**SHARAD: RADAR SOUNDER ON THE 2005 MARS RECONNAISSANCE ORBITER.** R. J. Phillips¹, R. Seu², and the SHARAD Team, ¹Dept. of Earth and Planetary Sci. & McDonnell Center for the Space Sciences, Washington Univ., CB 1169, One Brookings Drive, St. Louis, MO 63130 USA (phillips@wustite.wustl.edu), ²INFOCOM Department, University of Rome La Sapienza, Via Eudossiana, 18-00184 Rome, Italy (robseu@infocom.uniroma1.it)

**Introduction:** SHARAD (SHAllow RADar) is a subsurface sounding radar provided by ASI (Agenzia Spaziale Italiana) as a Facility Instrument for the 2005 Mars Reconnaissance Orbiter (MRO) mission. It is designed to characterize the upper several hundred meters of the martian subsurface. As of this writing, the instrument has been integrated into the payload on the spacecraft undergoing assembly at Lockheed Martin Aerospace in Denver, CO. The protoflight model has met all of its design requirements, including a dynamic range of 50 dB (in essence, detection of a subsurface signal 50 dB weaker than the strong surface reflection).

The properties of the SHARAD instrument are given in Table 1 below.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>15-25 MHz chirp</td>
</tr>
<tr>
<td>Vertical resolution, theoretical, reciprocal bandwidth, ε(_r) = 4</td>
<td>7.5 m</td>
</tr>
<tr>
<td>Transmitter Power</td>
<td>10 W</td>
</tr>
<tr>
<td>Pulse length</td>
<td>85 µs</td>
</tr>
<tr>
<td>Receive window</td>
<td>135 µs</td>
</tr>
<tr>
<td>PRF</td>
<td>750/375 (nom.) Hz</td>
</tr>
<tr>
<td>Antenna</td>
<td>10-m tip-to-tip dipole</td>
</tr>
<tr>
<td>Post-Processor SNR (worst-best)*</td>
<td>50-58 dB</td>
</tr>
<tr>
<td>Horizontal resolution</td>
<td>0.3-1 km × 3-7 km</td>
</tr>
</tbody>
</table>

Table 1. SHARAD instrument parameters. *Biggest source of uncertainty is antenna gain.

**SHARAD Objectives:** The primary objective of the SHARAD experiment is to map, in selected locales, dielectric interfaces to several hundred meters depth in the martian subsurface and to interpret these results in terms of the occurrence and distribution of expected materials, including competent rock, soil, water and ice [1].

This is a cautious set of objectives, making no promises about the unique detection of any specific material (e.g., water). The chief obstacles to the success of the SHARAD experiment are (i) subsurface loss tangents larger than anticipated, and (ii) inability to mitigate the effects of surface clutter. Surface clutter can be dealt with in a variety of ways including: (a) operating in areas of smooth terrain, (b) forward modeling of scatter from DEMs, and (c) the use of stereo techniques, as was successfully implemented in Apollo Lunar Sounder Experiment (ALSE) data analysis [2].

Uniqueness of interpretation will be another issue with SHARAD data. The best approach to this problem lies in the integration of SHARAD data with geologic information and with other remote sensing data sets.

**Some SHARAD Targets:** There are a plethora of potential subsurface targets for SHARAD; two are described below. Mapping of the Polar Layered Terrain with SHARAD is described in another abstract [Nunes and Phillips, this meeting].

**Mapping ice depth with SHARAD.** The Neutron and Gamma-Ray Spectrometers on the Mars Odyssey spacecraft discovered abundant evidence for subsurface ice [e.g., 3]. While the top of the ice is predicted by theoretical models [4], which are in good agreement with the Neutron Spectrometer data set [5], depths to the bottom of the ice are poorly known. If the ice in the shallow subsurface is just that in equilibrium with the atmosphere, then the equilibrium depth to the bottom of the ice is estimated to be in the range of 10-20 m when the thermal conductivity of ice in the pore spaces is taken into account (M. Mellon, personal communication, 2004). Estimating, or at least constraining, the subsurface ice volume is extremely important in understanding the present-day global water inventory of Mars.

Given SHARAD’s vertical resolution, detecting dielectric interfaces in the 10-20 m depth range seems feasible. However, resolution close to the theoretical limit can only be achieved when resolving signals of equal strength, which is not the case when attempting to detect a relatively weak signal from the base of the ice in the presence of a strong surface reflection.

Figure 1 shows the range-focused (chirp compressed) model results for a 15-m depth to the bottom of the ice. The two major points to be made are that choice of data processing parameters matters and (c) the use of stereo techniques, as was successfully implemented in Apollo Lunar Sounder Experiment (ALSE) data analysis [2].

Uniqueness of interpretation will be another issue with SHARAD data. The best approach to this problem lies in the integration of SHARAD data with geologic information and with other remote sensing data sets.
local slope. Further, the equilibrium calculations resulting in Figure 1 involve a sharp boundary at the base of the ice; the actual occupation of pore spaces by ice depends on the transient movement of water vapor in the subsurface. Calculations are currently underway to address this issue (M. Mellon, personal communication, 2004).

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 w(t) = C_1 - C_2 \cos(2 \pi t/T) \]

describes the chirp weighting function for pulse length \( T \), and \( C_1 + C_2 = 1 \). Nominal data processing for best sidelobe control is a Hanning function \((C_1 = C_2 = 0.5)\). It is not the best choice here.

**Mapping the Etched terrain with SHARAD.** The rover Opportunity landed at a hematite-rich region in Terra Meridiani. Earlier geomorphic mapping showed that the hematite occurrence was part of an extensive stack of Noachian layered deposits [6]. An important multi-layered member of this group is a differentially-eroded unit that is high in both thermal inertia and albedo [6,7], termed “etched” terrain. At the Opportunity landing site, hematite spherules weather out of a sulfur-rich bedrock [8] that is in fact the upper layers of the etched terrain [9]. Etched terrain is exposed over at least \(3 \times 10^5 \) km\(^2\) in the Meridiani and western Arabia Terra regions [9], yet is seen to disappear under younger units (Figure 2). As this sulfate-rich unit, in places hundreds of meters thick, is likely indicative of a large standing body of water, mapping the extent of the etched terrain is fundamental to estimating the magnitude of Noachian surface water occurrence. Of course, this is where SHARAD comes in. As a guide to the reflective properties of the top of the etched terrain, we note that the dielectric constant of anhydrite is about 6. Further, the large thermal inertia of this unit implies that it is a relatively highly indurated geological material. Thus SHARAD has a good probability of mapping subsurface occurrences of the etched terrain. Further, because this unit is exposed at the surface, it can be “followed” from there into the subsur-

**Data Processing and Products:** The ~28 Tb of processed SHARAD data holds the potential for a number of important discoveries. Of interest to the Mars science community are the data products to be available. The SHARAD-EDR product is a collection of radar echoes at full resolution, time ordered, with duplicates and transmission errors removed, and located in space and time. The SHARAD-RDR product consists of SHARAD-EDR data that have been converted to complex voltages, Doppler filtered and range compressed, and contains proper engineering and spacecraft information. The SHARAD-DDR product is a radargram, i.e., a 2-D (ground distance, time delay) image of individual sounding profiles (SHARAD-RDR) that have been collated and stacked along track in a way that is similar to that used in terrestrial GPR data displays.

**References:**