sensor and static pressure probes have been applied in a variety of field programs and can be adapted for use in different planetary atmospheres.

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DESIGN OF A PARTICLE BEAM SATELLITE SYSTEM FOR LUNAR PROSPECTING. D. H. Berwald and P. Nordin, Grumman Aerospace and Electronics, Bethpage NY 11714, USA.

One potential use for neutral particle beam (NPB) technology is as an active orbital probe to investigate the composition of selected locations on the lunar surface. Because the beam is narrow and can be precisely directed, the NPB probe offers possibilities for high-resolution experiments that cannot be accomplished using passive techniques. Rather, the combination of both passive and active techniques can be used to provide both full-coverage mapping (passively) at low resolution (tens of kilometers) and high-resolution information for discrete locations of special interest.

A preliminary study of NPB applicability for this dual-use application was recently conducted by Grumman and its subcontractors, McDonnell Douglas and SAIC. This study was completed in February 1993 [1]. A novel feature was that consideration of the use of a Russian launch vehicle (e.g., the Proton) and other Russian space hardware and capabilities was encouraged. This paper describes the lunar prospector system design. Toepfer et al. [2] discuss issues and opportunities involving lunar scientific experimentation using an NPB.

The NPB lunar prospector utilizes a modified design of the Far Field Optics Experiment (FOX) [3]. Like the Earth-orbiting FOX, the core capability of the NPB lunar prospector will be a pulsed RF LINAC that produces a 5-MeV proton beam that is projected to the target with a 30-μr beam divergence and a 10-μr beam-pointing accuracy. Upon striking the lunar surface, the proton beam will excite characteristic radiation (e.g., X-rays) that can be sensed by one or more detectors on the NPB platform or on a separate detector satellite.

Two principal design variants have emerged. The first, a non-nuclear design, utilizes a Proton fourth stage for transfer to lunar orbit. The electric power source is solar and the NPB satellite performs its experimental program while orbiting about 50 km above the lunar surface. When the NPB satellite passes over its target, the beam is activated and the experiment is performed. A key issue for this configuration is the design mass margin that can be achieved within the capabilities of the Proton fourth stage.

The second design variant is powered by a Topaz 3 nuclear reactor (40 KWe). Efficient but low-thrust electric propulsion (e.g., SPT-200 or larger) is used for orbital transfer. The payload delivered to lunar orbit is much larger, but a second spacecraft will be required to provide adequate separation of the nuclear reactor and the detector. A high-low configuration is employed. The detector and NPB orbit at altitudes of 25–50 km and 1980 km respectively. The issues for the second design are technology availability, reliability, and cost.

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LASER-INDUCED BREAKDOWN SPECTROSCOPY INSTRUMENT FOR ELEMENTAL ANALYSIS OF PLANETARY SURFACES. J. Blacic[1], D. Pettit[1], D. Cremers[2], and N. Roessler[3], [1]Geology and Geochemistry Group, Los Alamos National Laboratory, Los Alamos NM 87545, USA, [2]Photochemistry and Photophysics Group, Los Alamos National Laboratory, Los Alamos NM 87545, USA, [3]McDonnell Douglas Electronics Systems Co., St. Louis MO 63166, USA.

TABLE 1. Systems analysis summary for LIBS instrument.

Systems:	Diode-Pumped, Nd-YAG Laser System*			Spectrometer System‡		Optical System	Support System¶		Total Instrument§	
Maximum Analytical Range (m)	Optical Energy (mJ)	Average Electrical Power*(W)	Mass† (kg)	Mass (kg)	Power (W)	Mass (kg)	Mass (kg)	Power (W)	Mass (kg)	Power (W)
20–40	180	0.3	0.7	2.0	3.2	0.3	0.5	0.4	3.5	3.9
50–100	320	0.6	4.8	2.0	3.2	0.5	0.8	0.6	8.1	4.4
100–500	1000	1.5	16	2.0	3.2	0.8	1.8	0.8	20.6	5.5

*Assumes 10-ns pulse and 0.1-Hz repetition rate (McDonnell Douglas Electronic Systems Co.).
† Includes power conditioning and storage.
‡ Includes spectrograph, intensified CCD detector, thermoelectric cooler, and electronics.
¶ Includes structure, motors, and misc. hardware.
§ No power generation or communications allowance.

One of the most fundamental pieces of information about any planetary body is the elemental and mineralogical composition of its surface materials. We are developing an instrument to obtain such data at ranges of up to several hundreds of meters using the technique of Laser-Induced Breakdown Spectroscopy, or LIBS. We envision our instrument being used from a spacecraft in close rendezvous with small bodies such as comets and asteroids, or deployed on surface-rover vehicles on large bodies such as Mars and the Moon. The elemental analysis is based on atomic emission spectroscopy of a laser-induced plasma or spark. A pulsed, diode-pumped Nd:YAG laser of several hundred millijoules optical energy is used to vaporize and electronically excite the constituent elements of a rock surface remotely located from the laser. Light emitted from the excited plasma is collected and introduced to the entrance slit of a small grating spectrometer. The spectrally dispersed spark light is detected with either a linear photo diode array or area CCD array. When the latter detector is used, the optical and spectrometer components of the LIBS instrument can also be used in a passive imaging mode to collect and integrate reflected sunlight from the same rock surface. Absorption spectral analysis of this reflected light gives mineralogical information that, when combined with the elemental analysis from the LIBS mode, provides a complete remote geochemical characterization of the rock surface.

We have performed laboratory calibrations in air and in vacuum on standard rock powders to quantify the LIBS analysis. We have performed preliminary field tests using commercially available components to demonstrate remote LIBS analysis of terrestrial rock surfaces at ranges of over 25 m, and we have demonstrated compatibility with a six-wheeled Russian robotic rover vehicle. Based on these results, we believe that all major and most minor elements expected on planetary surfaces can be measured with absolute accuracy of 10–15% and much higher relative accuracy. We have performed preliminary systems analysis of a LIBS instrument to evaluate probable mass and power requirements; results of this analysis are summarized in Table 1.

N93-28772 0160716 P. 1

CLEMENTINE II: A DOUBLE ASTEROID FLYBY AND IMPACTOR MISSION. R. J. Boain, Jet Propulsion Laboratory, Pasadena CA 91109, USA.

Recently JPL was asked by SDIO to analyze and develop a preliminary design for a deep-space mission to fly by two near-Earth asteroids, Eros and Toutatis. As a part of this mission, JPL was also asked to assess the feasibility of deploying a probe on approach to impact Toutatis. This mission is a candidate for SDIO's Clementine II.

SDIO's motivations were to provide further demonstrations of precision, autonomous navigation for controlling the flight paths of both a spacecraft and a probe. NASA's interest in this mission is driven by the opportunity to obtain the first close-up images and other scientific measurements from a spacecraft of two important near-Earth objects. For Toutatis this is especially important since it was observed and imaged extensively just last December using Earth-based radar; Clementine II will provide the opportunity to corroborate the radar data and validate the ultimate potential of the radar technique.

Scientifically, the probe impact at Toutatis will allow the acquisition of data pertaining to the dynamic strength of surface material and data on the properties of the regolith and on stratification below the surface, and will potentially allow the measurement of thermal diffusivity between the interior and the surface. These determinations will be accomplished by means of high-resolution imagery of the impact crater and its surroundings in visible, ultraviolet, and infrared wavebands from the spacecraft flying by some 30 min after the probe strike. In addition, if the spacecraft can be equipped with a lightweight mass spectrometer and dust analyzer, the potential also exists to measure the particle sizes and distribution and the composition of the ejecta cloud.

This mission is planned to be launched in July 1995, with the Eros encounter on March 13, 1996, and the Toutatis flyby on October 4, 1996, some 440 days after launch. The Eros encounter is characterized by a flyby speed of 8.4 km/s and a Sun-target-spacecraft phase angle of 120°. Thus, the principal visible light images of Eros will be obtained after closest approach. The Eros miss distance is nominally set at 30 km. For Toutatis, the encounter is characterized by an approach speed of 17.8 km/s and a phase angle of 20°. With this approach geometry, Toutatis presents a sunlit face to the spacecraft and probe. The probe will hit the asteroid at approximately 18 km/s. To facilitate imagery of the impact crater and to assure continuous line-of-sight tracking through encounter, the closest approach distance at Toutatis is selected to be 50.0 km.

N93-28771 160717 P. 2

HIGH-PERFORMANCE VISIBLE/UV CCD FOCAL PLANE TECHNOLOGY FOR SPACEBASED APPLICATIONS. B. E. Burke, R. W. Mountain, J. A. Gregory, J. C. M. Huang, M. J. Cooper, E. D. Savoye, and B. B. Kosicki, Lincoln Laboratory, Massachusetts Institute of Technology, P.O. Box 73, Lexington MA 02173-9108, USA.

We describe recent technology developments aimed at large CCD imagers for spacebased applications in the visible and UV. Some of the principal areas of effort include work on reducing device degradation in the natural space-radiation environment, improvements in quantum efficiency in the visible and UV, and larger-device formats. One of the most serious hazards for spacebased CCDs operating at low signal levels is the displacement damage resulting from bombardment by energetic protons. Such damage degrades charge-transfer efficiency and increases dark current. We have achieved improved hardness to proton-induced displacement damage by selective ion implants into the CCD channel and by reduced temperature of operatlon. To attain high quantum efficiency across the visible and UV we have developed a technology for back-illuminated CCDs. With suitable antireflection (AR) coatings such devices have quantum efficiencies near 90% in the 500–700-nm band. In the UV band from 200 to 400 nm, where it is difficult to find coatings that are sufficiently transparent and can provide good matching to the high refractive index of silicon, we have been able to substantially increase the quantum efficiency using a thin film of HfO_2 as an AR coating. These technology efforts have been applied to a 420 × 420-pixel frame-transfer imager, and