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Potential changes in aircraft noise sound quality due to Continuous Descent Approaches

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Background and Objective

- This paper presents an analysis of how flying Continuous Descent Approaches (CDAs) can potentially impact the quality of sounds that aircraft produce in airport vicinities.
- It is known that CDAs can present potential benefits in terms of community noise impact with reductions in excess of 5 dBA (A-weigthed level) in peak noise level, L_{Amax}. A-weighted level is however known to be a poor predictor of perceived annoyance [1]. It is also not known if dBA reductions due to CDAs also correspond to an improvement in the aircraft noise sound quality (SQ) and perceived annoyance for residents on the ground.
- The study uses auralization to analyze how the sound of a representative aircraft changes due to CDA procedures, compared to standard approach procedures, and how this reflects in terms of changes in SQ and annoyance.

Methodology

- A short-range aircraft, similar to an A320-200, has been designed using the Multidisciplinary Integrated Conceptual Aircraft Design and Optimization (MICADO) Environment of RWTH Aachen University [2].
- Conventional step approaches with horizontal flight segments occurring at two different altitudes, 2000 ft and 3000 ft, are modelled using the Mission Analysis tool of MICADO. The CDAs are simulated for two different continuous descent glide slope angles of 3 and 4 degrees till final segment glide slope interception. As can be observed in Fig. 1, below around 1500 ft (Flight Level (FL) 15) there is no difference between the flight paths in the final segment.
- Two observer locations have thus been selected for analysis before final glideslope interception, located at 30 km and at 25 km below the flight path.
- Use of the Integrated Noise Simulation and Assessment module (INSTANT) has been made to model the aircraft noise [3]. The thermodynamic inputs required for engine component noise calculation are obtained from engine decks made using the gas turbine simulation software Gasturb.
- The aircraft noise is auralized using signal processing techniques of additive synthesis for tonal noise and white noise based overlap-add technique for broadband noise. The resulting sound at the observer is then assessed in SQ and overall annoyance metrics [4].

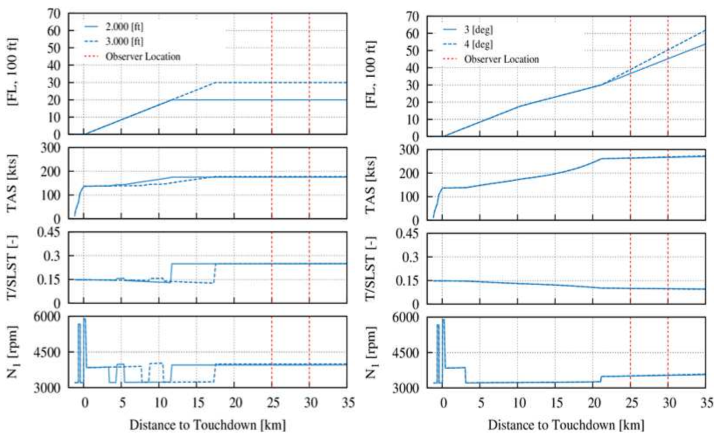

Figure 1: Flight path and parameter variation comparison of modeled standard approaches and CDAs

Results and discussion

- Figure 2 shows the synthesized spectrograms for the simulated standard approach and CDA with 4 deg glideslope, at the observer location of 30 km before aircraft touchdown.
- Although clear differences can be perceived in the sounds and seen in the spectrograms, it is beneficial to quantify the audible changes for an objective comparison. Table 1 shows the noise impact changes in L_{Amax} and SEL metrics. It can be seen that differences of close to 10 dBA can be observed between the 2000 ft reference approach and a 4 deg CDA. For the 3000 ft reference approach, these are up to 6 dBA, consistent with other references. These dBA values however don't indicate which sound characteristics have actually changed and how they relate to the perceived annoyance.

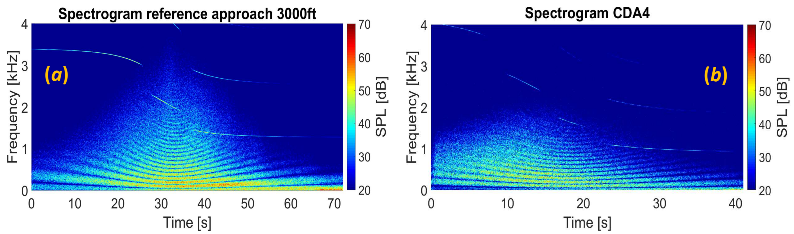

Figure 2: Synthesized spectrograms for a conventional approach (a) and a 4 deg CDA (b)

Table 1: Comparison of reference approach and CDA sounds in conventional metrics

Conventional metric results at 30 km	Ref. 2000 ft approach	Ref. 3000 ft approach	CDA 3 deg	CDA 4 deg
L_{Amax} [dBA]	71.21	65.77	63.53	61.97
SEL[dBA]	82.21	77.92	74.08	72.77

- Figure 3 shows the Overall Sound Pressure Level (OASPL) vs time variation as well as how this compares with the loudness vs time variation. It can be seen that the trends in dBA and loudness variation are similar but more amplified in terms of loudness.
- Table 2 shows how the remaining SQ metrics vary at 30 km for both reference approaches and CDAs.

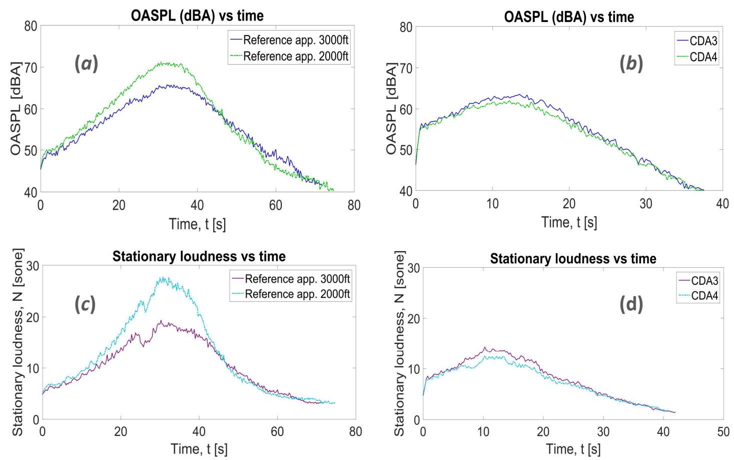

Figure 3: Comparison of reference approach vs CDA metric variation – (a), (b) OASPL vs time, (c), (d) stationary loudness vs time

Table 2: Comparison of reference approach and CDA sounds in SQ metrics

SQ analysis at 30 km	Ref. 2000 ft approach	Ref. 3000 ft approach	CDA 3 deg	CDA 4 deg
Loudness, N_5	25.9	17.9	13.3	11.6
Tonality, K_5	0.252	0.248	0.262	0.264
Roughness, R_5	1.72	1.74	1.70	1.69
Sharpness, S_5	1.47	1.51	1.36	1.26
Fluctuation Strength, FS_5	1.51	1.54	1.24	1.22
PA_{mod}	55.8	40.7	30.6	27.1

- It can be seen that the primary change in sound quality due to CDAs is in terms of loudness, with the 4 deg CDA being 55% quieter than the 2000 ft reference approach and 35% quieter than the 3000 ft approach.
- Changes in the other metrics are either small or not fully clear. The CDAs have lower sharpness due to reduced fan noise and increased airframe noise for the lower thrust and higher speed the CDAs undergo. The higher approach speed also yields less slow fluctuations in intensity over time, resulting in lower fluctuation strength.
- The tonality is seen to increase for the CDAs at 30 km due to more prominent fan tones whereas the roughness remains unchanged.
- The overall modified Psychoacoustic Annoyance (PA_{mod}) metric (Eqs. 1 , 2), as suggested by More [4], indicates similar reductions as the loudness metric, due to loudness (N_5) being the most dominant contributor to annoyance in the metric, compared to the other SQ characteristics.

$$PA_{mod} = N_5\left(1+\sqrt{\gamma_0+\gamma_1 w_s{}^2+\gamma_2 w_{FR}{}^2+\gamma_3 w_T{}^2}\right) \quad (1)$$

$$w_T{}^2 = [(1-e^{-\gamma_4 N_5})^2(1-e^{-\gamma_5 K_5})^2] \quad (2)$$

Conclusions and future work

- The primary sound characteristic that changes due to CDAs is the loudness of the sounds, due to the aircraft flying at higher altitudes. Some reductions in sharpness and fluctuation strength are also observed. Changes in tonality and roughness are less clear and can vary slightly with the ground location (with tonality slightly increasing at 30 km, cf. Table 2).
- The benefits of CDAs in terms of predicted annoyance are seen due to the dominant contribution of loudness in the annoyance metrics. These benefits are higher the farther away from the airport the residents live, with the benefits reducing considerably for residents who live closer to the airport.

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