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Prediction of Particle Number Density and Particle Properties in the Flow Field Observed by the Nephelometer Experiment on the Galileo Probe

Summary of Research for NASA-Ames
Award NCC 2-5236

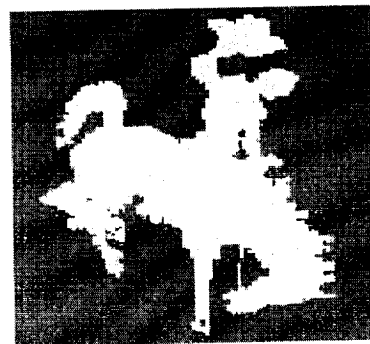*For the Period September 1, 1997 to*
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Introduction

This report summarizes the work performed to assist in the analysis of data returned from the Galileo Probe's Nephelometer instrument. A computation of the flow field around the Galileo Probe during its descent through the Jovian atmosphere was simulated. The behavior of cloud particles that passed around the Galileo probe was then computed and the number density in the vicinity of the Nephelometer instrument was predicted. The results of our analysis support the finding that the number density of cloud particles was not the same in each of the four sampling volumes of the Nephelometer instrument. The number densities calculated in this study are currently being used to assist in the reanalysis of the data returned from the Galileo Probe.

Description of Research

This project consisted of three primary computational tasks: (1) the development of a CFD model for the Galileo Probe, (2) the modification of an existing particle dynamics model to work with the complicated geometry of the Galileo Probe, and (3) the development of a post-processing routine to determine number density from a collection of particle paths. Each of these three tasks is discussed in further detail below.

Galileo Probe CFD Model

This work was primarily carried out by Periklis Papadopolous at NASA-Ames Research Center. A computer model of the Galileo Probe and Nephelometer instrument was first developed from a model of the instrument and drawings of the probe. A complex volume grid was then generated from this geometric model. A Chimera approach with six overlapping grids was used to encompass the volume around the Galileo Probe and Nephelometer assembly. The six grids contained over 650,000 grid points.

To use these grids with the Navier-Stokes Solver OVERFLOW (developed by NASA), information about how flow properties will be passed back and forth across the grid boundaries is required. To accomplish this, PEGSUS (developed by the AIR FORCE) is used to write files that OVERFLOW uses during a computation.

Having assembled the geometry, OVERFLOW was used to simulate the flow at three points in the Galileo Probe Trajectory. Details of the solution can be found in reference 1. For this study, OVERFLOW was modified to account for the viscosity relationship of the Helium/Hydrogen atmosphere. For the three cases run, approximately 2000 iterations provided sufficient convergence, which required approximately 10 hours of CPU time on a DEC Alpha.

Particle Path Computation

Particle trajectories around the Galileo Probe and Nephelometer assembly were found using GPATS, a particle dynamics computer program developed by personnel at the University of Wyoming. A brief discussion of the code is included in reference 1. For the present simulations, approximately 100,000 particles were followed through the flow-field for each particle size of interest. For each of the three points in the Galileo Probe trajectory calculated with OVERFLOW, six particle sizes ranging from 1 to 40 microns in diameter were simulated (or approximately 2,000,000 particles total were tracked). The time associated with running each of these 100,000 particle cases varied from minutes to hours depending on the particle size.

Number Density Computation

The goal of the present study was to determine the number density in each of the four sampling volumes of the Nephelometer. This information was desired to assist in the analysis of the data returned from Jupiter. Details of the number density calculation are given in reference 1. In brief, particles passing near a sampling volume were identified. The combined effects of the number of particles entering a sampling volume and the velocity of each particle were used to determine the number density relative to

that in the free stream. This number density was calculated in each of the Nephelometer's sampling volumes for six particle sizes at the three points in the probe's trajectory.

Important Results

A summary of the important results of this study is given here, and a more full discussion can be found in reference 1.

The ability to determine the number density in a complex flow has been demonstrated. This analysis requires the use of a computational fluid dynamics program, a particle dynamics program, and a post-processing routine to determine the number density from individual particle paths.

The flow-field computations reveal a very complex flow around the Galileo Probe. In particular, the flow near the Nephelometer's sampling volumes is complicated, and this is expected to account for the strange results returned from the Nephelometer instrument. The details of the results in the complex regions of the flow must be considered with caution since the computation is assumed to be steady. In the complex regions of the flow, unsteady results may be more likely.

The results from the particle trajectories confirm that the complex flow-field structure did affect the trajectories of all but the largest particles. The inertia of these larger particles makes them relatively insensitive to the flow field. However, when these particles encounter a solid surface, they normally strike it. Thus, the number densities of even these largest particles are affected.

The calculated number densities near the Nephelometer indicate that two of the sampling volumes have fairly constant number densities for all trajectory points and particle sizes. The other two sampling volumes experienced lower number densities, although the exact values varied with condition. A fair correlation between the number density and the Stokes number is evident in this flow.

It is evident from this work that this type of analysis done during the design phase of such an instrument would be exceedingly valuable for validating the design concept.

Publications, Inventions, and Patents

There were no inventions or patents associated with this work. A conference paper on this work was presented at the 37th Aerospace Sciences Conference in Reno, NV (see reference 1 below). Two journal articles based on this work are currently under preparation. The data from this study is currently being used to reanalyze some of the data sent back from the Galileo Probe.

References

1. Popp, J., Naughton, J., Papadopoulos, P., Venkatapathy, E., & Ragent, B., "Simulation of Galileo Probe Descent Through Jovian Clouds," AIAA Paper 99-0561, presented at the 37th Aerospace Sciences Conference, Reno, NV, January 1999.

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