Mars Surface Asset Positioning Using In-Situ Radio Tracking

by
Joseph Guinn, Todd Ely, and Brian Portock
Jet Propulsion Laboratory
California Institute of Technology

ABSTRACT

Introduction

In the past, positioning of Mars surface assets was accomplished by collecting Direct-To-Earth (DTE) radio metric observations and using ground-based navigation software to produce location estimates. Accuracy improvements required many weeks of observations and ultimately an accuracy floor was reached due to limited geometry and uncertainties in the observations. Accuracy improvements and reduction of the number observations can be achieved by using radio metric measurements from an in-situ orbiter. This paper compares positioning performance resulting from DTE only and in-situ orbiter tracking. Rapid turnaround of positioning solutions may enable improved rover operations through more accurate path reconstruction available from this technique. In addition, absolute cartography improvements may result form better correlation between images collected from orbiting cameras (e.g., Mars Global Surveyor) and surface landmarks visited by the rovers.

Analysis Assumptions

A linear covariance tool is used to produce estimates of the expected positioning performance using DTE and in-situ orbiter tracking. Tracking schedules for radio metric observations are assumed for NASA's planned 2003 Mars Exploration Rover Missions. The location of the NASA's 2001 Mars Orbiter can be predicted for the 2003 missions since strict orbit phase requirements ensure known sun relative geometries. Lander DTE only performance is scaled to reflect the expected performance based on results from Mars Pathfinder *(Folkner,1997)*. Geometric constraints such as minimum elevation angles, range limits and planetary occultations are considered. Concurrent observations between the in-situ orbiter, the Deep Space Network (DSN) and Mars lander are assumed. This allows for realistic (fully correlated) in-situ orbiter errors to be incorporated in the lander uncertainty estimates. Uncertainties are derived from the linear covariance analyses updated in one-hour batches as observation become available.

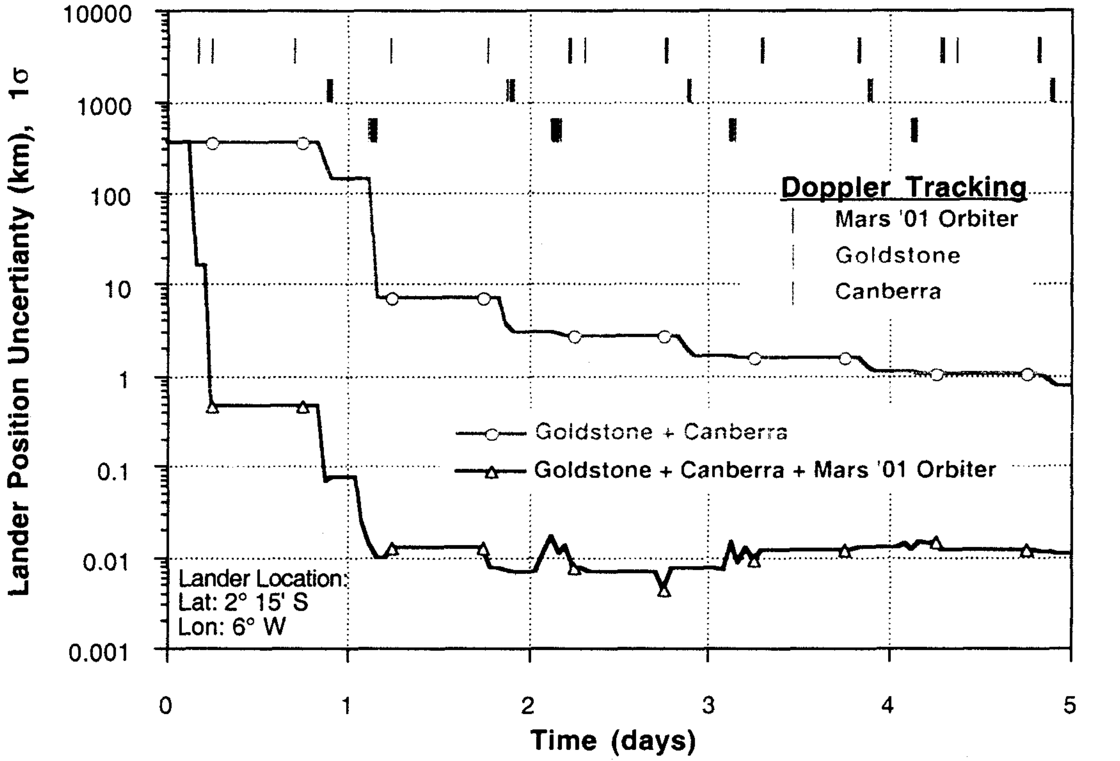
Results

The geometric benefit of in-situ radio metric observations is evident in Fig. 1. With only two short passes a lander position uncertainty is reduced to below one kilometer (one sigma). Within two days the uncertainty can be reduced to a level of 10's of meters. In contrast, the DTE only observations produce a much slower rate of uncertainty improvement. This is primarily due to the lack of various geometries between the Earth tracking stations and the lander. Lander observations from the in-situ orbiter are constrained to be above10 degrees. Some degradation is expected if these observations are limited to higher elevations such as the limits imposed for telecommunication.

Fig. 1 - 2003 Mars Exploration Rover Surface Positioning

Doppler Only Tracking - Minimal DTE Coverage

Mars '01 Orbiter Position Uncertainty: 10-100m Non-spherical, 1σ



Conclusions

Significant accuracy and time-to-solution improvements are available for lander positioning using in-situ orbiter radio metric measurements. The improved inertial or absolute positions are useful for rover operations planning and for cartographic improvements.

Acknowledgements
This work was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

References

Folkner,W.M., and others, "Interior Structure and Seasonal Mass Redistribution of Mars from Radio Tracking of Mars Pathfinder", Science 278, 1749 (1997).