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.

N93-28822 160768

P, 1

USE OF PARTICLE BEAMS FOR LUNAR PROSPECTING.

A. J. Toepfer, D. Eppler, A. Friedlander, and R. Weitz, Science Applications International Corporation, 2109 Air Park Road SE, Albuquerque NM 87106, USA.

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.

This work was partially supported by the U.S. Army Strategic Defense Command under Contract No. DASG60-90-C-0103, Grumman Corporation Subcontract # 52-87979.

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.).

N93-28823 160769 p-2

SUBNANORADIAN, GROUNDBASED TRACKING OF SPACEBORNE LASERS.

R. N. Treuhaft, Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109, USA.

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 the atmosphere to the target star, suggest that most of the atmospheric turbulence contributing to poor seeing is occurring within about 10 m of the ground. For the Table Mountain Ronchi telescope, signal-to-noise improvements will enable tracking of a visual magnitude 11 star. Demonstrations of this capability will occur this summer after hardware upgrades in the spring.

The above demonstrations will yield 10–50-nanoradian performance, but it has been shown that subnanoradian performance enables many mission enhancements. For example, subnanoradian angular tracking enables detection of Jupiter's spacecraft-relative position about 100 days before encounter. Subnanoradian tracking is largely prevented by atmospheric refractivity fluctuations for both the above mentioned devices. Methods of minimizing atmospheric effects using optimal stochastic estimation and direct calibration will be described.

References: [1] Bester M. et al. (1992) *Ap. J., 392*, 357. [2] Lanyi G. et al. (1992) *Telecommunications and Data Acquisition Progress Report 42-110* (E. Posner, ed.), 104–111, Jet Propulsion Laboratory, Pasadena, California. [3] Lesh J. R. et al. (1990) *Telecommunications and Data Acquisition Progress Report 42-103*, 97–109, July-September 1990, Jet Propulsion Laboratory, Pasadena, California.

S60-91 N93-28824 160770

p.1

A TEAM APPROACH TO THE DEVELOPMENT OF GAMMA RAY AND X-RAY REMOTE SENSING AND *IN SITU* SPECTROSCOPY FOR PLANETARY EXPLORATION MISSIONS.

J. I. Trombka[1] (Team leader), S. Floyd[1], A. Ruitberg[1], L. Evans[2], R. Starr[3], A. Metzger[4], R. Reedy[5], D. Drake[5], C. Moss[5], B. Edwards[5], L. Franks[6], T. Devore[6], W. Quam[6], P. Clark[7], W. Boynton[8], A. Rester[9], P. Albats[10], J. Groves[10], J. Schweitzer[11], and M. Mahdavi[11], [1]Goddard Space Flight Center, Greenbelt MD 20771, USA, [2]Computer Sciences Corporation, Calverton MD 20705, USA, [3]The Catholic University of America, Washington DC 20064, USA, [4]Jet Propulsion Laboratory, Pasadena CA 91109, USA, [5]Los Alamos Scientific Laboratory, Los Alamos NM 87545, USA, [6]EG & G Energy Measurements Santa Barbara, Goaleta CA 93117, USA, [7]Albright College, Reading PA 19612, USA, [8]University of Arizona, Tucson AZ 85721, USA, [9]University of Florida, Alachua FL 32615, USA, [10]Schlumberger-Doll Research, Ridgefield CT 06877, USA, [11]EMR Schlumberger, Princeton NJ 08542, USA.

An important part of the investigation of planetary origin and evolution is the determination of the surface composition of planets, comets, and asteroids. Measurements of discrete line X-ray and gamma ray emissions from condensed bodies in space can be used to obtain both qualitative and quantitative elemental composition information.

Remote sensing X-ray and gamma ray spectrometers aboard either orbital or flyby spacecraft can be used to measure line emissions in the energy region ~0.2 keV to ~10 MeV. These elemental characteristic excitations can be attributed to a number of processes such as natural radioactivity, solar X-ray fluorescence, and cosmic ray primary- and secondary-induced activity. Determination of composition for the following elements can be expected: O, Si, Fe, Mg, Ti, Ca, H, Cl, K, Th, and U. Global elemental composition maps can be obtained using such spectrometer systems.

More complete elemental composition can be obtained by landing packages that include X-ray and gamma ray spectrometer systems along with X-ray, charged particle, and neutron excitation sources on planetary surface. These *in situ* systems can be used on stationary, roving, and penetrator missions. Both the remote sensing and *in situ* spectrometer systems have been included aboard a number of U.S. and Russian planetary missions [1,2].

The Planetary Instrument Definition and Development Program (PIDDP) X-Ray/Gamma Ray Team has been established to develop X-ray and gamma ray remote sensing and *in situ* technologies for future planetary exploration missions. This team represents groups having active programs with NASA, the Department of Energy (DOE), the Department of Defense (DOD), and a number of universities and private companies. A number of working groups have been established as part of this research program. These include groups to study X-ray and gamma ray detectors, cryogenic cooling systems, X-ray and particle excitation sources, mission geochemical research requirements, detector space radiation damage problems, field simulation studies, theoretical calculations and X-ray and nuclear cross sections requirements, and preliminary design of flight systems. Major efforts in this program will be devoted to the development of X-ray/gamma ray remote sensing systems for the NEAR (Near Earth Asteroid Rendezvous) mission and for *in situ* X-ray and gamma ray/neutron systems for penetrators, soft landers, and rovers for MESUR missions.

References: [1] Fichtel C. and Trombka J. I. (1982) *Gamma Ray Astrophysics New Insight and into the Universe*, NASA SP-453, 19–65. [2] Boynton W. V. et al. (1992) *JGR, 97*, 7681–7698.

S41-31 N93-28825 160771 p.2

MINIATURE LONG-LIFE SPACE CRYOCOOLERS.

E. Tward, TRW, One Space Park, Redondo Beach CA 90278, USA.

Cryogenic coolers for use in space on small satellites require low power and minimum weight. The need for exceptional reliability in a space cooler is made even more critical on small satellites since cooler redundancy is often not an option due to weight constraints. In this paper we report on two reliable, small, efficient low-power, vibrationally balanced coolers designed specifically for use on small satellites.

TRW has designed, built, and tested a miniature integral Stirling cooler and a miniature pulse tube cooler intended for long-life space application. Both efficient, low-vibration coolers were developed for cooling IR sensors to temperatures as low as 50 K on lightsats.

The vibrationally balanced nonwearing design Stirling cooler incorporates clearance seals maintained by flexure springs for both the compressor and the drive displacer. The design achieved its performance goal of 0.25 W at 65 K for an input power to the compressor of 12 W. The cooler recently passed launch vibration tests prior to its entry into an extended life test and its first scheduled flight in 1995.

The vibrationally balanced, miniature pulse tube cooler intended for a 10-year long-life space application incorporates a nonwearing flexure bearing compressor vibrationally balanced by a motor-controlled balancer and a completely passive pulse tube cold head. The maximum cooling power measured at 80 K is 800 mW for an input power to the compressor of 30 W. The cooler is suitable for cooling sensors and optics between 60 K and 200 K, with cooling