Acoustic modeling of an aircraft fuselage
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Synopsis
During flight at cruising speed, a turbulent boundary layer (TBL) forms around the aircraft fuselage. The fluctuating pressure on the external surface of the fuselage skin causes the panels to vibrate resulting in the generation of noise which can be heard inside the cabin. Bombardier is interested in developing high level of understanding techniques, particularly via Boundary Element Methods (BEM), to remain commercially competitive and has expressed interest in reviewing their manufacturing processes. The first stage of the investigation sought to review the effects of varying panel thickness, and the milled pocket area of a panel. The second stage required an operational testing facility and involved 1) construction of an anechoic room to interface with a reverberation chamber, 2) develop an acoustic data acquisition (DAQ) program and 3) a post-processing procedure for the collected data. The third stage of the investigation entailed room qualification tests, acoustic testing of the panels, and computational modeling of the experiments.

Background
There are two principal measurement quantities of interest: sound pressure level (SPL), and acoustic power. These quantities are often expressed on a logarithmic scale [dB]. The frequency range of interest is within the audible spectrum (approximately 20Hz to 20kHz): between 100Hz and 4000Hz; the selection is because the TBL dominates the interior noise field between 500Hz and 2000Hz [1]. The data is collected in 1/3 octave bands and often presented in 1/1 octave bands.

Methods
The DAQ software is LabVIEW-based. Simultaneously, the software collects data from two inputs and outputs a signal to a sound source; some elementary arithmetic is performed. All acoustic tests follow ASTM C423, E90, E336, E477 and E2235, and ANSI S12.51 standards; all deviations are noted and consistent among compared tests. These standards outline general test and proper calculation procedures to account for flanking/breakout noise, source and receive room sound level corrections, etc. LMS Virtual.Lab is the modeling tool used to simulate the coupled vibro-acoustic analysis. In stage one, the tool was used to predict the acoustic performance of 1) panels of 40, 50, 60, 79, 158 and 197thou thicknesses and 2) 50thou panels with 0%, 20%, 50% and 80% of the panel area milled to 40thou. In stage three, 40thou and 90thou square panels were tested experimentally and modeled computationally.

Results & Conclusions
In the first stage, it was discovered that the amplitude of the SPL and power varied little when varying thickness between 40thou and 197thou. It was observed that with decreasing panel weight, the frequency modes were translating towards lower frequency values (contrary to $\sigma^2 = k/m$). It was hypothesized, verified experimentally, and supported by literature [2], that the stiffness of the panel dominated its mass-component at the given geometries and frequencies of interest by a factor of the square of the thickness. See Figure 1a & 1b. In the third stage, the experimental data was compared to that of the computational model. See Figure 2a & 2b. There are ongoing efforts in improving the accuracy and precision of the results by methodically determining available model parameters.

References