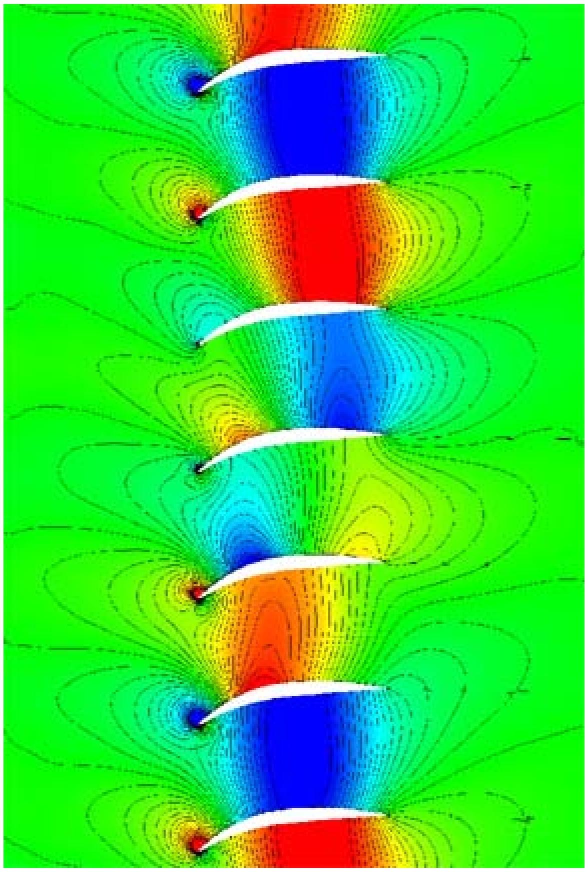
Benchmark Problems Used to Assess Computational Aeroacoustics Codes

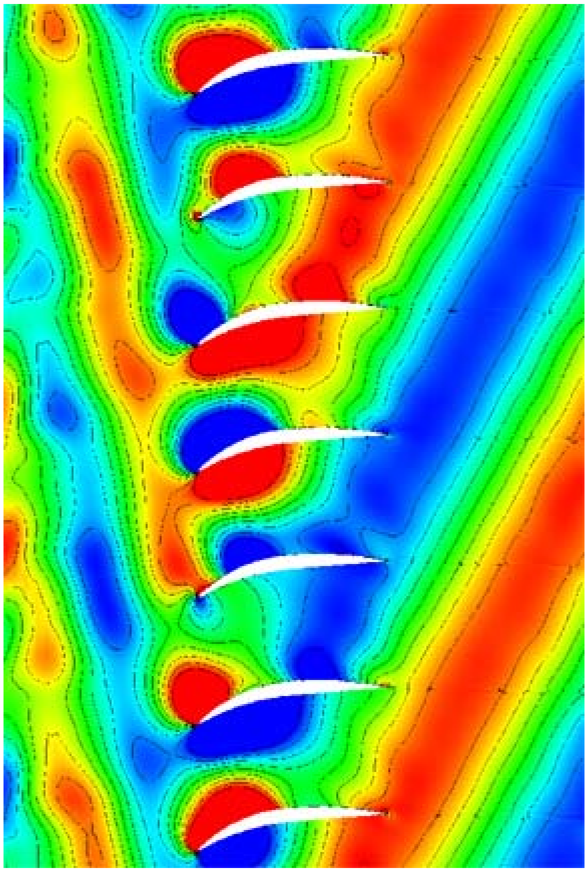
The field of computational aeroacoustics (CAA) encompasses numerical techniques for calculating all aspects of sound generation and propagation in air directly from fundamental governing equations. Aeroacoustic problems typically involve flow-generated noise, with and without the presence of a solid surface, and the propagation of the sound to a receiver far away from the noise source. It is a challenge to obtain accurate numerical solutions to these problems.

The NASA Glenn Research Center has been at the forefront in developing and promoting the development of CAA techniques and methodologies for computing the noise generated by aircraft propulsion systems. To assess the technological advancement of CAA, Glenn, in cooperation with the Ohio Aerospace Institute and the AeroAcoustics Research Consortium, organized and hosted the Fourth CAA Workshop on Benchmark Problems. Participants from industry and academia from both the United States and abroad joined to present and discuss solutions to benchmark problems. These demonstrated technical progress ranging from the basic challenges to accurate CAA calculations to the solution of CAA problems of increasing complexity and difficulty. The results are documented in the proceedings of the workshop (ref. 1).

Problems were solved in five categories. In three of the five categories, exact solutions were available for comparison with CAA results. A fourth category of problems representing sound generation from either a single airfoil or a blade row interacting with a gust (i.e., problems relevant to fan noise) had approximate analytical or completely numerical solutions. The fifth category of problems involved sound generation in a viscous flow. In this case, the CAA results were compared with experimental data.

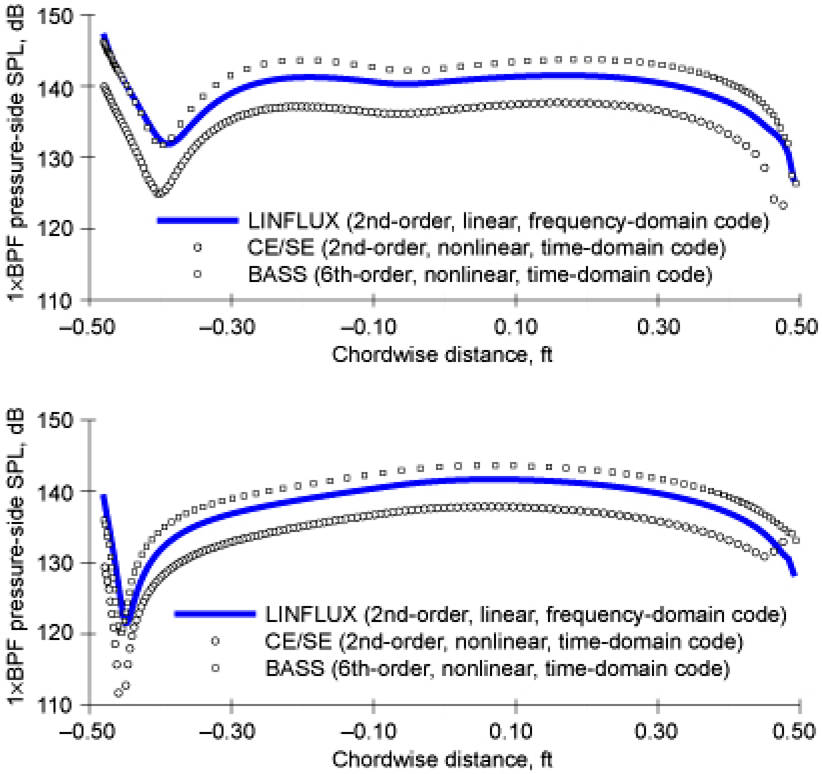


Computed pressure perturbation response to a gust at the primary frequency. This contour plot shows that the perturbations oscillate within the passages between the stator vanes and decay rapidly away from the vanes.



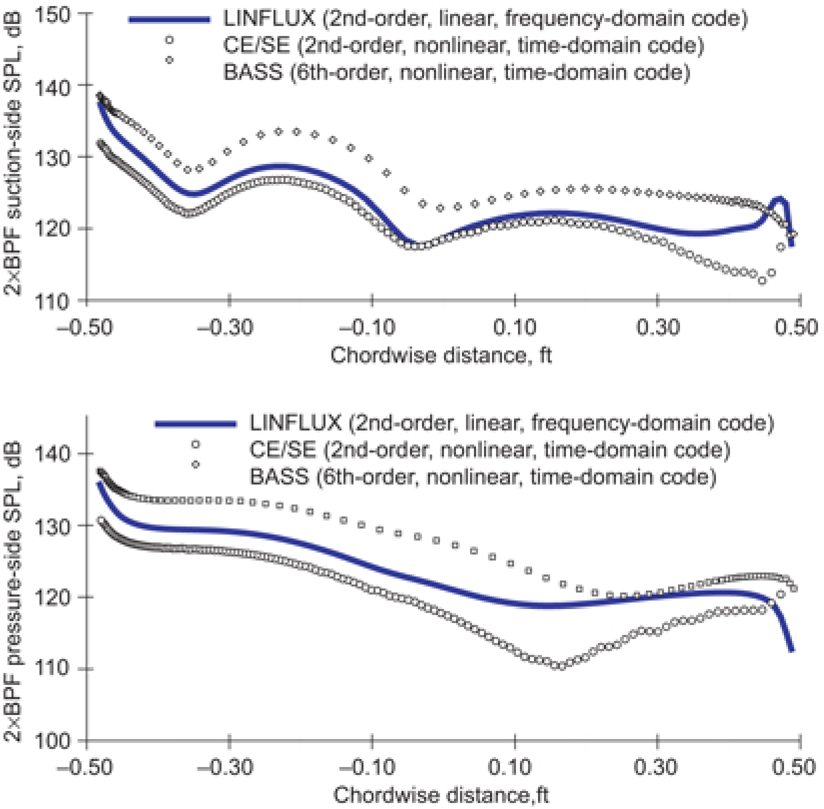
Computed pressure perturbation response to a gust at twice the primary frequency. This contour plot shows that the perturbations are propagating away from the stator vanes in both the upstream and downstream directions.

A sample result from the workshop is shown here for the case of sound generated by a gust interacting with a cascade of realistic stator vanes. This problem represents a principal source of fan noise in aircraft engines called the rotor-stator interaction noise, which is produced by the impingement of the fan rotor wakes on the fan exit guide vanes. A code called LINFLUX, which was developed at the United Technologies Research Center under Glenn funding, can be used to predict this source in realistic three-dimensional geometries. LINFLUX was used to compute the standard, or benchmark, solution to this problem. The contour plots show the computed pressure perturbations at one and two times the primary gust frequency, which for the specified operating conditions result in decaying (or evanescent) and propagating acoustic fields, respectively. The line plots show detailed pressure perturbation solutions on a typical vane. Good agreement is shown between the LINFLUX solution and two other codes being developed under Glenn sponsorship. Further comparisons for this problem and results for other problems are found in the proceedings (ref. 1).



Computed time-averaged pressure perturbation amplitude on each surface of a typical stator vane at the primary frequency of the gust. This plot compares results from three different codes, with the LINFLUX code representing the benchmark case. BPF, blade passing frequency; SPL, sound pressure level.

Long description of figure 3. Suction-side and pressure-side graphs of sound pressure level in decibels for the primary blade passing frequency versus chordwise distance in feet for LINFLUX (second-order, linear, frequency-domain code), CE/SE (second-order, nonlinear, time-domain code), and BASS (sixth-order, nonlinear, time-domain code).



Computed time-averaged pressure perturbation amplitude on each surface of a typical stator vane at twice the primary frequency of the gust. This plot compares results from three different codes, with the LINFLUX code representing the benchmark case. BPF, blade passing frequency; SPL, sound pressure level.

Long description of figure 4. Suction-side and pressure-side graphs of sound pressure level in decibels for twice the primary blade passing frequency versus chordwise distance in feet for LINFLUX (second-order, linear, frequency-domain code), CE/SE (second-order, nonlinear, time-domain code), and BASS (sixth-order, nonlinear, time-domain code).

Reference

1. Dahl, Milo D., ed., Fourth Computational Aeroacoustics (CAA) Workshop on Benchmark Problems. NASA/CP--2004-212954, 2004. http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2004/CP-2004-212954.html

Glenn contact: Dr. Milo D. Dahl, 216-433-3578, Milo.D.Dahl@nasa.gov
Authors: Dr. Milo D. Dahl and Dr. Edmane Envia
Headquarters program office: Aeronautics Research
Programs/Projects: QAT