Future space missions, such as planned asteroid sample return missions or interplanetary missions such as return from Mars, will involve entry speeds from 13 to 15 km/s. While current hyperbolic Earth re-entry conditions such as Apollo, Hayabusa, and Stardust all featured some degree of radiative heating, a 15 km/s Earth entry will cross the threshold into the region where radiative heat flux is of a similar order of magnitude to the convective heat flux and conditions will be 'radiatively coupled'. Radiative coupling means that the amount of radiative entry transfer in the shock layer results in significant departure from the assumption that the shock layer is adiabatic. For these flows to be modelled correctly, a radiative energy exchange term must then be added to the CFD source terms when the flow is simulated. This increases computational time and is a situation which has rarely been experimentally simulated.

The degree of radiative coupling is generally characterised using a non-dimensional number called the 'Goulard number' [1] which is the ratio of radiative energy flux to the total energy flux in the shock layer. A Goulard number above 0.12 is generally considered 'strongly coupled', with a Goulard number below that value being classed as 'loosely coupled'. Loosely coupled conditions can be simulated with a normal CFD flow solver, with radiation calculations able to be performed after the CFD calculations have finished. Generally, due to scaling increasing convective heat flux in ground testing facilities, it is very hard to generate proper strongly coupled conditions in expansion tubes. A flow velocity of around 14 km/s would be required to generate strongly coupled conditions in X2.

Recently, equilibrium radiative heating up to 15.5 km/s was investigated experimentally in the Electric Arc Shock Tube (EAST) facility at the NASA Ames Research Center by Brandis et al. [3] by studying shock relaxation and integrated radiative power from a passing shock wave. This was compared to recent simulation data by Johnston et al. [4] and used to lower parametric uncertainties for high speed Earth re-entry from [32%, −21%] to [9.0%, −6.3%].

While NRST facilities used for the study of planetary entry are generally limited to the study of shock relaxation due to their very short test times, expansion tubes are very useful in these situations as they are capable of generating a real aerothermodynamic test flow for a short period of time. This allows them to not only be used for the study of shock relaxation over a test model, but also other flow phenomena which occurs over test models. This includes the study of shock standoff, wall heat flux, or even the study of hot or cold wall ablation using either resistively heated test models [5,6] or plastic or epoxy test models [7].

This paper investigates the possibility and feasibility of generating these high speed Earth re-entry conditions in the X2 expansion tube [8] at the University of Queensland (UQ).

REFERENCES


**Summary**

Please find the abstract attached.

**Primary authors:** Dr JAMES, Christopher (The University of Queensland); Dr LEWIS, Steven (The University of Queensland); Dr GILDFIND, David (The University of Queensland); Prof. MORGAN, Richard (The University of Queensland); Prof. MCINTYRE, Timothy (The University of Queensland)

**Presenter:** Dr JAMES, Christopher (The University of Queensland)

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