shallow and deep structure of the planet. Problems that will be specifically addressed are (1) identifying the location of the crust/mantle boundary, (2) determining the presence or absence of a mantle low-viscosity zone, (3) establishing the state of the core (is there a liquid outer core?), (4) measuring the spatial and temporal distribution of Venus quakes, and (5) determining source mechanisms for Venus quakes.

Mission Structure: The Venus Interior Structure Mission (VISM) consists of three seismometers deployed from landers on the surface in a triangular pattern (two located approximately 250 km from each other and the third at the apex of the triangle at a distance of 1000 km). The landers will be delivered by a carrier bus that will be placed into Venus orbit so it can act as relay to transmit data from the surface to the Earth (data rate of 100 Mb/day/lander). By necessity, the surface stations must be relatively long-lived, on the order of six months to one year. In order to achieve this goal, each lander will employ a General Purpose Heat Source (GPHS)-powered Stirling engine to provide cooling (refrigeration to 25°C) and electric power. Upon reaching the surface, a seismometer is deployed a small distance from each lander and is directly coupled to the surface. Seismic data are recorded at a rate of 1100 b/s (including lander engineering telemetry). The seismometer will be enshrouded by a shield so as to isolate it from wind noise. The instrument is an accelerometer patterned after that proposed for MESUR, having a sensitivity in the range of 0.05 Hz to 40 Hz. On the basis of theoretical analyses, it should be possible to observe over 600 events of magnitude 4.0 or better over the lifetime of the network, which will provide sufficient data to characterize the large-scale interior structure of Venus.

References: [1] Head J. W. et al. (1992) *JGR, 97,* 13153–13197. [2] Solomon S. C. et al. (1992) *JGR, 97,* 13199–13255. [3] Kiefer W. S. et al. (1986) *GRL, 13,* 14–17. [4] Smerkar S. E. and Phillips R. J. (1991) *EPSL, 107,* 582–597.

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PLASMA DIAGNOSTICS BY ANTENNA IMPEDANCE MEASUREMENTS.

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The impedance of an electrically short antenna immersed in a plasma provides an excellent *in situ* diagnostic tool for electron density and other plasma parameters. By electrically short we mean that the wavelength of the free-space electromagnetic wave that would be excited at the driving frequency is much longer than the physical size of the antenna. Probes using this impedance technique have had a long history with sounding rockets and satellites, stretching back to the early 1960s [1]. This active technique could provide information on composition and temperature of plasmas for comet or planetary missions.

There are several advantages to the impedance probe technique when compared with other methods. The measurement of electron density is, to first order, independent of electron temperature, vehicle potential, probe surface contamination, and orientation to the geomagnetic field. Surface heating and variations of the antenna surface physics do not effect the VLF and RF characteristics of the antenna and hence do not effect the accuracy of the measurements. As such, the technique is ideal for probes plunging into planetary atmospheres where surface contamination is a concern.

Currently two classes of instruments are built and flown by SDL-USU for determining electron density, the so-called capacitance and plasma frequency probes. The plasma frequency probe [7] operates in nearly collisionless plasmas and can provide absolute electron density measurements with 1% accuracy at sampling rates as high as 20 kHz, and the capacitance probe can provide electron density measurements with about 5% accuracy in strongly collisional plasmas. The instrumentation weighs less than 0.5 kg, consumes less than 1 W (continuous operation), and only requires a simple 0.1-m antenna [4]. Recently, from 1987 to 1991, the plasma frequency probe has successfully flown on 11 sounding rockets launched into the Earth's ionosphere at low, mid, and high latitudes and 5 more are being readied for missions in the immediate future.

The impedance of such short antennas has been extensively studied theoretically [2,3,5] and laboratory experiments have shown excellent agreement with theory [6]. When the current distribution on the antenna matches a natural mode of the plasma, energy is carried away by a plasma wave resulting in a large contribution to the antenna impedance. A measurement of the antenna impedance provides information on the normal modes of a plasma from which electron density, temperature, or ion composition could be deduced. The versatility and simplicity of an impedance probe would be ideal for the limited resources of planetary missions.

References: [1] Baker K. D. et al. (1969) *Small Rocket Inst. Tech.,* 49–57. [2] Balmain K. D. (1964) *IEEE Trans. Antennas Propagat., 12,* 605–617. [3] Bishop R. H. (1970) Ph.D. thesis, Univ. of Utah. [4] Jensen K. D. and Baker H. D. (1992) *J. Spacecraft Rockets, 29,* 94–95. [5] Nakatani D. T. and Kuehl H. H. (1976) *Radio Sci., 11,* 433–444. [6] Nakatani D. T. and Kuehl H. H. (1976) *Radio Sci., 11,* 517–529. [7] Swenson C. M. (1989) M.S. thesis, Utah State Univ.

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LUNAR SCIENCE: USING THE MOON AS A TESTBED.

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The Moon is an excellent testbed for innovative instruments and spacecraft. Excellent science can be done, the Moon has a convenient location, and previous measurements have calibrated many parts of it. I summarize these attributes and give some suggestions for the types of future measurements.

Lunar Science: The Lunar Scout missions planned by NASA's Office of Exploration will not make all the measurements needed. Thus, test missions to the Moon can also return significant scientific results, making them more than technology demonstrations.

Location: The Moon is close to Earth, so cruise time is insignificant, tracking is precise, and some operations can be controlled from Earth, but it is in the deep space environment, allowing full tests of instruments and spacecraft components.

Calibrations: The existing database on the Moon allows tests of new instruments against known information. The most precise data come from lunar samples, where detailed analyses of samples from a few places on the Moon provide data on chemical and mineralogical composition and physical properties. Apollo field excursions provided *in situ* measurement of surface geotechnical properties and local magnetic field strength. Orbital data obtained by Apollo missions also supply a useful set of standards, although not global in extent; data include chemical composition by gamma and X-ray spectrometry, imaging, and magnetic field strength. Observations at high spectral resolution have been obtained from terrestrial telescopes, providing spectral calibration points for numerous 1–5-km spots on the lunar surface. Finally, additional multispectral imaging has been obtained by the Galileo spacecraft and a global multispectral dataset will be acquired by the Clementine mission. Thus, the Moon is a large, Earth-orbiting standard on which to test new instruments.

Potential Instruments: The following list shows examples of the types of instruments that could take advantage of the Moon's virtues as a testbed. Lunar Scout I and II do not include items 1–4. Items 5–7 are thus essential if Scout does not fly, but even if Scout is successful, new generations of these instruments (smaller, better resolution, etc.) can still use the global database obtained by Scout as calibrations. (1) Atmospheric sensors, such as UV spectrometers and mass spectrometers. (2) Magnetic field detectors, such as magnetometers and electron reflectometers. (3) Altimeters for topography measurements. (4) Microwave radiometers, especially for heat flow determination. (5) Imaging spectrometers to obtain mineralogical information about the Moon. (6) Imaging systems for geologic mapping. (7) Devices to make chemical analyses from orbit-present instruments, such as gamma ray spectrometers (these are currently large and heavy, so new, smaller devices are essential for future planetary missions).

***In Situ* Analyses:** Excellent lunar science could be done using rovers carrying experimental payloads. Possible instruments include devices to do chemical and mineralogical analyses, high-resolution stereo imaging systems, gas analyzers, seismometers, heat flow probes, and atmospheric sensors.

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USE OF PARTICLE BEAMS FOR LUNAR PROSPECTING.

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A key issue in choosing the appropriate site for a manned lunar base is the availability of resources, particularly oxygen and hydrogen for the production of water, and ores for the production of fuels and building materials. NASA has proposed two Lunar Scout missions that would orbit the Moon and use, among other instruments, a hard X-ray spectrometer, a neutron spectrometer, and a Ge gamma ray spectrometer to map the lunar surface. This passive instrumentation will have low resolution (tens of kilometers) due to the low signal levels produced by natural radioactivity and the interaction of cosmic rays and the solar wind with the lunar surface. This paper presents the results of a concept definition effort for a neutral particle beam lunar mapper probe. The idea of using particle beam probes to survey asteroids was first proposed by Sagdeev et al. [1], and an ion beam device was fielded on the 1988 Soviet probe to the Mars moon Phobos. During the past five years, significant advances in the technology of neutral particle beams (NPB) have led to a suborbital flight of a neutral hydrogen beam device in the SDIO-sponsored BEAR experiment. An orbital experiment, the Neutral Particle Beam Far Field Optics Experiment (NPB-FOX) is presently in the preliminary design phase. The development of NPB accelerators that are space-operable leads one to consider the utility of these devices for probing the surface of the Moon using gamma ray, X-ray, and optical/UV spectroscopy to locate various elements and compounds [2]. We consider the utility of the NPB-FOX satellite containing a 5-MeV particle beam accelerator as a probe in lunar orbit. Irradiation of the lunar surface by the particle beam will induce secondary and backscattered radiation from the lunar surface to be detected by a sensor that may be co-orbital with or on the particle beam satellite platform, or may be in a separate orbit. The secondary radiation is characteristic of the make-up of the lunar surface. The size of the spot irradiated by the beam is less than 1 km wide along the groundtrack of the satellite, resulting in the potential for high resolution. The fact that the probe could be placed in polar orbit would result in global coverage of the lunar surface. The orbital particle beam probe could provide the basis for selection of sites for more detailed prospecting by surface rovers.

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References: [1] Sagdeev R. Z. et. al. (1984) *Proc. Cospar Conference.* [2] Meinel C. et al. (1990) in *Proc. Space 90, Engineering, Construction, and Operations in Space II* (S. W. Johnson and J. P. Wetzel, eds.).

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SUBNANORADIAN, GROUNDBASED TRACKING OF SPACEBORNE LASERS.

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Over the next few decades groundbased tracking of lasers on planetary spacecraft will supplement or replace tracking of radio transponders. This paper describes research on two candidate technologies for groundbased, angular, laser tracking: the infrared interferometer and the optical filled-aperture telescope. The motivation for infrared and optical tracking will be followed by a description of the current (10–50 nanoradian) and future (subnanoradian) stellar tracking demonstrations with the University of California-Berkeley Infrared Spatial Interferometer (ISI) on Mt. Wilson [1], and the University of California-San Diego Optical Ronchi Telescope on Table Mountain [2].

In the long term, lasers will replace radio transponders to increase telemetry data rates, rougly tenfold, by communication over optical channels [3]. In the short term (next 10 years), few-nanoradian tracking of a low-power laser may outperform single-frequency radio tracking. For example, radio tracking at 3-cm wavelengths is afflicted by charged particle fluctuations at the 5–10 nanoradian level; charged particle effects are negligible for infrared and optical frequencies. Tracking of low-power lasers at planetary distances seems feasible with the above-mentioned instruments. For example, a 0.5-W laser through a 10-cm aperture at Mars could be tracked by both of the above instruments, with modest upgrades to be implemented before this spring-summer observing season.

Angular tracking interferometric phase-time series from ISI will be discussed. It will be shown that new hardware, which will improve detector efficiency, will enable reliable cycle ambiguity resolution in moderate seeing. High correlations between measurements of path lengths within ISI, and those along the paths through