

**APPLICATION OF INTERFEROMETRIC RADARS TO PLANETARY GEOLOGIC STUDIES.** P. J. Mouginiis-Mark<sup>1</sup>, P. Rosen<sup>2</sup>, and A. Freeman<sup>2</sup>, <sup>1</sup>Hawaii Institute Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822 (pmm@higp.hawaii.edu), <sup>2</sup>Jet Propulsion Laboratory, CalTech, Pasadena, CA 91109.

**Introduction:** Radar interferometry is rapidly becoming one of the major applications of radar systems in Earth orbit. So far the 2000 flight of the Shuttle Radar Topographic Mission (SRTM) is the only dedicated U.S. radar to be flown for the collection of interferometric data, but enough has been learned from this mission and from the use of foreign partner radars (ERS-1/2, Radarsat, ENIVISAT and JERS-1) for the potential planetary applications of this technique to be identified.

A recent workshop was organized by the Jet Propulsion Laboratory and the Southern California Earthquake Center (SCEC), and was held at Oxnard, CA, from October 20<sup>th</sup> – 22<sup>nd</sup>, 2004. At this meeting, the major interest was in terrestrial radar systems, but ~20 or the ~250 attendees also discussed potential applications of interferometric radar for the terrestrial planets. The primary foci were for the detection of planetary water, the search for active tectonism and volcanism and the improved topographic mapping. This abstract provides a summary of these planetary discussions at the Oxnard meeting.

**Moon:** Radar imaging could provide views of the permanently shadowed areas at the lunar poles. Together with interferometrically derived topographic data, such measurements could help in the characterization of potential landing sites at the meter-scale, and enable the determination of lighting geometry of these areas in order to evaluate the availability of solar energy for rovers and human exploration. At the global scale, terrestrial experiments such as the Shuttle Radar Topography Mission (SRTM) have demonstrated the value of having a consistent elevation data set for the Earth [1]. For the Moon, a digital elevation model at a horizontal resolution of 30 – 50 m/pixel would aid in crustal modeling and in quantitative geomorphic studies such as the analysis of impact crater geometry.

**Mars:** A key question about Mars is the identification of any near-surface liquid water. At a wavelength of 24 cm (L-band) or longer, radar imaging of high latitudes may penetrate the regolith to a depth where the Mars Odyssey neutron spectrometer data [2] indicate high concentrations of hydrogen-bearing materials, which may well be ice-rich regolith. In hyper-arid terrestrial environments, L-band radar signals have been shown to penetrate to a depth of 1 –

2 meters [3, 4], which is the same depth range within which hydrogen-bearing materials exist near to the poles on Mars [2]. The potential exists not only to identify the seasonal position of the boundary between the hydrogen-free and hydrogen.

Significant advances have been made in the terrestrial glaciology community in the use of radar interferometry for investigating ice sheet dynamics [5]. The same application may also hold true for Mars, where the North Polar Cap may experience surface flow over the Martian year. In addition, decorrelation of radar interferograms due to the sublimation of carbon dioxide frosts on the South Polar Cap [6] would be easily identified. Experience with Space Shuttle Radar (SIR-C) has shown that surface changes in the planimetric outline of features can be related to geologic processes [7], and the same technique could be applied to measuring the sublimation rate of ice at the poles.

Topographic mapping on Mars is also possible with radar interferometry but, unlike the Moon, there are other data sets already available (or to be collected on future missions) that make this radar-derived data set non-unique. The Mars Orbiter Laser Altimeter (MOLA) and the Mars Express Stereo Camera have already collected high precision elevation data for Mars. MOLA has provided a global data set [8] while Mars Express has improved spatial resolution of selected sites. Future measurements from the HiRISE instrument on Mars Reconnaissance Orbiter offer the potential for decameter-scale digital elevation models on a local scale. Radar interferometry could play a role in this instance in the collection of regional topographic data at the 10 – 20 m scale. Longer wavelength radar measurements (L-Band and P-Band for example) could provide key information on the topography of subsurface features currently obscured by a layer of dust up to 5 m thick. Such measurements would facilitate the analysis of potential landing sites, geomorphic features indicative of paleo-climates (possible shorelines, valley networks, gullies on the walls of impact craters, etc.).

**Venus:** Venus represents a fascinating comparison with the Earth, primarily because of its similarity in size and distance from the Sun. But the lack of liquid water on the surface and the thick carbon dioxide atmosphere appears to have been responsible for the lack of plate tectonics on Venus. No direct evidence

has been obtained for active tectonic or volcanic processes on Venus, although high dielectric materials at the summit of Maat Mons suggest that this volcano may have been active in the recent geologic past [9].

Radar interferometry is particularly good at the detection of the deformation fields associated with earthquakes [10, 11], and so would be an excellent way to detect any current tectonic activity on Venus, if it were to occur. Similarly, the same methods that were used to map new lava flows on Kilauea volcano, Hawaii [7] could be used to search for active volcanism on Venus.

The collection of high resolution topographic data for Venus can also be accomplished with an interferometric radar. The Magellan mission collected image data at a spatial resolution of 75 m, but the topographic data from the altimeter had a much lower resolution (~10 km, with ~50 m vertical accuracy). The collection of topographic data at the same scale as the existing image data would greatly facilitate an improved understanding of structural and volcanic features on Venus.

**Europa:** Radar interferometric studies of any of the Galilean satellites will be a challenge, partly because of the need for small baselines between successive orbits, and partly because of the likely short duration of the missions due to the high energy environment within the Jovian system. However, these experiments offer the exciting opportunity of answering questions related to the thickness of the icy crust on Europa [12, 13], as well as provide detailed topographic information that might be of value for planning future penetrator experiments. Investigating the origin of the cycloid ridges on Europa, and searching for deformation along triple bands, would enable the identification of parts of the crust that are flexing on a daily basis. In particular, if brines were leaking on to the surface at the present time, the decorrelation of the radar interferogram would permit the spatial mapping of this process. Polarimetric radar may also permit determination of the dielectric constant variability in this instance.

The acquisition of high resolution topographic data for Ganymede and Callisto via interferometric radar would also enable the analysis of crustal structure on these moons. Rheological models for the deformation of impact craters of different sizes require knowledge of decameter-scale topography, which could be obtained for selected regions using a short-lived interferometric radar mission.

**Technical Developments Needed:** The Oxnard Workshop identified several technical issues that need

to be addressed before an interferometric mission could be flown to any of the planets. Highest priority was for the need to develop on-board data processing for the recovery of topographic information. The very large data volumes involved in producing digital elevation models for any planet require that ways to reduce this data volume be devised. Collecting such data from spacecraft at the distance of Jupiter's moons will be particularly challenging. Secondly, navigation of the spacecraft in orbit around a planet or moon may require significant improvement in navigation capability. Baseline separation for the two radar passes needs to be within ~1 km for most applications, so that detailed knowledge of the spacecraft's position and orientation are needed. Radiation shielding for the radar electronics may be required for the inner moons of Jupiter. Imaging a whole planet, particularly one the size of Venus, to search for possible deformation due to earthquakes requires a wide swath width for the radar. In terrestrial studies, most radar interferograms are produced with a spatial resolution of a few tens of meters but a swath width of less than 100 km. A new technique for terrestrial studies, involving SCAN-SAR and Radarsat data, has recently been used experimentally and may offer the potential for routine large-area coverage. Finally, for selected small areas where landers may be sent to the surface of the Moon or Mars, Spotlight techniques for the production of topographic information at the meter-scale may also be possible.

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