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GSSR Mars Delay-Doppler Data Available for MER Landing Site Assessment. R. F. Jurgens, A. F. C. Haldemann, and M. A. Slade, Jet Propulsion Laboratory, California Institute of Technology, M/S 238-420, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, jurgens@shannon.jpl.nasa.gov.

Introduction: The Goldstone Solar System Radar (GSSR) has successfully collected radar echo data from Mars over the past 30 years. The older data provided local elevation information for Mars, along with radar scattering information with global resolution (e.g. [1,2]). Since the upgrade to the 70-m DSN antenna at Goldstone completed in 1986, Mars data has been collected during all but the 1997 Mars opposition. Radar data, and non-imaging delay-Doppler data in particular, requires significant data processing to extract elevation, reflectivity and roughness of the reflecting surface [3]. The spatial resolution of these experiments is typically some 20 km in longitude by some 150 km in latitude. The interpretation of these parameters while limited by the complexities of electromagnetic scattering, do provide information directly relevant to geophysical and geomorphic analyses of Mars.

Landing Site Assessment with Radar Data: 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 [4, 5] as well as, more recently, the Pathfinder landing site [6, 7]. In general, radar data have not been available to the Mars exploration community at large. One of us (Haldemann) has recently finished a project funded by the Mars Exploration Directorate Science Office at the Jet Propulsion Laboratory (JPL) to reprocess to a common format the last twelve years worth of raw GSSR Mars delay-Doppler data in aid of landing site characterization for the Mars Surveyor Program. The radar data used were obtained since 1988 by the GSSR, and comprise some 72 delay-Doppler radar tracks. Twenty-eight of the tracks lie in the latitude range proposed for landing sites for the 2003 Mars Exploration Rover (MER) and are listed in Table 1. The available data consist of Hagfors radar scattering model fits to the data every 0.1 degrees of longitude. The fit parameters are range (elevation), reflectivity (Fresnel), and surface roughness (rms slope) for each 20km x 150km resolution cell.

Table 1. Existing GSSR Mars Radar Data for MER

Date	Lat.	West Longitude (deg.)	
	(deg.)	Rise	Set
14 Sept 1990	-6.0	242	289
22 Sept 1990	-4.8	160	214
29 Sept 1990	-4.0	108	131
2 Oct 1990	-3.8	52	109
12 Oct 1990	-3.3	41	89
25 Oct 1990	-3.6	227	242
27 Oct 1990	-3.7	260	286
20 Nov 1990	-7.6	65	82
15 Dec 1990	-12.0	53	92
17 Dec 1990	-12.2	23	77
24 Dec 1990	-12.8	319	20
28 Dec 1990	-13.0	290	6
30 Dec 1990	-13.1	263	313
15 Dec 1992*	11.0	214	238
22 Dec 1992*	10.0	192	218
31 Dec 1992*	8.6	158	207
2 Jan 1993*	8.2	150	188
3 Jan 1993*	8.0	90	175
5 Jan 1993*	7.7	19	68
10 Jan 1993*	6.8	15	109
14 Jan 1993	6.0	308	353
21 Jan 1993	5.0	239	273
23 Jan 1993*	4.9	186	238
27 Jan 1993*	4.4	137	179
31 Jan 1993*	4.0	99	172
3 Feb 1993*	3.9	102	168
7 Feb 1993*	3.8	109	187
14 Feb 1993*	3.7	8	113

* Interferometric data recorded

Interferometric delay-Doppler radar: Observing the radar echo with more than one receiver provides a means to remove the north-south delay-Doppler ambiguity. Thirteen of the 72 radar tracks in the recently re-assembled radar dataset are interferometric radar tracks (called out in Table 1). The interferometric information has never been quantitatively processed, because the signal to noise is insufficient to constrain both the phases and the radar scattering parameters. The new topographic data from the Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Surveyor (MGS) spacecraft offer the best means to analyze these unused data to make radar maps that extend the radar properties coverage some 3 to 4 degrees beyond the sub-earth radar track. This would be a significant expansion of the dataset, and is all the more warranted as the radar spatial resolution improves away from the sub-Earth track (smaller range ring-Doppler strip intersections away from the sub-Earth track). At the outer edges the radar resolution cell is of the same order of size as the landing site ellipses for future missions (approximately 20 km diameter).

The Mars observations in interferometric mode were made in such a way that they would have no impact on the normal ranging experiments. To that end, the range and frequency resolution were identical to the normal ranging experiments with few exceptions. The baud was 6 microseconds over-sampled by two. The normal experiments have 35 range gates, but the interferometer processing would normally handle only about 33. The code had 63 elements, and no coherent summing. So, the frequency coverage was 2645.5 Hz and processed in real time to 128 bins or about 20 Hz resolution. Spectra were recorded about every 5 seconds. The spectra included the power from Goldstone DSN antennas DSS-14 and DSS-13 and the cross power products. Thus, each frame contains about 16,896 floating point numbers. As with normal ranging, the front cap coverage is about 5 degrees. This is limited by aliases and not by the radar processing capability (although these were at the limit).

The Doppler resolution is about 4.5 km (it varies a bit depending upon the latitude of the sub-radar point, but this is as good as it gets. The range resolution depends on the angle from the subradar point, and some values are given in Table 2. There is no appreciable degradation of the resolution due to averaging. Because these data are over-sampled in range, we actually get the resolution indicated in Table 2. As to SNR, signal can normally be seen in all range gates for DSS-14. Just how much trouble the North-South aliases will be with the new processing is not yet resolved.

Table 2. Interferometric Radar Resolution

Longitude separation from subradar track (deg.)	Resolution (km)
1	35.4
2	17.2
3	11.5
4	8.6
5	6.9

Future Data Coverage: The 2001 Mars opposition offers an opportunity to fill in some areas where radar data are lacking in the current dataset. In particular the latitudes of the so-called ›Hematite Site= will be covered by the radar near opposition. We are currently planning 18 radar tracks between May and July of 2001. The latitude and longitude coverages for each planned track are listed in Table 3. The goal of the observations will be to provide as much new, interferometric, improved-spatial-resolution radar data over the ›Hematite Site=, as well as over other regions of interest to the MER landing site selection process.

Significance: Currently the data along 28 delay-Doppler radar tracks are available for MER landing site evaluation. The topographic information these radar data used to provide for Mars missions is now superceded by MOLA. However, the data from that instrument offer a means to bootstrap radar data to higher spatial resolution. This offers the possibility of assessing the surface radar reflectivity and surface roughness over significant areas that meet the MER landing site selection criteria with data from 13 of the older tracks and all of the 18 tracks planned in 2001.

Table 3. Planned GSSR Mars 2001 Observations

Date	Lat (deg.)	Longitude (deg.) Rise	Set	Target
3 May	-1.8	321	35	'Hematite'
4 May	-1.8	312	24	'Hematite'
5 May	-1.8	302	15	'Hematite'
17 May	-1.3	201	252	Elysium
19 May	-1.1	182	233	Elysium
28 May	0.0	93	141	'Stealth'
7 June	1.7	355	39	'Hematite'
8 June	1.9	346	29	'Hematite'
9 June	2.1	336	19	'Hematite'
15 June	3.2	276	317	Isidis/Syrtis
17 June	3.6	257	297	Isidis/Syrtis
22 June	4.6	206	245	Elysium
1 July	6.0	116	154	'Stealth'
2 July	6.1	106	144	'Stealth'
12 July	7.1	2	43	'Hematite'
14 July	7.2	346	23	'Hematite'
23 July	7.3	255	292	Isidis/Syrtis
28 July	7.1	203	241	Elysium

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