[1.]**Nicolaie ORĂŞANU,** [2.]**Marius DEACONU,** [2.]**Laurențiu CRISTEA,** [1.]**Ioan MAGHEȚI**

SOME ASPECTS AND CONSIDERATIONS ABOUT AIRPORT NOISE MONITORING

[1.]University "Politehnica" of Bucharest / ROMANIA
[2.]National Research and Development Institute for Gas Turbines COMOTI / ROMANIA

Abstract: Acoustic monitoring is necessary in the acoustic assessment of both airports and aircraft, to be able to determine exactly how the acoustic events due to flights affect the quality of life of people living in their vicinity. An assessment of the noise produced by aircraft requires the use of monitoring stations whose location must cover the inhabited area, placed on the active runways of the airport, so that the information obtained can be correlated with the traffic data. The development aims to achieve sound pollution management with real data and a smartphone application that will allow the population to directly access this system.
Keywords: noise impact; monitoring of airports, noise data analysis, aircraft noise

1. INTRODUCTION

The noise produced by road, air, railway traffic, agricultural works or various factories has come to represent a major environmental concern in terms of evaluating the quality of everyday life. More and more recent surveys show that the percentage of those who are dissatisfied and annoyed by the noise at home has increased a lot, to over 85% (*Morel, J., et al, 2016*), and among the noise sources mentioned, air traffic and road traffic are the ones that cause the most discomfort.

The total economic impact of noise–related illnesses in Western European countries alone amounts to more than €80 billion per year (*Morel, J., et al, 2016; Basner, M. et al, 2017*). Addressing this issue, especially in large urban agglomerations, it can be done by drawing up noise maps for different community noises: road traffic, railway, aircraft and industrial noises (*Yang, W. et al, 2020),* by evaluating the noise exposure of the population according to the network noise data and population density (*Cai, M. et al, 2019*) or through permanent noise monitoring (*Bello, J. et al., 2019; Maisonneuve, N., 2009*).

The concrete aspects related to unattended monitoring of aircraft near airports are stipulated in ISO 20906–2009, which describes in detail what such monitoring involves. Certain aspects regarding the identification of specific sound events produced by aircraft must be analyzed from an objective point of view, in terms of the data to be analyzed and correlated. Many of the world's major airports are acoustically monitored to the above standard.

Internationally there is a wide range of monitoring equipment and all existing systems are based on a sound level meter. The most important equipment manufacturers that offer precision class 1 sound level meters are: 01dB, EMS Bruel & Kjaer, Svantek, Larson Davis, Rion CO, which also offer monitoring systems (*Acoem; Larson D*).

There are research centers or companies such as: Cirrus, Topsonic Systemhaus GmbH, NLR, AnotecEngineering, which use equipment from major manufacturers, offering expertise in noise monitoring (*Cirrus, Topsonic, Anotec Engineering).* The basic package offered for noise monitoring contains the measuring equipment (consisting of: sound level meter, weather station, control panel, GPS unit) and a web/software platform for on–site and remote configuration and monitoring of the stations/stations. In addition to the basic package, EMS Bruel & Kjaer, Rion CO and Topsonic add an ADS–B receiver with which to take the identification data of only the ADS–B system aircraft, and the noise data is then correlated with the data received from this receiver.

This technique improves the percentage of validated aircraft and excludes unwanted events such as traffic noise or airport utility vehicles from the measurement. In addition to the technique of correlating the data received from the receiver with the noise, Svantek and Rion CO implemented a technique to detect the direction of the dominant noise source both vertically and horizontally, a technique based on measuring the signal from multiple microphones MEMS located on the surface of the sound level meter, such as the one from Svantek.

This noise source direction detection method is based on the plane wave method and calculates the cross spectrum between each microphone to identify the phase shift and amplitude difference between the microphones. A similar system is the one developed by RION CO, which provides that the location of the microphones should be on a metal support and the angle of incidence of the acoustic wave is almost the same for all microphones. However, identifying the direction of the noise source alone is not sufficient for airport noise and it is necessary to identify the aircraft that produced the event.

2. LEGISLATIVE RESTRICTIONS ON NOISE

The ongoing development of air transport leads to the adoption of complex measures to ensure both the efficient operation of transport systems and compliance with environmental requirements. For the population who lives in the vicinity of airports, noise exposure, which sometimes creates discomfort, must be taken into account in the context in which it is forecasted a 42% increase in air traffic by 2040 compared to 2017, ie from 9.56 million to 13.6 million of flights (take–offs and landings). For example, in 2011, 3.2% of the world population was exposed to L_{zsn} levels> 55 dB, due to aviation.

The number of major airports (with over 50,000 annual aircraft movements) will increase from 82 in 2017 to 110 in 2040, a situation in which the effect on the population may extend to much larger areas. According to GD 944/2016 there are 20 urban agglomerations in Romania, 261 main roads, 5 sections of railway and 3 ports for which strategic noise maps must be made and according to the new noise assessment trends, its monitoring with monitoring stations is foreseen (*Decision no. 944/2016; Neda, T. et al, 2012*).

Noise operating restrictions imposed on Romanian airports since 16.07.2019 are detailed in the legislation (*Decision no. 944/2016*).

The quantities measured during monitoring to identify a sound event are characterized by the noise exposure level, $L_{E,A}$, and the maximum sound pressure $L_{p,AS,max}$, or $L_{p,A,eq,1s,max}$, in which (Figure 1): $L_{p,AS}$ –A weighted sound pressure level on Slow scale; $L_{p,AS,max}$ – maximum A weighted sound pressure level ; t – time; $t_{10} = t'_{10} + t''_{10}$ – maximum A weighted sound pressure level time interval with variation of 10 dBA;

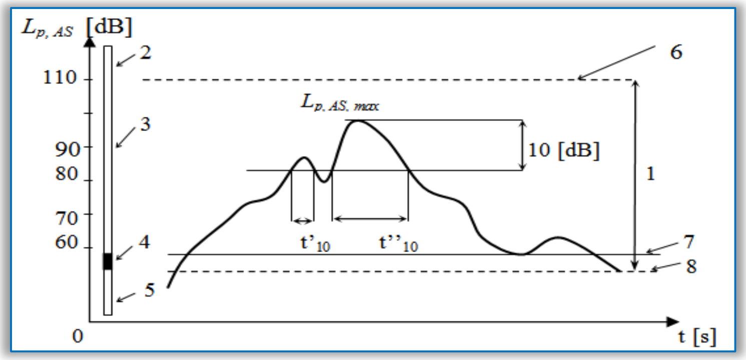

Figure 1 – Identifying a sound event (ISO 20906–2009)
1 – range of primary indicators / dynamic range; 2 – overload interval; 3 – domain considered; 4 – ignored interval; 5 – intervals not transmitted; 6 – upper limit of the main indicator range / dynamic range; 7 – threshold level; 8 – lower limit of the linear operating range.

3. MATERIALS AND METHODS – MONITORING ISSUES

Location of the monitoring station (Decision no. 944/2016)

The analyzed monitoring station is located in the area of Avram Iancu International Airport in Cluj–Napoca, near its eastern end, with the following coordinates: latitude λ=46.79113, longitude: φ = 23.69418 and altitude 315 m (1033 feet) placed in the marked area (Figure 2).

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Figure 2 – Monitor station position near the Avram Iancu International Airport runway (*Decision no. 944/2016*)

For an accurate graphical analysis, two points located on the main runway of the airport were chosen, A_1 (φ=23.67206, λ=46.78463) and point A_2 (23.69494, 46.78989), which are, with reasonable approximation, the closest points of the runway axis, about 150–200 m away.

If it is considered that the horizontal axis is "x" and the vertical one "y", the elementary variations have the expressions

$$dx = \frac{\pi}{180} R_P d\varphi \cos\lambda; dy = \frac{\pi}{180} R_P d\lambda \tag{1}$$

where $R_P \cong 6370\,km$ is the radius of the Earth.

In this case, a variation of 0.000001= 10^{-6} of φ or λ, leads to:

$$dx = 0.07611[m/grad \times 10^{-6}]; \quad dy = 0.111[m/grad \times 10^{-6}] \tag{2}$$

By graphical measurement, using the image scale, the length of the track $|A_1A_2|$ figurative in Figure 3 has value 1848m, close to the approximate theoretical value

$$|A_1A_2| = \frac{\pi}{180} R_P \sqrt{(\Delta\lambda)^2 + \cos^2(\lambda)(\Delta\varphi)^2} = 1891m \tag{3}$$

Also, the law of planar variation of latitude as a function of longitude for the runway axis can be approximated by the expression

$$\lambda = 41.342539 + 0.2298951\varphi \tag{4}$$

Some aspects of the data measured and archived by the monitoring system

Monitoring the airport noise involves the collection and processing of sound pressure values with the help of properly calibrated sound transducers, in a correctly chosen position, respecting the criteria imposed by the ISO 20906–2009 standard. It is also necessary to obtain information on the flight data of the aircraft so that a completely correct identification of the event produced by a particular aircraft can be made, especially in conditions of high air traffic.

The data obtained by measuring the sound pressure are sufficient to determine: $L_{p,AS}$ – the *A* weighted sound pressure level and $L_{p,AS,max}$ – the maximum level of the *A* weighted sound pressure, values required according to the mentioned standard. Also, by processing the measured values, the 1/3 octave spectra are saved every second, in a * .txt file, in the form of a table with 36 columns. These results can only provide partial information about acoustic events at an airport, without accurate information about the aircraft producing the sound event. For example, the file NMS2_20210701_1.txt contains information from 00: 00–12: 00, 01.07.2021.

The exact determination of the sound events of the aircraft that produce them requires the development of specialized programs of numerical analysis, which make a correlation of the measured acoustic data with the received ADS–B traffic data. The traffic data were obtained by

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

using the Radarcape from Jetvision, which was installed in the same position as the noise monitoring station. The archived ADS–B files are in the form of a text file.

In example: B738_20210617_4CA703_RYR2698_ EGSS_LRCL.txt., the title of this file provides important information on: aircraft type B738, flight date 17/06/2021, flight code 4A09AC, airline and flight RYR2698 (*Rynair, flight 2698*), abbreviation of departure airport: EGSS (London Stansted) and the arrival airport – LRCL (Cluj–Napoca).

Table 1.1–3 shows the data contained in such a file. It can be seen that the file provides information about the spatial (latitude, longitude and altitude) and temporal (time in hhmmss) position of the aircraft near the airport on take–off or landing procedure. Even if a small airport is monitored, such as the one in Cluj–Napoca, where there are still between 25–35 flights a day, identifying and classifying an aircraft is difficult.

This is obvious if you consider the daily schedule of flights, which are mostly grouped only in certain time slots, and delays of any kind can lead to wrong correlations regarding the association of a sound event with a particular aircraft.

Table 1. Flight data

Fly	Company	Lat	Long	Alt[feets]	Departure	Landing	Plane	Time[hhmmss]
4A08E7	ROT647V	46.78866	23.68973	875	LROP	LRCL	B737	185543
4A08E7	ROT647V	46.78825	23.68799	850	LROP	LRCL	B737	185545
...			...			...		
4A09AE	BLA3738	46.78826	23.68791	1025	LCLK	LRCL	B738	002056
4A09AE	BLA3738	46.78810	23.68719	1025	LCLK	LRCL	B738	002057

A detailed analysis shows that certain values of the flight data have large deviations from the real ones. For example on line 2 of table 1, marked, two significant deviations can be identified, applying the relation (4).The landing takes place at a point offset of 180 m from the track axis and the altitude indicate 55.77 m (183 feet) below the real one. Also the flight data are not transmitted continuously from a temporal point of view, marked in table 1.

4. RESULTS OBTAINED BY PROCESSING THE DATA ARCHIVED BY THE MONITORING SYSTEM

Determination of acoustic events

From the analysis of the data saved by the monitoring system, the sound events that can be associated with an aircraft, according to the ISO 20906–2009 standard are exemplified in Figure 1. In this sense, Figure 5 shows a sound event, a landing of a B738 aircraft (4A08EA, ROT641V, 46.78895, 23.69091, 875, LCLK, LRCL, B738, 001548), see Table 1.

From the analysis of the graph in Figure 3 it is observed that around 00: 21: 00 a sound event takes place, identified as a landing.

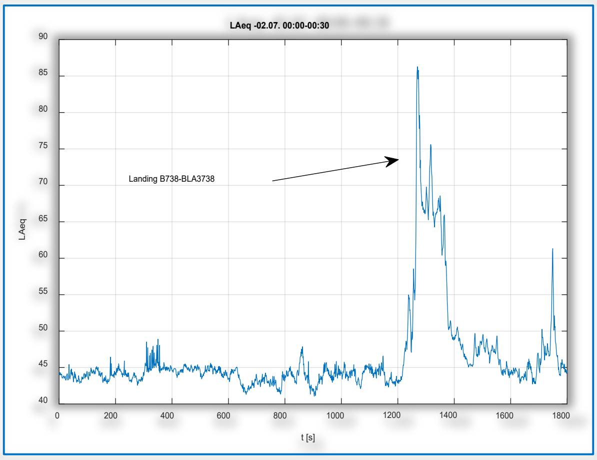

Figure 3 – Acoustic event (L_{Aeq} in dB(A))

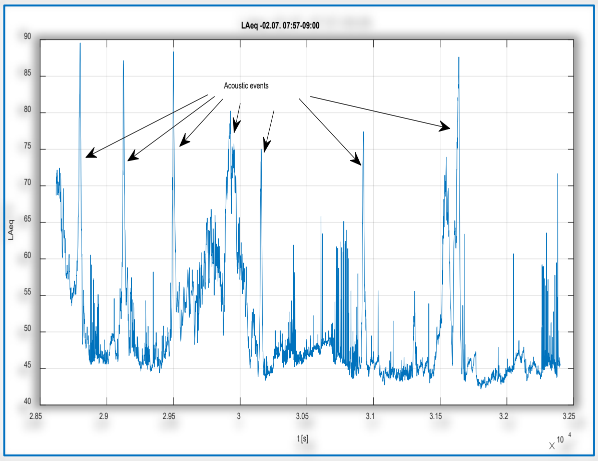

Figure 4 – Acoustic events during the day (L_{Aeq} in dB(A))

Determining the acoustic events during the day is more complex due to the large number of events (see Figure 4).

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

As noted above, there are some discrepancies and differences between the values that are reported by the ADS–B system and obviously stored by the monitor, which can lead to some confusion in identifying an aircraft sound event, especially if the incidence of flights is extremely high. Finding an alternative method of identifying an aircraft in parallel with the direct one, especially in the case of multi–runway airports, can provide much more accurate information.

To this end, programs have been developed in the Matlab environment that allow a detailed analysis of airport acoustic events, which can be more easily associated with flight data. With such a method, the spectra and multispectra of aircraft noise could be done in order to find their spectral finger prints for possible spectral modeling (*Georgieva, H. et al, 2018*).

Processing of stored information and analysis of obtained results

Although the purpose of monitoring is to identify sound events in real time (*Cristea, L. et al, 2021; Decision no. 944/2016*) and possibly classify aircraft according to take–off / landing noise, as mentioned earlier, there are many question marks in crowded airports related to the exact correlation of a sound event with a particular aircraft. Clarifications are needed for the method of finding the position in which an aircraft generates a maximum level of noise, its spectral composition, precisely in order to predict how these noises may affect neighboring inhabited areas. Another significant point is the accuracy of the flight data received from the aircraft (ADS–B) and as a consequence the corrections that we may consider. For this purpose, Matlab programs have been developed to process the noise data archived by the monitoring station to obtain important numerical and graphic information, sometimes necessary in the case of complaints whose solution requires concrete and correct answers.

The necessary steps for developing of such data–processing programs consists, first of all, in splitting of the large file data in smaller files, as follows:

- traffic data, were processed in the form of tables with 432400 rows and 37 columns (1/2 day);
- creating daily folders containing both the traffic data files and all the ADS–B files of the aircraft that had events that day.

The programs do the following:

- converting the data from files type *.txt in Matlab format *.mat;
- converting the time format [hhmmss] in numerical format [ss];
- identify from the flight data of each aircraft, the location in time, the type of maneuver (takeoff / landing) and then search for the sound event produced by it in the traffic data;
- identifies from the traffic data the maximum values of the L_{Aeq} level and the time at which this happens;
- identifies from the flight data the position of the aircraft at the time when the noise level is maximum;
- the program can perform spectra depending on the type of aircraft and the type of takeoff / landing maneuver, figure 3, 4;
- can interactively display the position in which an aircraft has produced a maximum noise level, figure 7;
- it can plot a multispectrum (FFT in time domain) depending on the time at which the L_{Aeq} noise level is maximum, figure 8, 9.

In the following section different noise spectra computed from different aircraft are presented, the *x* axis represents the number of the octave band as is presented in Table 2, figure 5, 6.

Table 2. The 1/3 octaves center frequency used in the figures

no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]	no. – f_c[Hz]
1–10	2–12.5	3–16	4–20	5–25	6–31.5	4–20	5–25	6–31.5
10–80	11–100	12–125	13–125	14–160	15–200	16–315	17–400	18–500
19–630	20–800	21–1000	22–1250	23–1.6k	24–2k	25–2.5k	26–3.15k	27–4k
28–5k	29–6.3k	30–8k	31–10k	32–12.5k	33–16k			

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

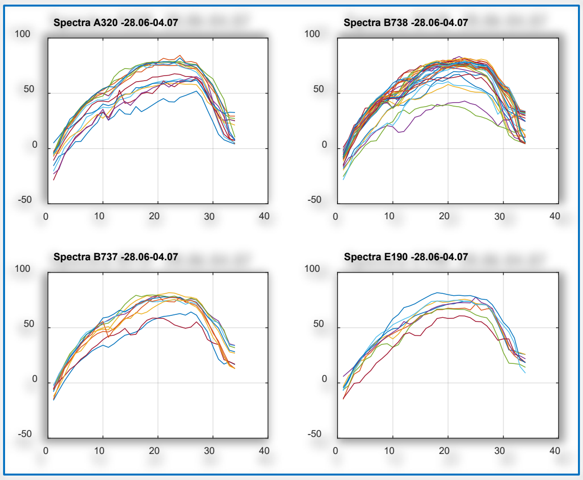

Figure 5 – Spectra of 4 aircraft types (X axis – 1/3 octave bands number; Y axis – sound pressure level)

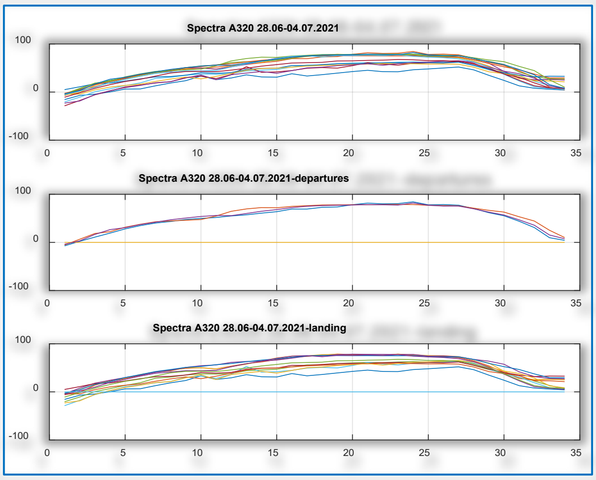

Figure 6 – Spectra of A320 (X axis – 1/3 octave bands number; Y axis – sound pressure level)

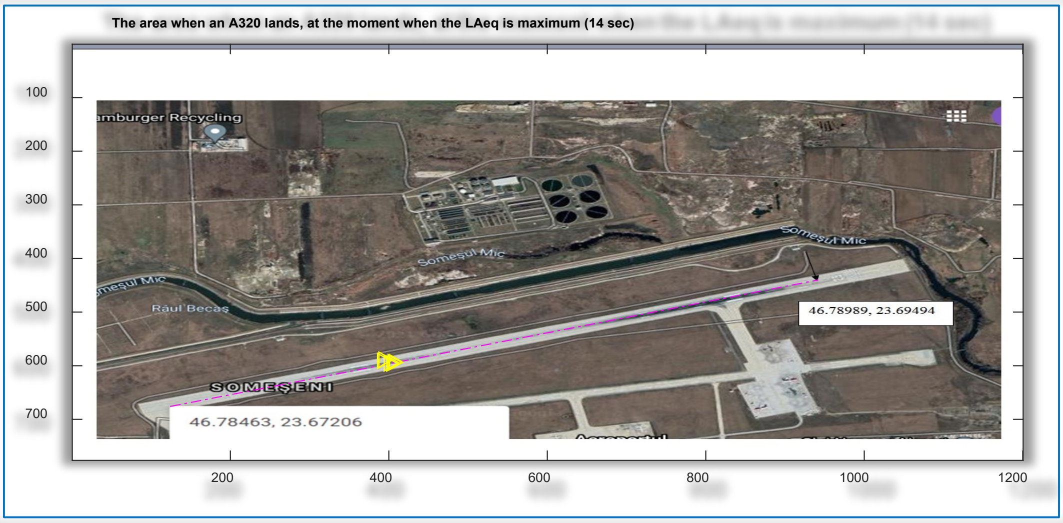

Figure 7– Position where the noise level is maximum

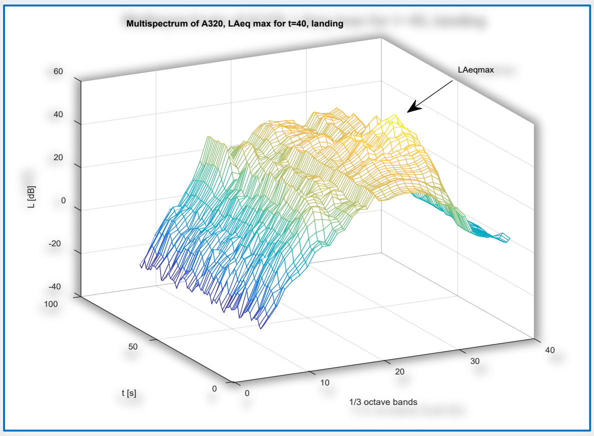

Figure 8 – Multispectrum of a landing A320

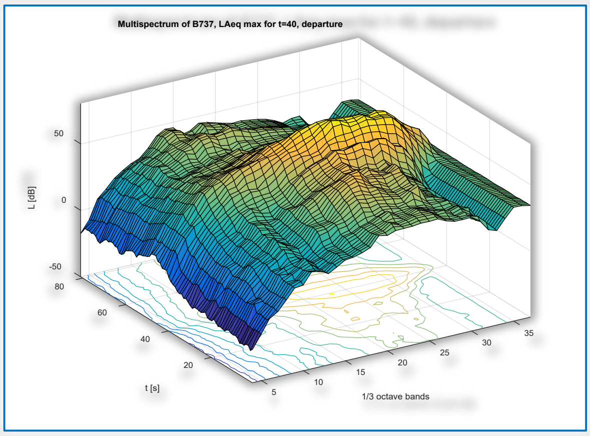

Figure 9 – Multispectrum of a departure B737

5. CONCLUSIONS

This paper presents in a briefly manner some of the results acquired during the monitoring process at Cluj International Airport and how this activity can be improved as a result of processing the obtained noise and air traffic data. It can be stated with certainty that, through the developed Matlab program package, additional useful information can be presented both in solving concrete issues such as notifications, complaints, reports on a certain type of aircraft, the correction of flight

data or the evolution in time and frequency of an acoustic event. The results presented can be accessed in other forms, both graphical and numerical.
It should also be noted that the set of the developed programs can make an exact correlation between the graphical image of the monitored area, the traffic data of a particular aircraft and the data measured and processed by the monitoring system, sound pressure, A weighted sound pressure level, spectra, etc.
The obtained results provide useful information, which together with the data provided online, can fill specific needs on a certain level.
In addition to the results mentioned above, a clear distinction can be made between a landing and a takeoff, which leads to an increase in the identification level of the noise produced by an aircraft. Although attempts have been made to find spectral fingerprints for a particular type of aircraft, the results obtained in this regard have not been satisfactory because even aircraft of the same type may have different features in terms of noise reduction (*Bennamia, I. et al, 2018*), and also because the level of noise emitted may differ depending on the aircraft load, weather conditions, flight mode, etc. It is well known how important acoustic prediction is (*Bratu, P., 2021*), so the ideal solution would be if each aircraft could be distinguished by a distinct, spectral, distinct noise footprint.
However, this can only be achieved through a statistically large–scale project, accurate information with flight operators, complete destination and weather data, and other issues such as the way of flighting by pilots. In other words, only through artificial intelligence systems could such a goal be achieved.

Acknowledgments

Acknowledgements. This research was supported by a grant of the Romanian Ministry of Education and Research, CCCDI–UEFISCDI, project number PN–III–P2–2.1–PTE–2019–0306, within PNCDI III, in project number 31PTE/2020.

References

[1] Acoem, 01 dB DUO, https://www.01db.com/our–solutions/our–products/monitoring–solutions/noise–monitor/.
[2] ***Anotec Engineering, https://www.anotecengineering.com/.
[3] Bello, J., Silva., J., Nov, O., Dubois, L., Arora, A., Salamon, J., Mydlarz, C., SONYC: A System for Monitoring, Analyzing, and Mitigating Urban Noise Pollution, Communications of the ACM, Volume 62, Issue 2, February 2019, pp. 68–77
[4] Bennamia, I., Badereddine, A.–E., Yahia Cherif., M., Zebbiche., T., Frequency Response Analysis of Composite Aircraft Wing Using a Finite Element Euler–Bernoulli Beam Model, Romanian Journal of Acoustics and Vibration, Vol. 15, Nr. 1, 2018, pp. 26–32.
[5] Basner, M.,Clark, C., Hansell, A., Hileman, J., Janssen, S.,Shepherd, K., Sparrow V., Aviation Noise Impacts: State of the Science, Noise Health. 2017 Mar–Apr; 19(87), pp. 41–50
[6] Bratu, P., The performance in acoustics and vibration engineering, Romanian Journal of Acoustics and Vibration, Vol. 18, Nr. 1, 2021.
[7] Cai, M., Lan, Z., Zhang, Z., Wang, H., Evaluation of road traffic noise exposure based on high –resolution population distribution and grid –level noise data, Building and Environment, Volume 147, January 2019, Elsevier, pp. 211 –220
[8] Cirrus, https://www.cirrusresearch.co.uk/applications/ aircraft–noise/.
[9] Cristea, L., Griguță, A., Tănase, R., Deaconu, M., Selection of the parameters that influence the noise produced by aircraft on cities within online monitoring systems, The Romanian Journal of Technical Sciences. Applied Mechanics. Vol. 66, nr. 1, 2021, pp. 49–61.
[10] Decision no. 944/2016 for The amendment and completion of the Government Decision no. 321/2005 on the assessment and management of environmental noise, https://legislatie.just.ro/Public/DetaliiDocumentAfis/185147.
[11] Georgieva, H., Georgiev, K., Modeling of aircraft jet noise in airports, EDP Sciences, 2018.
[12] International Standard ISO 20906–2009, Acoustics–Unattanded monitoring of aircraft sound in the vicinity of airports, https://www.onlineocr.net/.
[13] Larson D., http://www.larsondavis.com/products/soundlevelmeters/soundadvisor/nms045–permanent–soundadvisor–system.
[14] Maisonneuve, N., Niessen, M.E., Hanappe, P., Citizen noise pollution monitoring, Proceedings of the 10th International Digital Government Research Conference, 2009, pp. 96–103
[15] Morel, J.,Marquis –Favre, C., Gille, L. –A., Noise annoyance assessment of various urban road vehicle pass –by noises in isolation and combined with industrial noise: A laboratory study, Applied Acoustics, Volume 101, 1 January 2016, pp.47 –57
[16] Neda, T., Bite, M., Pbite, P., Dombil., Noise Mapping in Hungary and Romania, Romanian Journal of Acoustics and Vibration, Vol. 9, Nr. 1, 2012, pp. 61–65.
[17] Order of the Ministry of Environment and Sustainable Development no. 1830/2007 for the approval of the Guide on the creation, analysis and evaluation of strategic noise maps, https://legislatie.just.ro/Public/ Detalii Document /87963.

[18] Topsonic, https://topsonic.aero/en/solutions.
[19] Wright, M. D., Newell, K., Maguire, A., O'Reilly, D., Aircraft noise and self–assessed mental health around a regional urban airport: a population–based record linkage study, Environmental Health, 17, 74, 2018.
[20] Yang, W.,He, J.**,** He, C., Cai, M, Evaluation of urban traffic noise pollution based on noise maps, Transportation Research Part D: Transport and Environment, Volume 87, October 2020, Elsevier

Note: This paper was presented at ISB–INMA TEH' 2023 – International Symposium on Technologies and Technical Systems in Agriculture, Food Industry and Environment, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research–Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research–Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 5–6 October, 2023.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665