Preliminary Results of Mars Exploration Rover In-Situ Radio Navigation

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

ABSTRACT

Introduction
This paper presents preliminary results from the first ever use of *in-situ* radio navigation measurements at Mars. NASA's two Mars Exploration Rover (MER) spacecraft carry UHF-band radios that enable trajectory reconstructions of the atmospheric descent and surface positioning phases. Solutions based on *in-situ* Doppler measurements between each MER and either the Mars Global Surveyor (MGS) or Mars Odyssey orbiters are compared with traditional Direct-To-Earth (DTE) Doppler and range measurements estimates. All measurements are transmitted to Earth and processed with ground-based navigation software at the Jet Propulsion Laboratory. Accuracy improvements and a reduction in the number of required observations is achieved by using these *in-situ* radio metric measurements. With feasibility demonstrated, *in-situ* measurement processing can be extended to future mission applications such as near real-time onboard trajectory determination and path planning.

Assumptions
Both MER landers are targeted near Mars' equatorial region. However, they are separated by nearly 180 degrees in longitude. Figure 1. shows the measurements used to reconstruct the entry trajectories and estimate the Mars surface locations. The estimation process relies on high precision navigation software with an improved Mars orientation model that includes precession, nutation and spin rate updates *(Konopliv,2001)*. Simultaneous orbit determination solutions are produced for the Mars Odyssey orbiter using its DTE observations. Mars Odyssey is capable of producing high quality coherent (2-way) Doppler measurements. However, non-coherent (1-way) measurements are also used from both MGS and Mars Odyssey to provide small improvements before the 2-way measurements begin. Geometric constraints such as minimum elevation angles and range limits reduce the *in-situ* passes to durations of 10 to 15 minutes, while MER transmit power limits constrain the DTE tracking to a pair of four hour passes per sol.

Results
On January 4th and 25th, 2004, MER-A and MER-B respectively, enter Mars' atmosphere and land after short six minute descents. During descent each entry capsule deploys a parachute and begins transmission of a one-way, UHF-band radio link to the MGS orbiter flying about 400 km overhead. Upon landing the UHF-band transmission is lost and re-established two hours later when the Mars Odyssey orbiter, also at 400 km is in view. Fig. 2 presents the expected initial landing uncertainties from descent trajectory reconstructions with and without the UHF-band data. Fig. 3 shows the surface positioning

predicted when processing UHF-band coherent measurements. Also shown for comparison are the DTE only estimates. 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. The in-situ improvements are primarily due to the increased various geometries between the Earth tracking stations and the Mars lander.

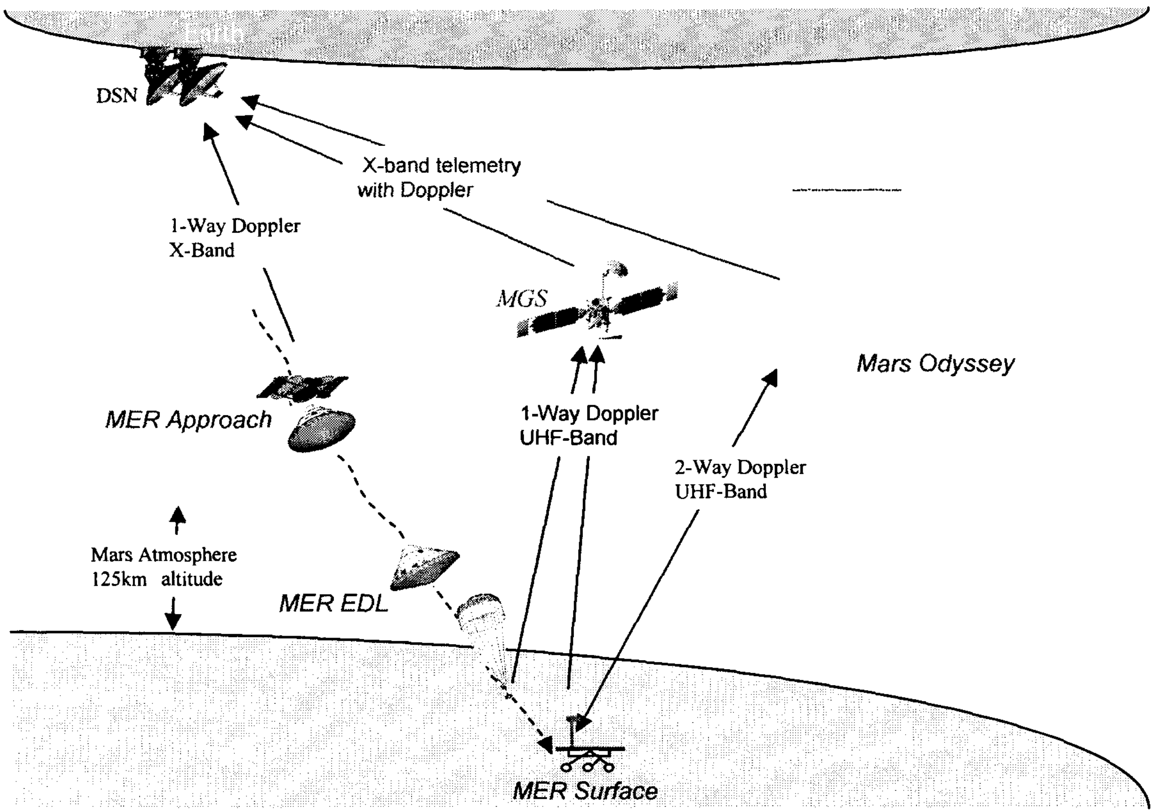

Fig. 1. - Mars *In-Situ* Navigation Measurements

Conclusions

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

Acknowledgements

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

References
Konopliv, A., and Myles Standish, “Mars Rotation Model for the ODP”, JPL Internal Document, IOM 312.B-002-01, 13 June 2001.

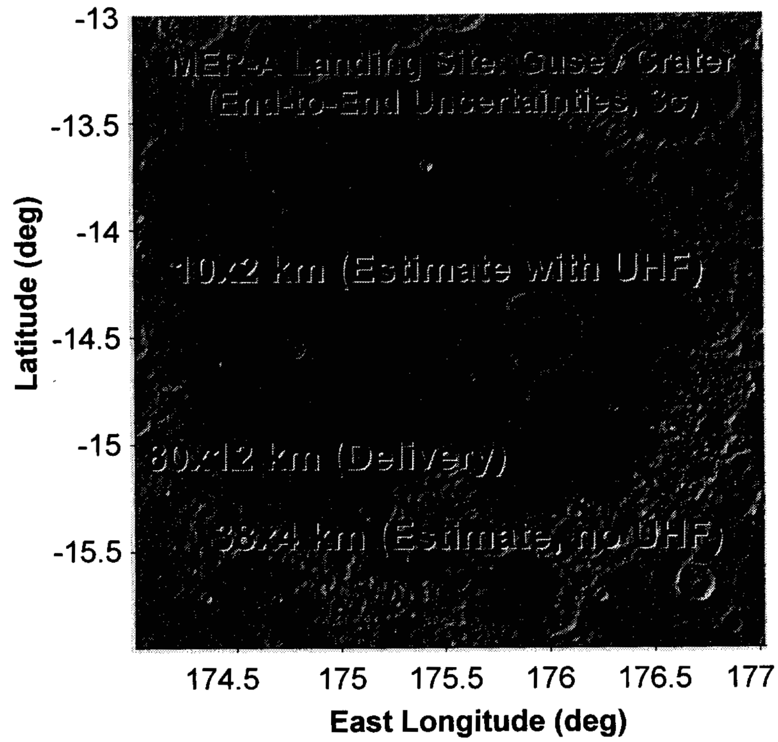

Fig. 2. – Initial Landing Estimates from Descent Trajectory Reconstructions

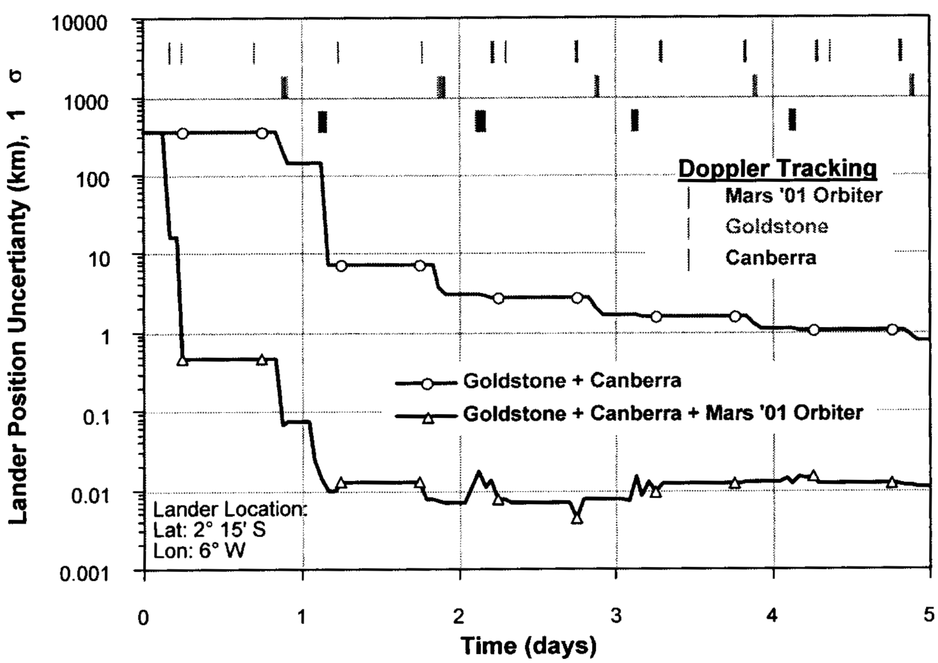

Fig. 3. - Rover Surface Positioning Estimates.