Paper ID: 47395
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IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Upper Stages, Space Transfer, Entry and Landing Systems (3)

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MULTIDISCIPLINARY ANALYSIS OF REUSABLE ABLATIVE THERMAL PROTECTION SYSTEMS

Abstract

Atmospheric entries are characterized by an extreme heating of the fluid surrounding the spacecraft. To prevent damage to the internal part of the probe or vehicle, Thermal Protection Systems (TPSs) are employed. As any other spacecraft system, TPS encounter stringent weight constraints and must perform their task using the minimum amount of mass possible. The most used and reliable TPSs are ablative materials. These materials undergo a degradation during the atmospheric entry which absorbs part of the thermal energy involved and partially consumes the material. For this reason they are considered non-reusable. However, past experiences have shown that ablative TPSs are designed to be very conservative and might be able to withstand more than one atmospheric entry.

In this study, multiple re-entries will be considered, taking into account no heat shield refurbishment between flights. The vehicle is modelled as a point mass for the trajectory optimisation of the descent path, able to change its angle of attack and bank. The orientation of the vehicle towards the incoming flow is analysed with a first order aerodynamic tool on a 3D mesh to obtain aerodynamic forces and local heat fluxes. These values are then used to calculate the local temperatures and changes in density of the TPS and compute its recession. The 3D mesh is then updated reflecting the ablation process, changing the aerodynamic characteristics of the vehicle.

This work will therefore evaluate the performances of pre-charred heat shields, assess the feasibility of reusable ablative TPSs and analyse the evolution of the controls and performances of such vehicles. It will also analyse the maximum temperature encountered by the spacecraft cold structure and study how this value changes throughout the TPS re-uses.

This analysis is applied to both lifting body vehicles and blunt bodies therefore, it can be used to study the feasibility of TPS solutions for any specific spacecraft from the single use planetary probes to Space Shuttle like re-usable vehicles.