# REVIEW OF THE TRAJECTORY AND ATMOSPHERIC STRUCTURE RECONSTRUCTION FOR MARS PATHFINDER

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**Introduction:** Mars Pathfinder (MPF) used a novel landing technique to reach the surface of Mars on July 4th, 1997. It entered the martian atmosphere at 7.6 km $s^{-1}$ on a direct-from-Earth trajectory, descended to 9 km altitude inside its aeroshell, to 100 m altitude on a parachute, to 15 m altitude on retrorockets, then dropped to the surface inside a cocoon of airbags.

**Accelerometers:** MPF's entry state, given in [7], differs from [4] and [6], see discussion in [8]. There is also a timing error of 1.5 seconds that may affect some of the published and archived data, which is discussed in [6]. MPF's aeroshell was a Viking-heritage 70-degree half-angle sphere-cone, diameter 2.65 m, see Figure 2 of [7]. MPF carried 6 Allied Signal QA-3000-003 accelerometers (3 science and 3 engineering), which "sensed acceleration by electromagnetically restricting a test mass to a precise null position" [4]. It did not carry any gyroscopes. MPF's centre of mass was on its symmetry axis, which kept its angle of attack below 5 degrees. "Each accelerometer had three gain states with dynamic ranges of +/- 16 mg, +/- 800 mg, and +/- 40 g. 14-bit digitization gave resolutions of 2 microg, 100 microg, and 5 mg, respectively." [4]. Sampling rates during EDL were 32 Hz. Signal filtering reduced the effective sampling rate.

**Parachute Phase:** The parachute (Viking-heritage, 12.7 m diameter, Dacron fabric, disk-gap-band design) was deployed about 170 s after entry when MPF was travelling at 380 m $s^{-1}$ (Mach 1.8) at 9 km altitude. MPF hung from the parachute on a 20 m bridle, which caused a complex range of motions. Temperature sensors did not measure the atmospheric temperature reliably. Reliable dynamic pressure data have not been converted to atmospheric pressure, owing to the complex motion of the lander-bridle-parachute system. The accelerometers recorded the 18 g impact and 13 subsequent bounces, but switched off before MPF came to rest. MPF's final position (~1 km away from first impact) was accurately determined by radio tracking. The accelerometers accurately measured the surface gravity, testing their calibration. A radar altimeter, which ranged to the surface from 1.4 km to 400 m altitude, also provided additional useful data.

**Reconstructions:** MPF maintained a small angle of attack passively, using aerodynamic static stability, during its entry, so MPF's orientation can be reconstructed simply by aligning its symmetry axis with the relative velocity vector. Starting from the known entry state and this assumption, MPF's axial acceleration data was used to integrate its trajectory until parachute deployment. Once the trajectory was been reconstructed, MPF's aerodynamic database [2,5] was used with the measured axial and normal accelerations to iteratively reconstruct profiles of atmospheric density and angle of attack. If desired, this angle of attack profile could be used to refine the original trajectory reconstruction. The density profile was converted into pressure and temperature profiles in the usual manner. Three different trajectory and atmospheric structure reconstructions were made, one by the science team [4] and two by the engineers [7]. Differences are minor and mostly due to problems in relating the near-impact radar altimeter data and the accelerometer data, which are separated by the poorly-understood parachute descent.

**Caveat:** The present authors were not involved in the MPF reconstruction effort.

**References:** [1] Braun et al. (1995) J. of Spacecraft and Rockets (JSR), v32, pp993-1000 [2] Gnoffo et al. (1996) JSR, v33, p169-177 [3] Gnoffo et al. (1998) http://techreports.larc.nasa.gov/ltrs/PDF/1998/aiaa/NASA-aiaa-98-2445.pdf [4] Magalhaes et al. (1999) J. Geophys. Res., v104, pp8943-8955 [5] Moss et al. (1998) http://techreports.larc.nasa.gov/ltrs/PDF/1998/aiaa/NASA-aiaa-98-0298.pdf [6] MPAM_0001, Planetary Data System archive, http://atmos.nmsu.edu/PDS/data/mpam_0001 [7] Spencer et al. (1999) JSR, v36, pp357-366 [8] Withers et al. (2003) Analysis of Entry Accelerometer Data: A case study of Mars Pathfinder, Planetary and Space Science, in press.