Computations of radiating expansion tube flows for the simulation of planetary entry

**Rowan J. Gollan and Peter A. Jacobs*

The University of Queensland, Brisbane, Australia

During planetary entry, aeroshell spacecraft experience high thermal loads due to the elevated temperatures of the atmospheric gases around the vehicle. The experimental study of typical aeroshell configurations is currently being done to assess heat transfer rates to the vehicle surface. These experiments are on subscale models and are performed in the superorbital expansion tubes at the University of Queensland. Computational modelling of the experimental configurations is also used to aid and extend the results of the experiments. The challenge for the numerical work is to include all the effects of high-temperature gas physics which are likely to be present in the experimental conditions. To this end, this paper describes a model to compute the radiating flowfield for a gas in thermal and chemical nonequilibrium.

In a previous paper, the problem of radiative transfer within the flowfield was treated with air as the test gas. It was shown that, at the subscale sizes tested in the superorbital expansion tubes, there is little effect of radiation in the flow. In this paper, we turn our attention to the entry trajectory of a typical mission to Titan, the largest moon of Saturn. The gases in Titan's atmosphere of methane and nitrogen react in the high temperature shock layer behind the bow shock. One of the products formed is the cyanide molecule which is a strong radiator at moderate temperatures. The presence of this molecule significantly increases the level of radiation in the flowfield.

This paper presents computations of the flowfield for a typical experimental condition and subscale model size. There are two phases to the modelling. The first is a large-scale parallel simulation of the expansion tube facility to provide flow conditions at the end of the expansion tube. These flow conditions are used as input to the second, small-scale calculation of the radiating flow around the aeroshell. The numerical model used treats the gas as being in both thermal and chemical nonequilibrium. The problem of radiative transfer is treated as one-dimensional — a tangent-slab approximation, with the radiative properties of the gas computed by a modern multi-band approach.