GAMMA-RAY SPECTROMETER FOR LUNAR SCOUT II*; C. E. Moss[1], W. W. Burt[2], B. C. Edwards[1], R. A. Martin[1], G. H. Nakano[3], and R. C. Reedy[1]. [1]Los Alamos National Laboratory, Los Alamos, NM 87545; [2]TRW Space and Technology Group, Los Angeles, CA 90278; [3]Consultant, Los Altos, CA 94022.

We review the current status of the Los Alamos program to develop a high-resolution gamma-ray spectrometer for the Lunar Scout-II mission, which is the second of two Space Exploration Initiative robotic precursor missions to study the Moon. This instrument will measure gamma rays in the energy range of ~0.1–10 MeV to determine the composition of the lunar surface. The instrument is a high-purity germanium crystal surrounded by an CsI anticoincidence shield and cooled by a split Stirling cycle cryocooler. It will provide the abundance of many elements over the entire lunar surface.

Figure 1 shows details of the design. It will contain a $\approx 70\%$ efficient (relative to a 7.62-cm-diameter × 7.62-cm-length NaI(Tl) scintillator) n-type germanium crystal. N-type is used because it is much less susceptible to radiation damage than p-type germanium. Although the radiation damage accumulated in the one-year mission is not expected to degrade the energy resolution if the crystal remains below ~100 K and there are no major solar particle events, we have decided to provide annealing capability to be safe. Because a Stirling cycle cooler will be used, the crystal will be mounted using techniques developed in recent years for operating germanium detectors on vibrating platforms. The inner can, which will be very similar to the Mars Observer one, will be supported by a re-entrant tube design that gives good rigidity and thermal isolation. A CsI(Na) anticoincidence shield on the sides and spacecraft end of the germanium crystal will eliminate most events due to charged particles, gamma rays produced by cosmic rays incident on the spacecraft, and Compton-scattered events in the crystal. This shield will be segmented so that a sector on the side away from the spacecraft can serve as a backup detector with a resolution of about 10%, which is only slightly worse than the 8% value expected with a stand alone CsI(Na) crystal and the resolution for the Apollo NaI(Tl) gamma-ray spectrometers. A plastic scintillator segmented into two pieces surrounds the CsI(Na). The plastic scintillator covering the aperture over the nadir-pointing surface of the germanium crystal rejects charged-particle events without significantly attenuating the lunar gamma-ray flux. Similarly, the plastic scintillator over the backup CsI(Na) segment provides a charged-particle anticoincidence shield in the backup mode. The detector will be on a short pedestal to further reduce the background from the spacecraft.

Because a germanium detector operates at about 80 K, the critical issue for space applications is the method of cooling. For short missions, stored cryogens such as liquid or solid nitrogen, solid methane, or solid argon can be used. For long missions, a passive radiator, as used on the Mars Observer, or an active device, such as a mechanical refrigerator, is required. Because of the complications in shielding a radiator from the Sun, Earth, and Moon when the spacecraft is in a lunar polar orbit, we have chosen to use a split Stirling cycle refrigerator. Such a refrigerator with a germanium detector was successfully flown in 1979 for an extended mission [1]. We selected the British Aerospace (BAe) design [2], which was developed at Oxford University. Designed for a ten-year lifetime, this refrigerator has operated successfully in the laboratory for four years. Two of these units were launched on 12 September 1991 as part of the ISAMS multi-channel infrared radiometer on the Upper Atmosphere Research Satellite, and they are still operating successfully.

Because the germanium detector energy resolution may be degraded by vibration, we will use a pair of these cryocoolers with two compressors and two expanders mounted back to back to minimize vibration. We will also use a flexible vibration decoupler between the expander cold tips and the germanium crystal. Research is being done on these coolers [3] concerning vibration, thermal performance, and reliability, but mainly focused on applications other than germanium detectors. We started tests in 1992 with a single BAe cryocooler coupled via a flexible thermal link to a germanium crystal mounted in a Mars Observer-like can. The compressor and expander were mounted on a 200-pound mass.

The germanium crystal and preamplifier were isolated by suspending them on springs, and the whole system was operated in a vacuum chamber. Preliminary results indicate that the force transmitted to the germanium crystal was only 0.1 N. Based on previous work [1,4] in which known forces were applied to germanium detectors and the resolution was measured, we expect the resolution in a back-to-back configuration to be ~3 keV.

The gamma-ray spectrometer will provide data on many elements over all of the lunar surface. Published estimates of the detection limits for similar detectors range from 0.016 ppm for uranium to 1.3% for calcium [5]. The value for hydrogen is 590 ppm based on the 2.2-MeV hydrogen capture gamma ray. The spatial resolution is about 140-km × 140-km, which is determined by the orbit altitude of 100 km [6]. This instrument senses the elemental composition of the lunar surface to depths of tens of centimeters.

The interpretation of the data will be enhanced by comparisons with data from other instruments. To facilitate this we plan to use software and experience of Mars Observer and to put the data into the Planetary Data System. The neutron spectrometer [7] has a potential sensitivity of 100 ppm hydrogen but needs information from the gamma-ray spectrometer about other elements that can absorb or moderate neutrons. The uncertainties in the elemental abundances from the gamma-ray detector can be reduced if the neutron source intensity in the lunar regolith is provided by the neutron spectrometer because most of the gamma rays are produced by neutron reactions. Comparison of the gamma-ray data with data from instruments having higher spatial resolution and spatial deconvolution of stronger gamma-ray lines will help in understanding lunar features smaller than 140 km.

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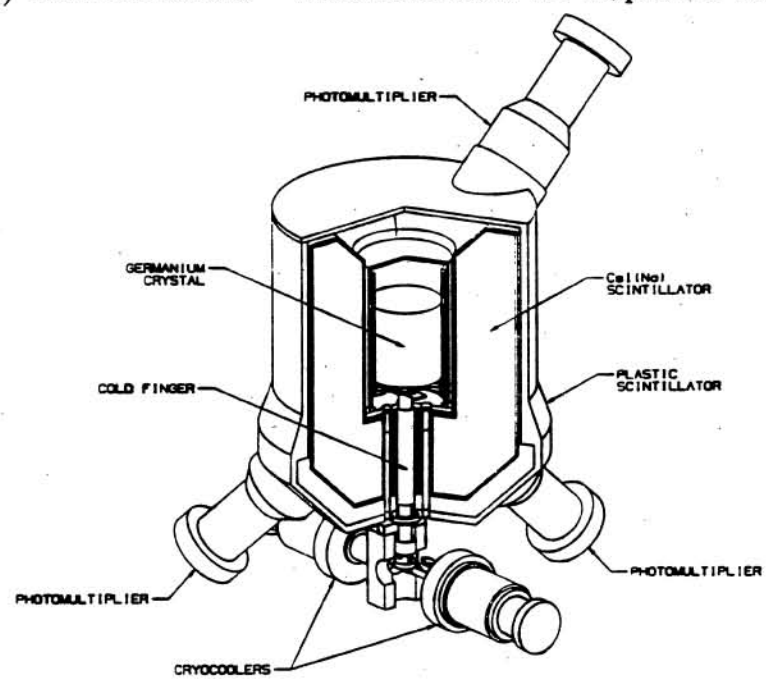

Fig. 1. Gamma-ray spectrometer. The scintillators "shield" the germanium crystal from charged particles and other background radiations. The germanium crystal is cooled via the cold finger from the cryocoolers, which are located on the spacecraft side of the spectrometer.