Aircrafts' taxi noise emission

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Introduction

During planning stages, when noisy activity has not been implanted or while evaluating operation changes, it is necessary to find an environmental noise mapping prediction tool for future scenarios. When an activity is already implanted, it is possible to measure noise emissions, but this is expensive, so prediction tools can also be useful. Because of these reasons, for the last 10 years, as a response to the increasing concern for noise pollution in developed countries, several simulation models have appeared to predict noise levels outdoors.

Many of those models are customized for specific noise sources:

5. INM (Federal Aviation Administration Integrated noise model) evaluates aircraft noise impacts in the vicinity of airports.
6. FHWA TNM (Federal Highway Administration Traffic Noise Model) is a computerized model used for predicting noise impacts in the vicinity of highways.
7. The Calculation of Railway Noise (CRN) is the UK standard method, which defines the measurement and prediction procedures.

Other models are based in ISO 9613[1], which describes sound attenuation during its propagation outdoors. Most popular software packages (like Cadna, Lima, Mithra or Sound Plan) use these general purpose sound prediction models for noise mapping.

The noise consultant must create an acoustic model using a digital terrain model which includes ground, buildings, screens... and noise sources.

Noise sources' emission must be described in terms of sound power levels. But for most common noise sources, such as road or railway traffic, models allow the user to describe emission in terms of easy-to-know parameters, which can be converted into sound power levels.

Industrial noise sources can be modelled as point, line or surface virtual sources, but noise emission is parameter necessary for the model. The European Commission WG-AEN[2] recommends that aircraft taxiing "should be considered as industrial noise and mapped accordingly so that the full impact of all the noise sources at these airports can be assessed". But there is no data available to describe directivity or sound power level emitted by aircrafts during taxiing.

Objectives

The objective of this investigation is to create a database of inputs that can be used with noise prediction software to evaluate noise of aircraft taxiing movements and community noise exposure levels.

The acoustic consultant can use these data with any of the software packages to simulate taxiing by moving point source.

The main procedures, references and results of the investigation were published by the authors in Refs 3 and 4.

Methodology

Sound power level

When it is needed to estimate sound power levels emitted by a noise source, usually ISO 3744[5, 6] is used, which describes a procedure based on sound pressure level measurements in a free field over a reflecting surface. The main steps in the procedure are:

8. A measurement surface grid must be defined to envelope the noise source. It is used to locate microphone positions and its dimensions are defined in the standard.
9. Linear averaged third octave band spectra must be measured for all microphone locations.
10. Averaged surface sound pressure levels must be calculated from measurements.
11. Third octave bands sound power levels are obtained and can be A-weighted to obtain overall levels.

Applying this standard to aircrafts' taxi in an airport can be very difficult because of several reasons, so we had to make some simplifications to apply an ISO3740 based method.

We also tried an alternative method based in ISO 9613, which describes sound propagation physics, to find requested sound

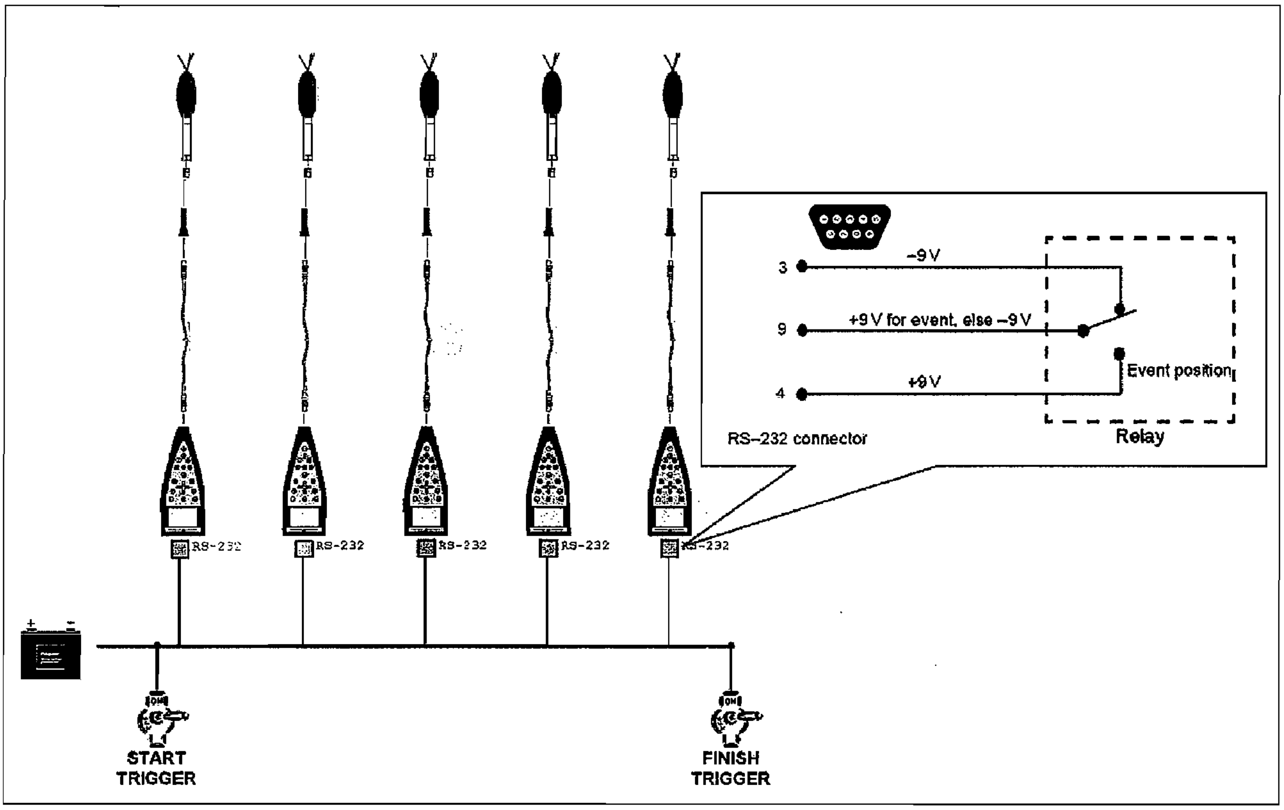


Figure 1. Synchronized markers

power levels from measured sound pressure levels.

Test platform and measurements positions

Airport's operation, security and safety standards make it impossible to control many of the conditions referred to in the test platform. So airport authorities suggested a 200 meter length area, where operations are representative of aircrafts' taxi, there are no reflections but ground and aircrafts move in a straight line with constant speed.

A reference surface covering the whole test platform was defined. The measurement surface had to be defined quite far from the reference surface because of safety reasons. Because of these same reasons, it was not possible to locate any measurement position over the aircraft, in the front or back of the measurement surface, or at a height over 4m.

According to all these restrictions, five microphone positions were uniformly distributed parallel to the runway. All of them were located in one lateral of the measurement box, as it is assumed that noise emissions are symmetrical with respect to the runway axis.

In order to get some information about vertical directivity, two different heights above ground were used: three microphones were located at a height of 2 meters, and the other two were located at a height of 4 meters.

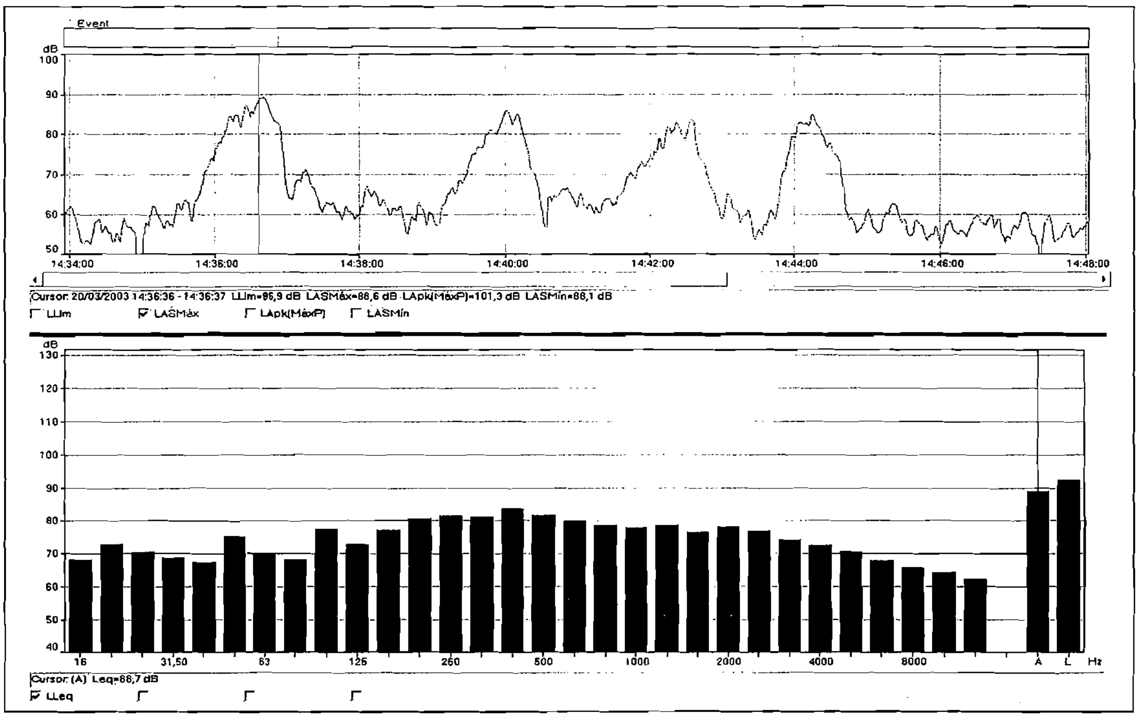
Five third octave band analyzers (Brüel & Kjaer 2260) were used to register time history for spectra and overall equivalent noise level in 1 second intervals (L_{Aeq1s}).

A technician was located at the beginning of the platform to trigger an event at the aircraft entrance to the test platform, and another one at the end of the platform finished the event... The trigger was registered in all the synchronized analyzers, so that every 1 second lineal average spectra were recorded while the aircraft was inside the platform. Figure 1 shows the scheme we used for marking events, and Figure 2 obtained data for one of the analyzers.

Because of its randomness, background noise could not be evaluated, and no corrections could be made. Because of this, many of the measured events had to be discarded by technicians. More than 300 events were measured, but only 240 could be used and classified into families.

Data processing: ISO3740 based method

While the aircraft is moving inside the platform, surface averaged measurements can be made at two different heights over the ground. We can assume that these measurements are representative for emissions



Cursor: 20/03/2003 14:36:36 - 14:36:37 LLlm=86,9 dB LASMáx=88,6 dB LApk(MáxP)=101,3 dB LASMin=88,1 dB

Cursor: (A) Leq=88,7 dB

Figure 2. Analyzer data

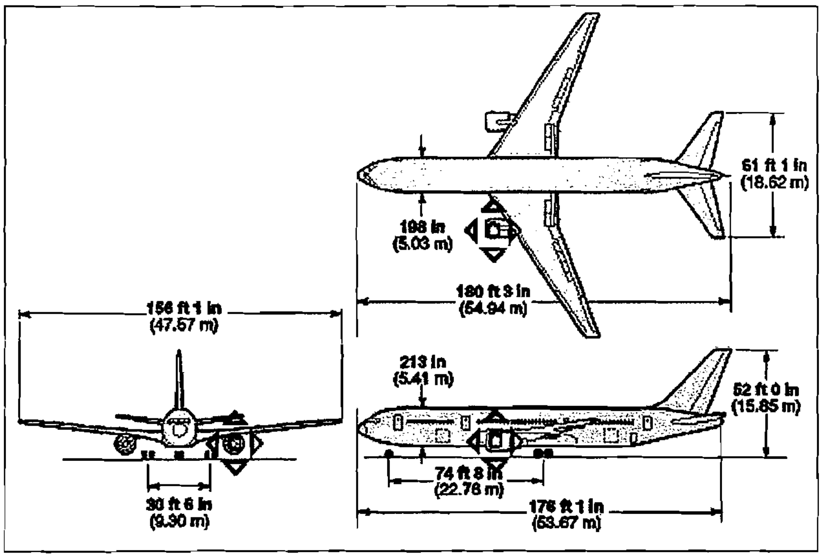


Figure 3. Noise source location

at greater heights, because the vertical emission of engines is symmetrical and most aircrafts have their engines at a height lower than 5 meters.

For each valid aircraft measurement, five third octave band spectra were obtained. Using photographs, technicians' field records, airport's data, and measurements, it was possible to make a classification of events in families, taking into account manufacturer, model and noise emissions. For each family, and each microphone location, sound pressure level spectra were averaged and used to calculate sound power level.

Data processing: ISO9613 based method

An acoustic model was created to simulate sound emissions. Aircraft movement along the path was simulated using some omnidirectional point noise sources over a concrete surface. Each source was located at its correct time dependent location along the path.

The model includes receiver positions, temperature, relative humidity, and ground effect. Family averaged sound pressure spectra were assigned to each receiver.

Then an ISO 9613 inverse calculation was made to estimate the sound power level of each point source. Eqn 1 defines the basic relation between pressure and power levels. It can be applied for all source-receiver combinations and for each frequency band.

$$\begin{aligned} Lw = Lp + Adiv + Aatm +\\ Agr + Abar + Amisc - Dc \end{aligned} \qquad (1)$$

Lw is the octave band sound power level, in decibels, produced by the point sound source. Dc equals the directivity index DI of the point sound source plus an index Do, that accounts for sound propagation into solid angles. Adiv is attenuation due to geometrical divergence. Aatm is attenuation due to atmospheric absorption. Agr is attenuation due to ground effect. Abar is attenuation due to barrier.

Amisc is attenuation due to miscellaneous other effects.

Adiv is calculated by software using distance from sources to receivers. Aatm can be calculated from relative humidity, atmospheric pressure and temperature, applying ISO 9613-1. Agr can be estimated for reflective ground. No additional attenuation effects have been built-in.

Directivity is not explicitly considered, but its effects are integrated in the final results because the model was created by several independent and omnidirectional point sound sources, instead of a single line sound source.

Directivity

Measured time histories were also used to calculate the directivity index of noise sources.

We measured third octave band sound pressure spectra in one second intervals while the aircraft is on the platform. For each frequency band, we can describe a function relating time history intervals and the angle between the axis of the aircraft and each microphone. So we can express measured levels against time or its related angle.

Then we can make some calculations using ISO 9613.

It is assumed that noise emission does not change along the path, for each frequency band, for each receiver, Lw (sound power) and Agr (ground effect) do not change while the aircraft is on the test platform. Aatm (atmospheric attenuation) can be also considered as a constant; Abar=0 because no barrier is considered.

Then we must find the distance (r) from source to receiver, so that we can calculate divergence attenuation (eqn 2),

$$A_{div} = 20 \log r + 11 \qquad (2)$$

Adiv must be calculated for each microphone and for each position in the source path, which is related to an interval in the measured time history. Using Adiv, we can remove the influence of distance in measurements, so only directivity has an influence in time history spectra. After this correction, sound pressure level changes from one second to next, only because the angle from source to receiver changes. We have to find a function that relates both, time and angle, to obtain a new data series which describes the aircraft directivity in an angle that ranges from approximately 20 to 160 degrees (angles nearer the axes cannot be defined because of the receivers' locations).

This process has been applied for every measured aircraft.

Depending on such factors as aircraft speed or length, obtained directivity is described for different angle steps. After interpolation, and averaging, directivity was obtained for every aircraft family.

Results

Third octave band sound power levels were calculated using the ISO 3740-based method, but because of software limitations, ISO 9613-based results were expressed in octave bands terms.

We have calculated A-weighted overall results, and the difference between methods for each family. Overall results are very similar: 75% of the differences were lower than 1dB, while 100% were lower than 1.5dB.

Both methods have obtained very similar overall results and even spectra are very similar, but some differences appear at high frequencies in spectra, because the ISO3740 based method does not include corrections for sound attenuation in the air. Figure 4 shows the main overall results and differences.

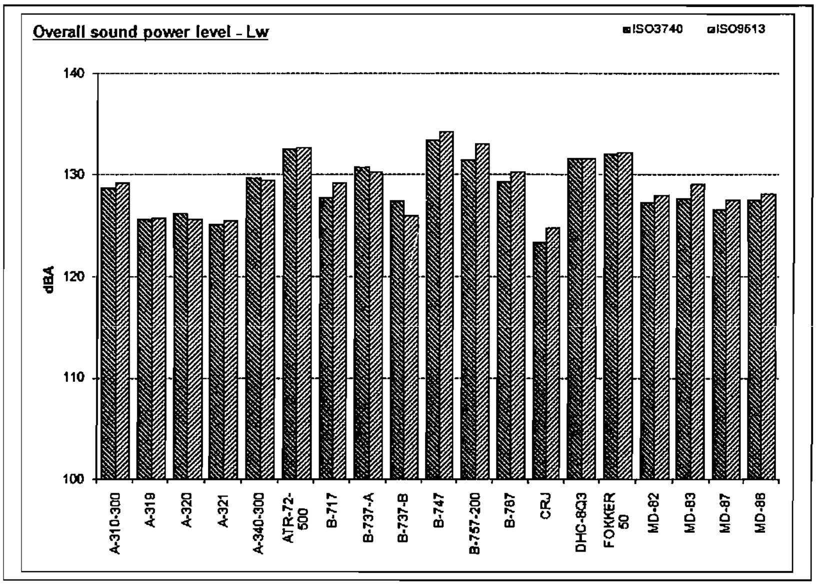


Figure 4. Sound power level

Table 1 shows octave band sound power level for some of the most representative aircrafts families (Boeing, Airbus, McDonnell Douglas, and Fokker)·

Calculated data can be used in prediction software that consider attenuation of sound during propagation outdoors creating a model of a moving point source, several point sources or a line source. It is necessary to include in the model corrections to consider parameters not described in this article, such as the number of operations of each family,

Table 1. Sound power level spectra

	Sound power level (dB) - ISO9613 based method						
Frequency (Hz)	B 747	B 767	A 320	A 321	MD 82	MD 88	Fokker 50
63	129,7	120,0	120,3	122,0	122,3	116,5	124,3
125	126,3	126,2	124,4	125,3	125,3	122,8	129,3
250	127,6	127,8	118,5	117,7	119,7	118,1	124,2
500	124,8	122,8	119,1	117,4	119,7	120,8	124,6
1k	124,4	122,8	119,2	117,5	119,3	119,3	123,9
2k	128,9	122,7	118,5	118,1	122,0	121,3	126,4
4k	127,4	124,3	119,3	120,1	120,3	119,2	125,4
8k	127,2	121,7	115,8	116,8	122,4	124,5	124,6

Table 2. Line source sound power level spectra for studied runway

	63	125	250	500	1k	2k	4k	8k
Lw, dB/m	93	96	91	91	92	92	93	92

paths, speed and the event duration, the studied period for calculations, ... For instance, according to Madrid-Barajas airport statistics, we can predict long-term equivalent noise level (LAeq,24h) using a line source which sound power level is shown in Table 2 (2dB security range included).

Figure 5, shows some charts describing directivity indexes at 500 and 1000 Hz.

ACKNOWLEDGEMENTS

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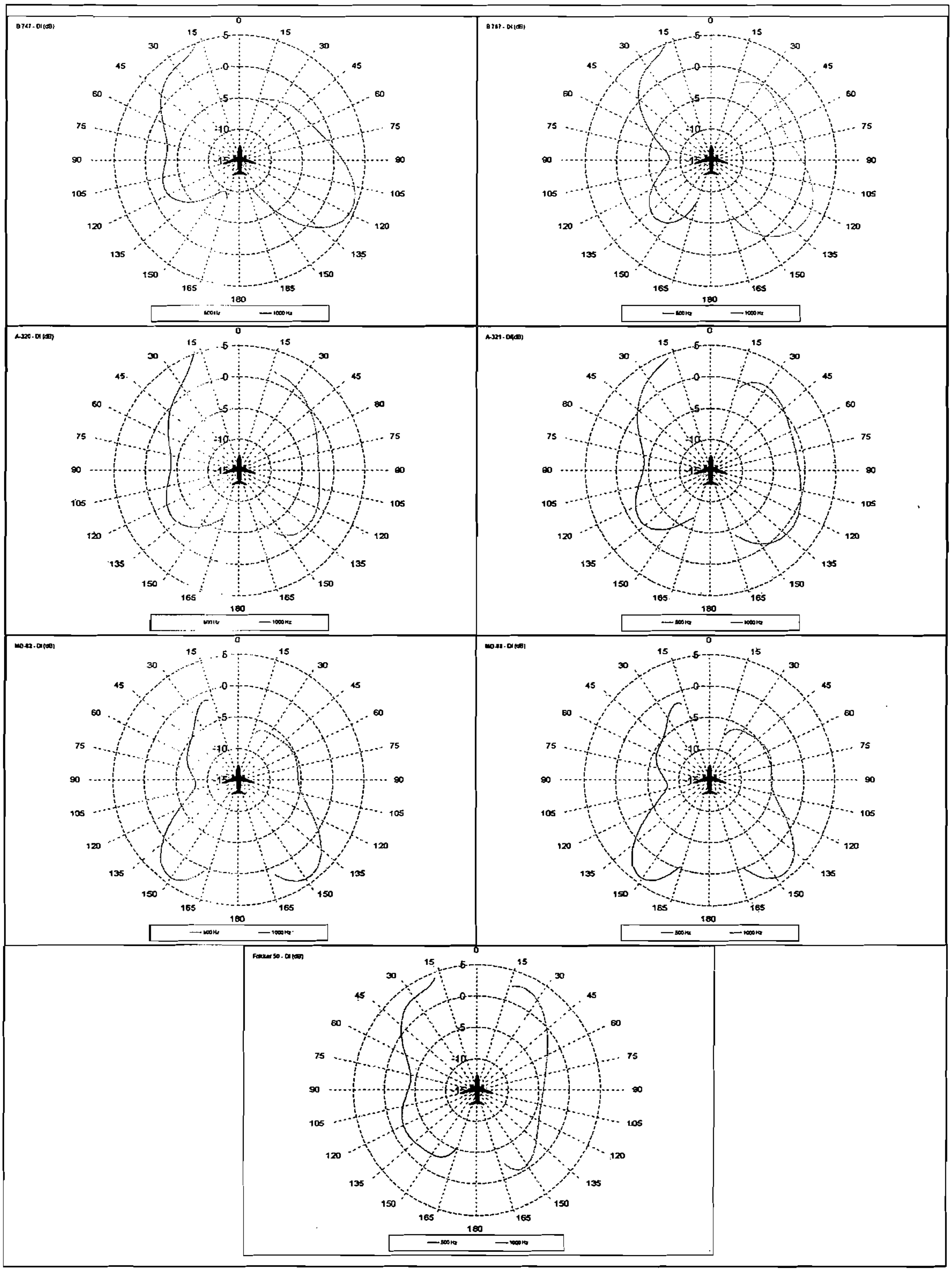

Figure 5. Directivity index

More planes, more noise?

The Boeing Company projects that the global air cargo market will continue to exhibit strong, long term growth, according to the company's Current Market Outlook 2008. During the 20-year forecast period, Boeing projects that the industry will grow at an annualised average of 5.8 percent with the world freighter fleet increasing from 1,948 to 3,892 aeroplanes. This growth requires a total of 3,358 aeroplanes joining the freighter fleet by 2027, taking into account anticipated aeroplane retirements of 1,414 aeroplanes, according to the annual Outlook which was released prior to the 2008 Farnborough Air Show.