GLOBAL DATABASE OF GSSR MARS DELAY-DOPPLER RADAR OBSERVATIONS: ANALYSIS FOR LANDING SITE CHARACTERIZATION AND ROVER TRAFFICABILITY.

A. F. C. Haldemann[1], R. F. Jurgens[1], M. A. Slade[1], T. W. Thompson[2], and F. Rojas[2], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109-8099 (albert@shannon.jpl.nasa.gov), [2]University of Arizona, Tucson, AZ.

Introduction: Earth-based radar data remain an important part of the information set used to select and certify spacecraft landing sites on Mars. Constraints on robotic landings on Mars include: terrain elevation, radar reflectivity, regional and local slopes, rock distribution and coverage, and surface roughness, all of which are addressed by radar data [1]. Indeed, the usefulness of radar data for Mars exploration has been demonstrated in the past. Radar data were critical in assessing the Viking Lander 1 site [2, 3], and more recently, the Mars Pathfinder landing site [4].

Radar Data: The Goldstone Solar System Radar (GSSR) facility has successfully collected radar echo data from Mars over the past 30 years. The older data provided local elevation information for Mars (ranging-only data), along with radar scattering information with global resolution (Doppler-only or continuous-wave data), and some small amount of higher spatial resolution range and scattering data (delay-Doppler data) [5, 6]. Since the upgrade to the 70-m DSN antenna at Goldstone completed in 1986, delay-Doppler data were collected during the 1988, 1990, 1992-93, and 1994-95 Mars oppositions. Much of this Mars data since 1990 has not been analyzed beyond a cursory examination of data quality. The ranging information provided by these data [7] is in fact similar to that offered by earlier delay-Doppler experiments from the 1970's.

Delay-Doppler radar data, after significant data processing, yields the elevation, reflectivity and roughness of the reflecting surface. The further interpretation of these parameters, while limited by the complexities of electromagnetic scattering, does provide information directly relevant to geophysical and geomorphic analyses of Mars. The improved quality of the more recent GSSR data allows for more consistent analysis of the scattering behavior which can be related to surface roughness and rock coverage than was possible in the 1970's. In general, scattering parameters are sampled every 0.09° of longitude along a radar track. The size of the resolution cell this information relates to is about 0.17° of longitude by 2.6° of latitude (approximately 10 km by 160 km). That portion of recent GSSR delay-Doppler data that has been fully examined, is the half of the 1994-1994 Mars opposition data analyzed expressly for the Mars Pathfinder Project [4].

In general, processed radar data have not commonly been available to the Mars exploration community at large. (The pre-1986 data are publicly available via anonymous ftp at ftp://asylum.jpl.nasa.gov/marty/, filenames mars6mb.lbl and mars6mb.tab.Z). In aid of the landing site selection process for future missions in the Mars Surveyor program, a comprehensive effort has been undertaken to present all the data since 1988 in a coherent form, accessible to the Mars research community. The data are viewable via the World Wide Web at http://wireless.jpl.nasa.gov/RADAR/Mars/.

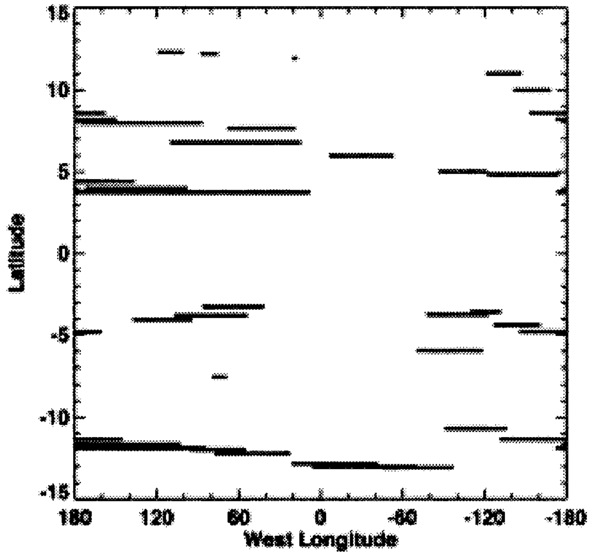
Landing Site Selection: New datasets other than radar offer some of the site selection information provided by radar in the past. However, radar data still retain certain strengths. A critical element of NASA's future robotic Mars exploration is roving, and **rover trafficability** on the surface becomes a key landing site selection criterion. Two parameters for rover trafficability, **rock coverage**, and in particular, **surface roughness**, are ascertained from radar echo modelling.

With the advent of the Mars Orbiter Laser Altimeter (MOLA) instrument on Mars Global Surveyor (MGS), the importance of Earth-based radar to provide Mars elevation and regional slope information with ranging is diminished. However, the roughness parameters extracted from the scattering modeling of delay-Doppler echoes at 3.5 cm wavelength directly probe the scales of roughness that meter-sized rovers will encounter. MOLA data may provide some surface roughness information, and would certainly profit from a careful and direct comparison with the better-understood radar results in different regions. More generally, the correlation of radar roughness with Martian geomorphic units is worthy of further study.

The **radar reflectivity** of the surface of Mars as a whole is known well enough now [8] for the purposes of lander radar altimeters. However, radar reflectivity also provides a measure of rock abundance versus dustiness on and near the surface. Certainly this is also probed by thermal measurements with the Thermal Emission Spectrometer (TES) on MGS and existing Viking Infrared Thermal Mapper (IRTM) datasets, but corroborating data are most useful when "policy" decisions such as landing site selection are required.

Mars Surveyor 2001: One constraint on the Mars Surveyor 2001 landing site is a latitude range from 12°S to 3°N. The relevant radar data coverage is from the 1990 oppositios, and is shown graphically in Figure 1 and tabulated in Table 1. The data have been used for initial landing site assessment: regions and locations with appropriate elevations within the radar data set have been identified, and their radar scattering properties documented. Any interested party may now examine radar data pertinent to a candidate landing site.

Figure 1. Delay-Doppler Radar Track coverage in the Mars Surveyor 2001 Lander Latitude Band.



References:

[1] Golombek, M. P. et al., (1997) *Science*, 278, 1743-1748. [2] Masursky and Crabill, (1976) *Science*, 193, 809-812. [3] Tyler et al., (1976) *Science*, 193, 812-815. [4] Haldemann, A. F. C. et al., (1997) *JGR*, 102, 4097-4106. [5] Downs, G. S. et al., (1975) *Icarus*, 26, 273-312, 1975. [6] Downs, G. S. et al., (1978) *Icarus*, 33, 441-453. [7] Goldspiel, J. M. et al., (1993) *Icarus*, 106, 346-364. [8] Butler, B. J. (1994) Ph.D., Caltech.

Acknowledgments: Part of the research described here was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

Table 1. 1990 Mars Opposition GSSR Data

Track Date	Latitude	Longitude (°)	
	(°)	Begin	End
1990-12-30	-13.1	262.7	313.9
1990-12-28	-13.0	-70.6	6.0
1990-12-24	-12.8	-41.5	20.7
1990-12-17	-12.2	22.4	77.8
1990-12-15	-12.0	54.9	95.3
1990-12-14	-11.9	84.2	187.9
1990-12-12	-11.6	102.7	183.1
1990-12-10	-11.3	145.0	228.8
1990-12-06	-10.7	223.6	269.2
1990-11-20	-7.6	68.7	79.3
1990-11-02	-4.4	199.2	233.3
1990-10-27	-3.7	-122.8	-77.7
1990-10-25	-3.6	-131.7	-110.0
1990-10-12	-3.3	41.5	86.3
1990-10-02	-3.8	53.9	107.2
1990-09-29	-4.0	94.1	136.9
1990-09-22	-4.8	160.0	214.1
1990-09-14	-6.0	-118.5	-70.6