A Study Of Atmospheric Entry Profiles For Mars

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Introduction

- An atmospheric profile is a set of data that contains information about atmospheric density, pressure, and temperature as a function of height in an atmosphere.

- Atmospheric profiles can be derived using measurements from different types of instruments and spacecraft.

- Atmospheric entry profiles are atmospheric profiles derived from measurements taken by an entry vehicle as it descends through an atmosphere.

- There have only been 6 vehicles ever to descend through the atmosphere of Mars and take measurements useful for deriving atmospheric entry profiles. The vehicles are: Viking 1 & II, Pathfinder, Mars Exploration Rovers Spirit & Opportunity, and the Mars Phoenix Lander.

Derivation Methodology

Entry vehicles take measurements of changes in velocity in three orthogonal directions (x, y, z), they take measurements that keep track of the direction in which the entry vehicle points (its orientation/attitude), and they keep track of time.

With this information and few assumptions it is possible to (1) reconstruct the trajectory of the vehicle's entry, descent, and landing, and (2) derive the density, pressure, and temperature of the atmosphere at each altitude.

Derivation Methodology

To make the derivations it is necessary to determine the direction of the travel for the spacecraft. Call this the z axis. Since changes in velocity are measured in three orthogonal directions we know (or can easily determine) what Δv_z is.

From this point it is possible to determine the magnitude of the net acceleration of the entry vehicle:

$$a_z = \frac{\Delta v_z}{\Delta t}$$

If the total velocity at entry is known, then it is possible to know the total velocity for the spacecraft through its entire entry, descent, and landing (EDL) phase. Combined with orientation information it is possible to reconstruct the entire trajectory during the EDL phase.

Once the acceleration is known it is possible to determine the atmospheric density using if you assume that high speed friction is the only force acting on the entry vehicle besides gravity.

$$\rho = \frac{2ma_z}{Av_{rel}^2 C_A}$$

Derivation Methodology

The derivations of atmospheric pressure and temperature are performed using an adapted hydrostatic pressure equation and an adapted version of the ideal gas law.

Other information that is need to perform the derivations is the mass of the spacecraft, the mass of Mars, the altitude at which atmospheric entry is defined, the initial angle of attack of the entry vehicle, the axial force coefficient, and the cross sectional area of the entry vehicle that is orthogonal to the flight path.

What does it tell us?

Atmospheric Entry Profiles allow us to

- Have high resolution data of a specific geographic location of Mars.
- Analyze vertical dust distribution in detail
- Analyze solar radiation on Mars
- Investigate wind patterns at various scale-heights in the atmosphere