Radar Observations of Recent Mars Landing Sites. K. W. Larsen[1], A. F. C. Haldemann[1], R. F. Jurgens[1], M. A. Slade, [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA, 91109. Kristopher.W.Larsen@jpl.nasa.gov

Introduction: The Mars Exploration Rovers Spirit and Opportunity will arrive at their respective landing sites of Gusev Crater and Terra Meridiani in January 2004. During the 2001 and 2003 Mars Oppositions both landing sites were targeted for a series of radar observations using the telescopes of the Goldstone Deep Space Communications Complex (GDSCC).

This paper will present results of terrestrial delay-Doppler radar observations of the landing sites, predictions for the surface properties that will be encountered, and, after successful landings, correlation between the predicted and observed surface properties. The in-situ observations made by both missions serve as ground truth for the validation of the high resolution radar mapping results.

Observations: Radar observations of Mars have been an active field of research at almost every opposition since the 1960's and have been used to investigate past landing sites [1,2,3]. Observations prior to 2001 were limited to one dimensional profiling of the radar properties along the sub-radar track due to the hemispheric ambiguity inherent to delay-Doppler radar observations. One dimensional profile results based on the 2001 data for the Terra Meridiani landing site have been presented at past meetings [4].

Each observation presented here was conducted based on the same transmit, receive, and processing parameters. The GDSCC 70-meter radio telescope, DSS-14, transmitted a X-band (3.5 centimeter) radar signal encoded with a 63 unit length pseudo-random binary phase code, with a baud length of 4 microseconds. The received signal was processed using a 256 length Fourier transform, which when combined with the range coding parameters above, produces a delay-Doppler power spectrum with a maximum spatial resolution of five kilometers.

In both the 2001 and 2003 observations, the reflected radar signal was received simultaneously at four of the GDSCC telescopes. Delay-Doppler observations map the radar signal reflected from a target into a coordinate system based on time delay and frequency shift imparted by the planets shape and rotation, respectively. Since multiple points on the surface will have the same delay and frequency coordinates, the signal from those regions are merged, and must be deconvolved by other techniques in order to create an unambiguous radar map. Pairs of receiving telescopes are used to create interferometric baselines. The signal from each baseline pair, both complex power-spectra, are multiplied to form a power spectra that contains the radar reflection's magnitude and phase, due to the varied path lengths. An iterated maximum likelihood function algorithm can then unwrap the north-south ambiguity and map the radar backscatter coefficient of the surface, at a resolution of five kilometers per pixel.

Mapping Results: Composite radar backscatter coefficient maps, an example of which is shown in Figure 1, demonstrate the high resolution of the data as well as the bulk radar properties of the target surfaces. General conclusions about the radar properties of a surface may be made from such maps. For example, in Figure 1B, the floor of both Gusev Crater and Ma'adim Valles, which enters into Gusev Crater from the south, is less radar reflective than the surrounding highlands. To create these maps, the radar cross-section is corrected to account for the projected area of each pixel in addition to a simple cosine scattering model. Because of the simple nature of the scattering model applied, case must be taken in the interpretation of these maps. Smooth surface features near the sub-radar track, and thus viewed closer to the quasi-specular reflection regime, will appear radar bright but, if observed at higher incidence angles will appear radar dark, both relative to rougher regions which will reflect the incident radar in a diffuse manner.

Table 1	RMS Slope	Fresnel Reflectivity
Terra Meridiani	2.0° ± 0.5°	0.02±0.01
Gusev Crater	1.0° +1.0°/-0.5°	0.02±0.01

Table 1: Predicted Hagfors' Model parameters for the Terra Meridiani and Gusev Crater landing sites, calculated by a nonlinear least squares fit to error weighted data. Errors on the radar backscatter coefficients were based on the signal-to-noise ratios of the data as recorded by each of the component receiving telescopes.

Further interpretation of the surface characteristics of the valley floor requires modeling of the radar backscatter coefficient as it varies by incidence angle. The Hagfors' Model has been used to model the behavior of the radar backscatter coefficient [5]. In particular, the model was fit to the radar signal reflected from within the MER landing ellipses in both Terra Meridiani and Gusev Crater, Table 1. The Terra Meridiani model values are calculated from data collected on June 7, 2001, whereas the Gusev Crater data were collected on August 21, August 22, and September 27, 2003. Modeled RMS slopes, on the scale of one to ten radar wavelengths, within the landing ellipses predict that surfaces within the Terra Meridiani landing site will be smoother than those at Gusev Crater.

Successful landings by Opportunity and Spirit, in Terra Meridiani and Gusev Crater, will provide points of ground truth to validate the predictions made by high resolution radar observations. Analysis of early images returned by the twin rovers will validate the process and technique used herein and allow the extension of our analyses to other regions of Mars observed during the past two oppositions

References: [1] Masursky and Crabill, (1976) *Science*, 193, 809-812. [2] Tyler et al., (1976) *Science*, 193, 812-815 [3] Haldemann, A.F.C. et al., (1997) *JGR*, 102, 4097-4106. [4] Larsen, K.W. et al., (2002) LPS XXXIII, Abstract #1800 [5] Hagfors, T., (1964) *JGR*, 69, 3779-3784.

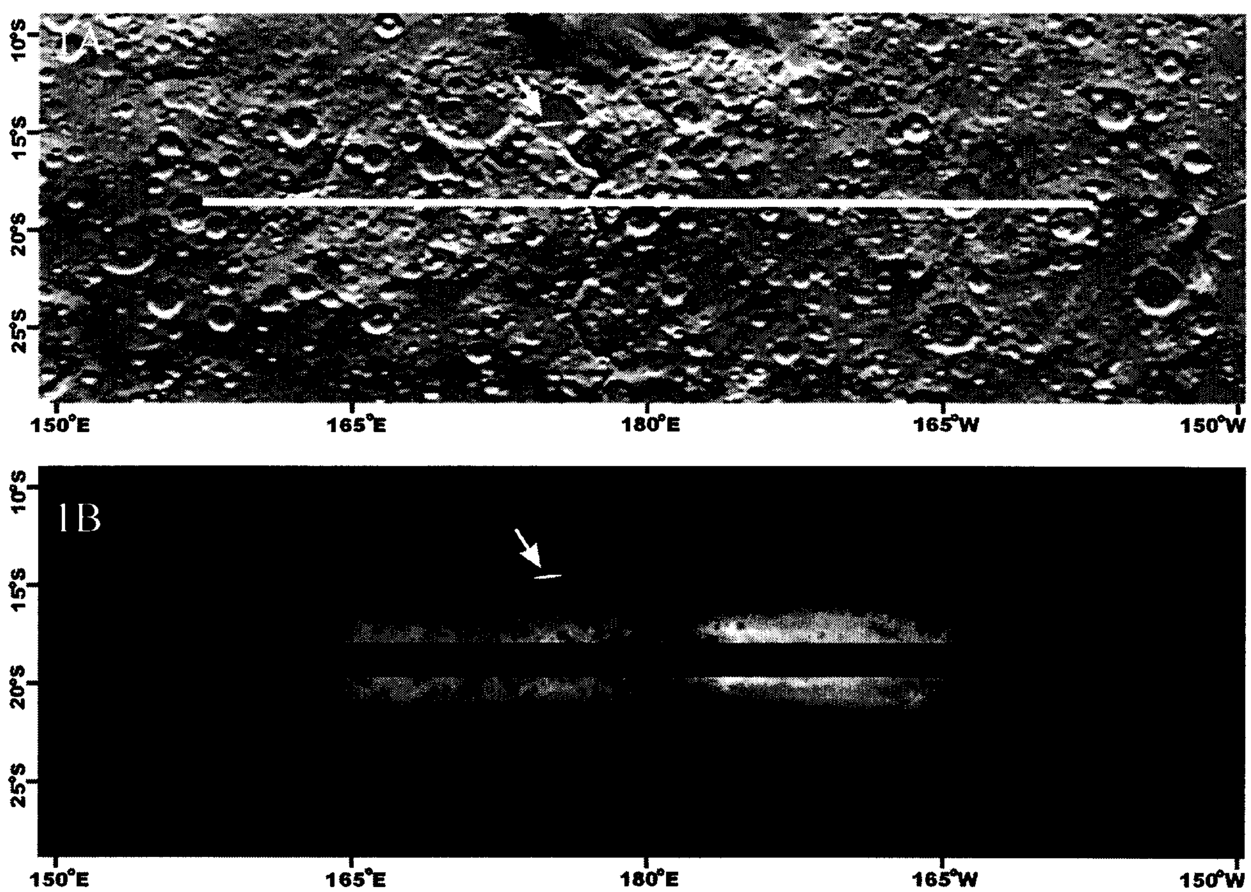

Figure 1: A) MOLA shaded relief map (sun incident from the top) for the August 22, 2003 observation. The heavy white line designates the sub-radar track and the longitudinal extent of the observation. The arrow points to the Gusev Landing site.

B) Composite radar backscatter coefficient map for August 22, 2003. The covered area is the same as shown in Figure 1, with the Gusev Crater landing site again labeled. The unmapped exclusion zone extending down the middle of the image is the extent of the first range gate, in which the delay-Doppler ambiguity can not be resolved. Bright regions in the map have the highest radar backscatter coefficients. Near the sub-radar track, smooth regions will reflect the greater amount of incident radiation and appear bright, while rough areas will be darker. Further from the sub-radar track, the smooth areas will reflect the radar away from the receiver and look dark, while diffuse reflection from rougher areas will make them appear brighter.