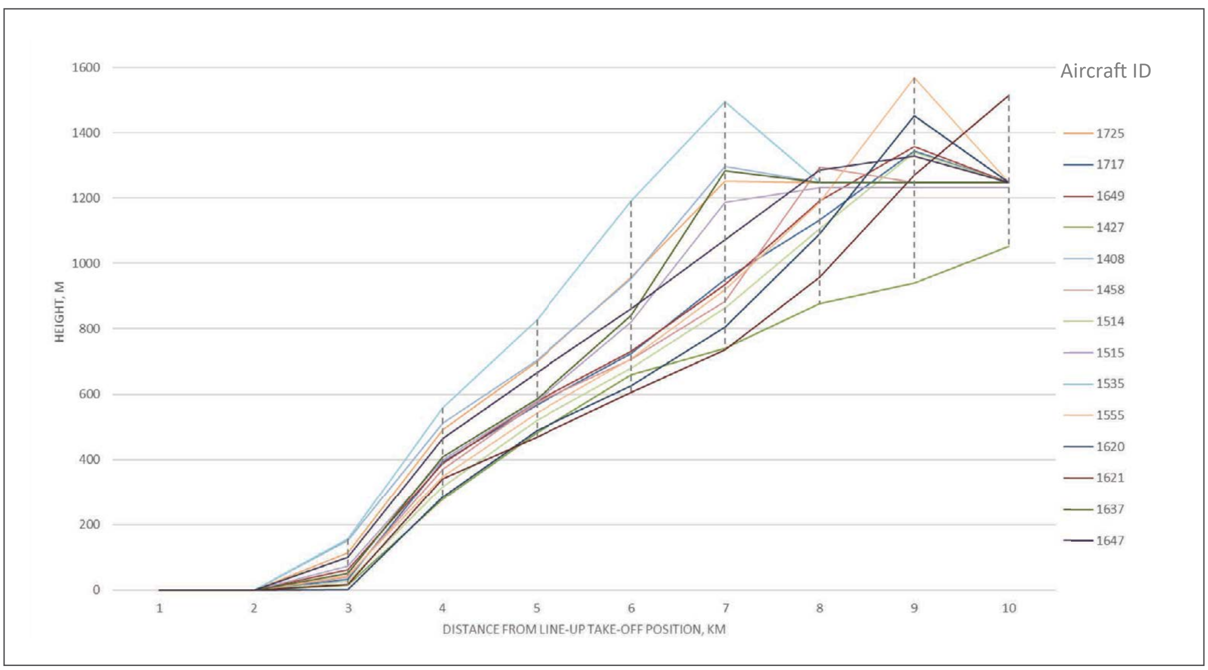


FIGURE 3: Changes in flight altitude of monitored aircraft during takeoff



CONCLUSION

Further applications of the approach described above could include creating a database of initial experimental data for each operated aircraft type by organizing and conducting comprehensive aircraft noise measurements to be subsequently synchronized with FDR data for an active airport. This would allow the ongoing monitoring of the acoustic environment in the vicinity of the aerodrome and could assess the degree of aircrew compliance with the requirements for low-noise flight modes during the landing and takeoff cycle.

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