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Submitted by:

H. T. Howard
Center for Radar Astronomy
Durand Building, Rm. 213
Stanford University
Stanford, CA 94305

(415) 497-3533

ABSTRACT

This report covers the period of January 1 through September 30, 1975, and has been combined with our annual proposal to bring the reporting into synchronism with the new federal fiscal year and to eliminate duplication. The period has been a particularly rewarding one on both theoretical and practical fronts. We see a very promising year ahead and therefore propose that NASA continue to support two senior staff members of the Center for Radar Astronomy; H.T. Howard and G.L. Tyler, on a part-time basis for the calendar year 1976.

Research at the Center for Radar Astronomy related to solid body aspects of planetology continues to focus upon the analysis and interpretation of radar experiments. We have continued our radar study of Mars in conjunction with the Viking landing site selection process, including, for the first time, a collection of data by a Center for Radar Astronomy staff member (R. A. Simpson) at Arecibo. Our lunar work has been continued with considerable progress in the interpretation of the quasi-specular scattering from the lunar surface in terms of horizontal scale dependence upon observing wavelengths, and in a collaborative effort with the USGS, principally Henry Moore in Menlo Park. We have instigated a small study of the effect of the extremely high temperatures encountered on the surface of Venus upon the dielectric constant of geophysical meterials and hence on the interpretation of radar results. Finally, in the study of large systems of "little planets", there has been completed a Ph.D. dissertation on the use of radio and radar techniques for the study of Saturn's Rings. Each of these topics will be discussed in more detail below.

In August 1975 radar observations of Mars were begun at Arecibo Observatory in Puerto Rico, partly sponsored by the Viking Project Office. This work represents an extension of an earlier study, summarized in a report by Simpson, Tyler, and Lipa (1974), in which a comprehensive review of previous Mars radar studies was made and newly (1973) acquired data were examined in an attempt to infer surface properties at potential Viking landing sites. The present effort is being carried out in an operational context for the purpose of choosing and certifying these sites. Observations are being made in conjunction with experimental programs by other investigators on the Arecibo staff and at the Massachusetts Institute of Technology.

The observations in 1975 include ranging at 430 MHz using the 2.5 Mw system and spectral studies using the recently added 2380 MHz facilities. Data obtained in August and September were of superior quality to those produced during 1973 despite the fact that the planet was more than twice as distant. By opposition (December 1975) ranging capability will have been incorporated in the S-Band system to further enhance its usefulness.

Of primary interest to the Viking program have been radar observations at several C-sites, potential back-up sites should either the A or B prime and alternate landing areas be declared unusable. These sites are located within 10° of the Martian equator in regions which, from imagery, appear smooth and have altitudes low enough for parachute landing.

A conclusion of the 1974 report was that imagery is an unreliable indicator of surface properties on scales important to the lander. The radar, on the other hand, should be sensitive to structure on scales of 1 to 100 meters. In many instances the radar has indicated roughness at the proposed C-sites much more severe than would be deduced from the imagery.

Surface roughness on Mars is apparently not a function of scale length for scales below a few hundred meters, a conclusion based on a lack of wavelength dependence observed in the data from the 1973 opposition. If true, this implies that the processes which shape the Martian surface are independent of size for sizes below 1 km.

From point to point on the surface, Mars exhibits a great deal of heterogeneity. Expressed in terms of rms slopes and surface reflectivity, Mars varies over at least ranges of 5:1. Units of fairly constant properties may be as large as several tens of degrees in extent or smaller than the radar resolution cell, typically 700 km^2.

Variation of radar properties within units mapped as geophysically homogeneous from Mariner 9 imagery is almost as great as the variation among units. Direct comparison of imagery and radar results also shows a general lack of correlation. These two conclusions imply that there is a marked change in surface characteristics when observed on scales of 1000 and 100 m.

Especially in time-domain studies of radar scattering it is also clear that topography has a significant influence on inference of small-scale surface parameters such as rms slope and on estimation of surface reflectivity and hence, density. For the most recent data taken at Arecibo, only spectral information was obtained so this was not a problem.

Of six sites which were observed during August and September, 1975, the preliminary analysis indicates unacceptable conditions at three (sites 8', 10, 18), marginal conditions at one (site 19), possibly good conditions at a fifth (site 23), and promising (but inconclusive) conditions at the last (site 20'). In some cases the radar ground track was offset from the nominal landing area by as much as 3° in latitude, but runs over neighboring terrain and generally uniform properties as deduced from other remote sensing methods showed little indication of differentiation and hence little reason to believe extrapolation was not a valid procedure.

Of the three sites which appear worst, all could be discarded on the basis of roughness, heterogeneity of scattering properties (as a function of position), low reflectivity, and poor correlation of radar behavior with imagery. The site judged marginal suffers from most of the above, but appears to have a small region of smoother surface embedded in the generally poorer surroundings. The two most promising areas in the radar sense are moderately cratered in imagery but appear to be generally smooth otherwise.

Of scientific interest has been the detection of scattered energy out to angles of 20° and more from the subradar point. Previously it had been concluded that the echo was largely specular and that most of the scattered energy came from a region perhaps 5° in extent about the subradar point. Pettengill et al. (1969) had previously concluded that a sizeable diffuse component to scattering was present, but their measurements had been largely ignored in recent years. The spectral representation of the echo in the August-September 1975 experiments and the obvious non-zero power returned from locations far from the subradar point makes investigation of this component important for future interpretation of surface properties.

Observations of Mars are continuing under supervision of the Arecibo staff. Stanford personnel will return for six weeks in December and January and then again for twelve weeks in May through July of 1976. The second visit will be to continue the C site studies and the third to make observations near the Chryse and Tritonis Lacus A Sites.

Our lunar work has been directed toward completion of the efforts started under the lunar synthesis program. Over the past year this work has been centered around consolidating our understanding of the principal relationships between radar data and other quantitative geophysical measures of the surface. (This work is in close collaboration with Henry Moore of the USGS.) Specific efforts have been to obtain systematic measures along the Apollo bistatic-radar tracks of lunar surface slope frequency distribution at the 13 and 116 cm wavelengths, and to pursue work on the theoretical problem of understanding the observed wavelength dependence both in surface roughness and reflectivity. This work has led to completion of slope frequency distribution data books for Apollos 14, 15, and 16 which has been distributed to our colleagues at the USGS. Theoretical work on wavelength dependence has resulted in a quantitative model for this effect in terms of lunar surface power spectral density. There has also been closely related work on theoretical modeling of sub-surface reflections apropos the bistatic-radar experiment and a re-interpretation of previous ground-based results in terms of wavelength dependence for both surface roughness and sub-surface structure. Papers on these subjects are currently in press in scientific journals.[1,2,3] The collaborative work with the USGS has appeared in U.S. Government Interagency reports, one of which has been published and another of which is in draft form.[4, 5]

There has been a small effort, undertaken as an undergraduate research project, to understand the possible effects of the high surface temperature of Venus on radar observations. This work has consisted of a literature search for laboratory work regarding the effects of temperature on electromagnetic properties of geologic materials, and of elementary calculations to determine the implication of such effects for radar observations. At

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[1] Tyler, G.L., "Wavelength Dependence in Radio-wave Scattering and Specular-Point Theory," Radio Science, in press, (2/76)

[2] Simpson, R.A., "Electromagnetic Reflection and Transmission at Interfaces Involving Graded Dielectrics with Applications to Planetary Radar Astronomy," IEEE Trans. on Antennas and Propagation, AP-24, 1, in press, (1/76).

[3] Simpson, R.A., "Surface Roughness Estimation at Three Points on the Lunar Surface, Using 23 cm Monostatic Radar," J. Geophys. Res., in press, 1975.

[4] Moore, H.J., with G.L. Tyler et al., "Correlation of Photogeology and Remote Sensing Data Along the Apollo 14 Bistatic-Radar Ground Track, Part I - A Working Compendium," Interagency Report, Astrogeology 75, USGS Openfile Report, 75-284, 1975.

[5] Moore, H.J., with G.L. Tyler et al., "Correlation of Photogeology and Remote Sensing Data Along the Apollo 15 and 16 Bistatic Radar Ground Track, Part II - A Working Compendium," Interagency Report, Astrogeology 75, USGS Openfile Report, in preparation, 1975.

the present time no firm conclusions have been reached, but it seems unlikely that all of the enhanced radar reflectivity of Venus can be accounted for on the basis of temperature alone.

There has been significant progress in the understanding of radar scatter from conglomerations of particles such as exist in Saturn's rings and in the analysis and design of an experiment to study those particles. This work has been published as a Stanford University Ph.D. dissertation.[1] It will find practical realization in radio occultation experiments of Saturn's rings to be conducted by MJS-77 spacecraft.

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[1] Marouf, E.A., "The Rings of Saturn: Analysis of a Bistatic-Radar Experiment," Technical Report 3240-1, SU-SEL-75-006, Stanford Electronics Labs., Stanford University, Stanford, CA, March 1975.

CENTER FOR RADAR ASTRONOMY

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COGNIZANT PERSONNEL

For scientific or technical matters relating to the grant:

H. T. Howard, Principal Investigator
Center for Radar Astronomy
Stanford Electronics Laboratories
Stanford University
Stanford, California 94305

Telephone: (415) 497-3537

For administrative matters relating to the grant:
(Procurement, property control, funding budgets, etc.)

Dr. D. C. Bacon, Associate Director
Stanford Electronics Laboratories
Stanford University
Stanford, California 94305

Telephone: (415) 497-1803

For contractual matters relating to the grant:
(Patents, amendments, overhead, including negotiation of grant)

Sponsored Projects Office
Old Pavilion
Stanford University
Stanford, California 94305

Telephone: (415) 497-2883