Realistic Simulation of Jet Engine Noise using Petaflop Computing

Sponsor: National Science Foundation (NSF), Office of Cyberinfrastructure (PetaApps Program)
PI: Gregory Blaisdell, School of Aeronautics and Astronautics, Purdue University
Co-PIs: Anastasios (Tasos) Lyrintzis, Dept. of Aerospace Engineeing, Embry Riddle Aeronautical University; Zhiyuan Li, Department of Computer Science, Purdue University
Graduate Students: Nitin Dhamnakar (AAE), Shanmukesh Vankayala (AAE), Sashwat Mishra (AAE)
Project Period: 09/01/2009 - 08/31/2015

Summary

The goal of this study is to advance the science of subsonic and supersonic jet noise prediction for modern-day turbofan aircraft engines using petascale computing. Jet noise is an important issue due to increased air traffic, penalties for noisier aircraft, future stringent noise regulations and military operational requirements. We will focus on the effect on noise of mixing devices, i.e. chevrons and lobed mixers. The PIs will investigate turbulent mixing by accurately simulating it with advanced computational techniques based on large eddy simulation (LES). Integral acoustic methods will extend the computational fluid dynamics (CFD) results to the far-field. Previous experiments have shown that a 50% decrease in jet noise power output can be achieved by certain chevron and lobe mixer designs without essentially changing the net thrust of the engine. However, the physical mechanisms for the reduced noise are not well understood. Processing speeds and memory sizes of existing supercomputers limit current simulations to low Reynolds numbers and idealized geometries for the mixing devices. Thus, these simulations do not allow design and optimization of mixing for noise reduction, especially since these mixing devices influence the high frequencies of the noise spectrum, increasing the grid resolution requirements. Modeling at realistic Reynolds numbers and nozzle geometries requires tens of billions of points. Simply running existing codes on bigger computers is not the answer. The PIs algorithms will be designed to take advantage of multi-level parallelism and, within a node of such an architecture, address the 'memory wall' aspect of multicore architectures where the cost of arithmetic operations is much smaller than memory references. Our algorithms will be based on a mixture of the transposition scheme and the multi-block approaches we used in the past. This project is a 'first principles' approach that will enhance our level of understanding of the problem. Our methodology will be validated by making comparisons with both turbulence and acoustics measurements from high-quality experiments using realistic nozzle geometries. This project represents a computational engineering activity integrating modern modeling, parallel algorithm design and fine-tuned implementations on petascale architectures. The project will help promote interdisciplinary research, teaching, training, and learning by training three Ph.D. graduate students. We will also involve one undergraduate research assistant during each summer for the five years of the project. Outreach to inner-city high school students from Indianapolis will be done through Purdue's Science Bound Program. The findings of this research will be shared with the aerospace and computer industries. As appropriate, results will also be shared with the general public through the Purdue News Service.

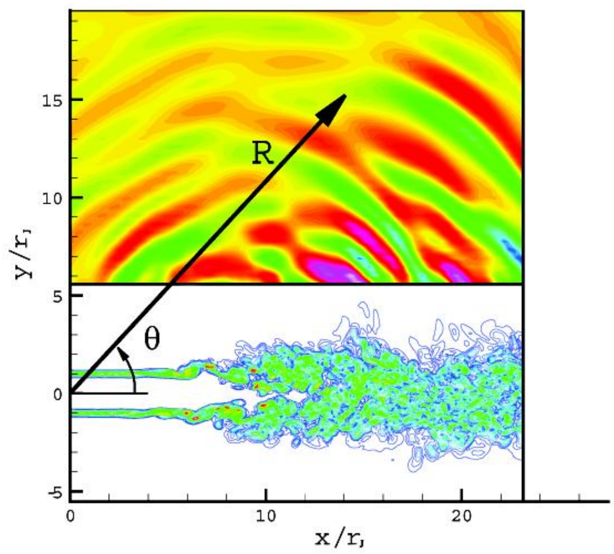

Figure 1. Part of an x-y plane at one instant in time from a large eddy simulation of a turbulent jet. In the near field vorticity magnitude contours are used to visualize the turbulence, while away from the jet contours of divergence of velocity help show the acoustic field. (The nozzle exit plane is located at x=0, between y=-1 and 1.)

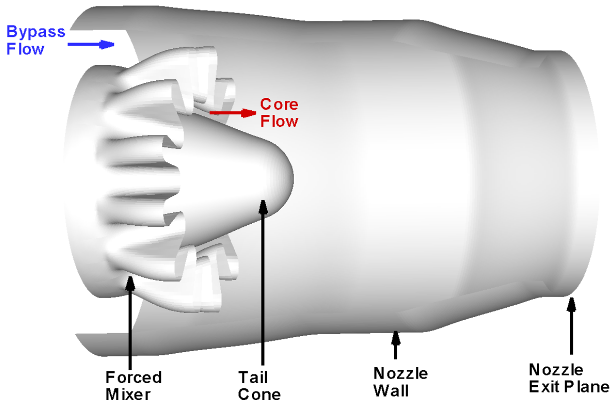

Figure 2. Cut-away diagram of a nozzle with a lobbed (or forced) mixer, which mixes the hot flow through the core of the engine and the cooler bypass flow. This is an example of a mixing device.