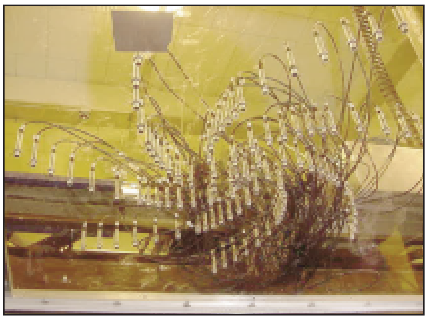


Figure 1. The **Array of Microphones** was mounted above the aircraft model in the test section of the wind tunnel. A cloth cover has been removed from under the microphones to make the model visible in this view.

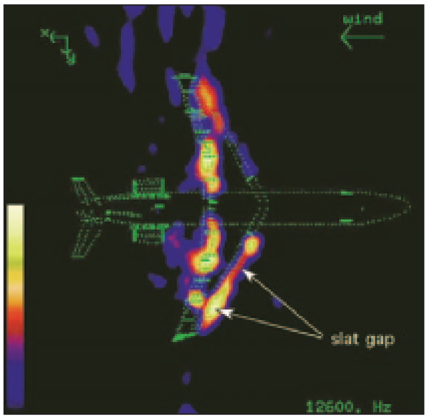


Figure 2. A **Contour Map of Wing-Slat Noise** at a frequency of 12.6 kHz was computed from measurements made by the microphone array. The color-contour range is 8 dB.

noise sources in the high-lift system, landing gear, fins, and miscellaneous other components were located and compared for sound level and frequency at one flyover location. Numerous noise-alleviation devices and modifications of the model were evaluated. Simultaneously with acoustic measurements, aerodynamic forces were recorded to document aircraft conditions and any performance changes caused by geometric modifications.

Most modern microphone-array systems function in the frequency domain in the sense that spectra of the microphone outputs are computed, then operations are performed on the matrices of microphone-signal cross-spectra. The entire acoustic field at one station in such a system is acquired quickly and interrogated during postprocessing. Beam-forming algorithms are employed to scan a plane near the model surface and locate noise sources while rejecting most background noise and spurious reflections. In the case of the system used in this study, previous studies in the wind tunnel have identified noise sources up to 19 dB below the normal background noise of the wind tunnel. Theoretical predictions of array performance are used to minimize the width and the side lobes of the beam pattern of the microphone array for a given test arrangement.

To capture flyover noise of the inverted model, a 104-element microphone array in a 622-mm-diameter cluster was installed in a 19-mm-thick poly(methyl methacrylate) plate in the ceiling of the test section of the wind tunnel above the aircraft model (see Figure 1). The microphones were of the condenser type, and their diaphragms were mounted flush in the array plate, which was recessed 12.7 mm into the ceiling and covered by a porous aromatic polyamide cloth (not shown in the figure) to minimize boundary-layer noise. This design caused the level of flow noise to be much less than that of flush-mount designs. The drawback of this design was that the cloth attenuated sound somewhat and created acoustic resonances that could grow to several dB at a frequency of 10 kHz.

A correction methodology has been developed to account for the signal interference. The first side lobe of the beam pattern was 13.4 dB down from the peak response at 8 kHz and at an angle of 23° from the normal vector: these characteristics made it possible to obtain good acoustic signals from the model when the model was located at a distance of 1.11 m from the array. Data were acquired at 12,321 scan points in a plane encompassing the model. From these data, aerodynamic noise from sources as small as 6 mm on the model surface could be identified easily.

The microphone signals were digitized at a rate of 153,600 samples per second on 104 channels simultaneously by use of analog-to-digital converter circuits and a computer. The resulting maximum acoustic frequency was 60 kHz with a bandwidth of 300 Hz. The data for frequencies <2 kHz were found to be of marginal utility because the microphone beam pattern at those frequencies was too wide. The data for frequencies >32 kHz were found to be of marginal utility because at those frequencies, the sources were too weak and the side lobes too strong. The frequency limits of 2 and 32 kHz correspond to limits of 140 and 2,240 Hz, respectively, on the full-scale aircraft.

A sound-convection correction was included in the processing of the data so that sources appeared to come from the model rather than being swept downstream. The acoustic sources were depicted, one frequency at a time, as color contours on the scan plane with the model outline superimposed, as shown in Figure 2. Various integration schemes have been developed to compute the combined effects on a listener and to generate narrowband and third-octave acoustic spectra.

Ten airframe noise sources that might be important to approach and landing noise of the full-scale aircraft were identified in the study. The relative strengths of these sources and their dependences on the configuration of the aircraft were documented. Although the data were scaled to the frequencies for the full-scale aircraft, no extrapolation to full-scale flyover was performed.

This work was done by Paul T. Soderman of **Ames Research Center**. *For further information, contact the Ames Technology Partnerships Division at (650) 604-2954.*
ARC-14967

Loci-STREAM Version 0.9

Marshall Space Flight Center, Alabama

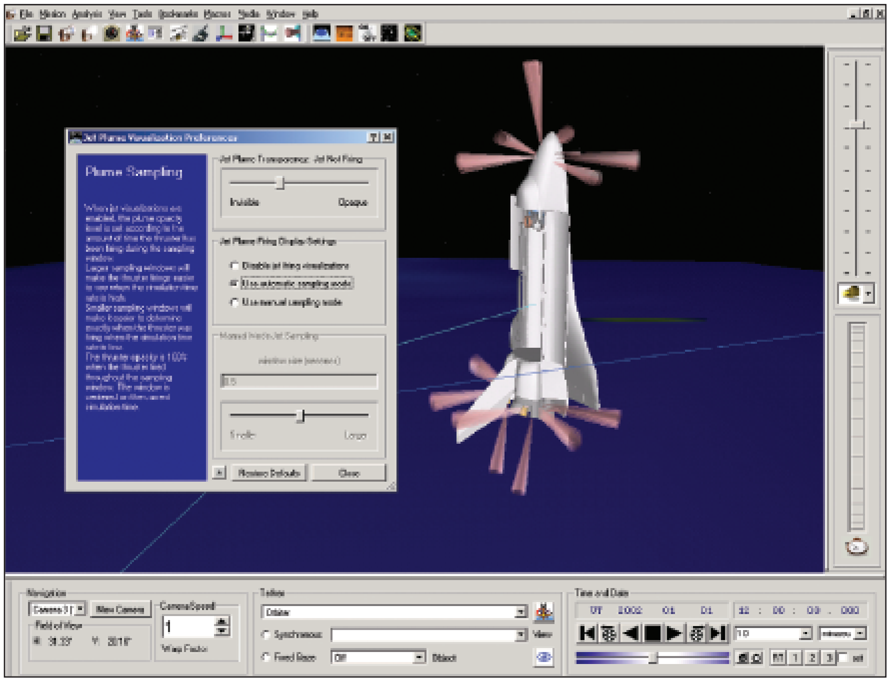
Loci-STREAM is an evolving computational fluid dynamics (CFD) software tool for simulating possibly chemically reacting, possibly unsteady flows in diverse settings, including rocket engines, turbomachines, oil refineries, etc. Loci-STREAM implements a pressure-based flow-solving algorithm that utilizes unstructured grids. (The benefit of low memory usage by pressure-based algorithms is well recognized by experts in the field.) The algorithm is robust for flows at all speeds from zero to hypersonic. The flexibility of arbitrary polyhedral grids enables accurate, efficient simulation of flows in complex geometries, including those of plume-impingement problems. The present version — Loci-STREAM version 0.9 — includes an interface with the Portable, Extensible Toolkit for Scientific Computation (PETSc) library for access to enhanced linear-equation-solving programs therein that accelerate convergence toward a solution. The name "Loci" reflects the creation of this software within the Loci computational framework, which was developed at Mississippi State University for the primary purpose of simplifying the writing of complex multidisciplinary application programs to run in distributed-memory computing environments including clusters of personal computers. Loci has been designed to relieve application programmers of the details of programming for distributed-memory computers.

This program was written by Jeffrey Wright and Siddharth Thakur of Streamline Numerics, Inc. for **Marshall Space Flight Center**. *Further information is contained in a TSP (see page 1).*
MFS-32303-1

The Synergistic Engineering Environment

Langley Research Center, Hampton, Virginia

The Synergistic Engineering Environment (SEE) is a system of software dedicated to aiding the understanding of space mission operations. The SEE can integrate disparate sets of data with analytical capabilities, geometric models of spacecraft, and a visualization environment (see figure), all contributing to the creation of an interactive simulation of spacecraft. Initially designed to satisfy needs pertaining to the International Space Station, the SEE has been broadened in scope to include spacecraft ranging from those in low orbit around the Earth to those on deep-space missions. The SEE includes analytical capabilities in rigid-body dynamics, kinematics, orbital mechanics, and payload operations. These capabilities enable a user to perform real-time interactive engineering analyses focusing on diverse aspects of operations, including flight attitudes and maneuvers, docking of visiting spacecraft, robotic operations, impingement of spacecraft-engine exhaust plumes, obscuration of instrumentation fields of view, communications, and alternative assembly configurations. The SEE continues to undergo development at Langley Research Center.



Plumes of Jet Firings can be displayed by the SEE. The user can turn off the firing visualization without disabling the visualization of the location.

This program was written by Jonathan Cruz of **Langley Research Center** *and Scott Angster of Analytical Mechanics Associates, Inc. Further information is contained in a TSP (see page 1).*
LAR-16842-1

Reconfigurable Software for Controlling Formation Flying

Goddard Space Flight Center, Greenbelt, Maryland

Software for a system to control the trajectories of multiple spacecraft flying in formation is being developed to reflect underlying concepts of (1) a decentralized approach to guidance and control and (2) reconfigurability of the control system, including reconfigurability of the software and of control laws. The software is organized as a modular network of software tasks. The computational load for both determining relative trajectories and planning maneuvers is shared equally among all spacecraft in a cluster. The flexibility and robustness of the software are apparent in the fact that tasks can be added, removed, or replaced during flight. In a computational simulation of a representative formation-flying scenario, it was demonstrated that the following are among the services performed by the software:

- Uploading of commands from a ground station and distribution of the commands among the spacecraft,
- Autonomous initiation and reconfiguration of formations,