



PLANNING NASA VENTURES—Dr. Thomas Wilson, NASA, (*l.*), Dr. Larry Pinsky (*c.*), chair, UH Physics Department, and Dr. David Criswell (*r.*), ISSO director, meet at NASA to review data gathered by the Mars Radiation Environment Experiment (MARIE). Researchers are measuring surface and solar energetic particle events and galactic cosmic rays, based upon data from the Mars Odyssey spacecraft when it orbited Mars for two months in October 2001.

Analysis of the Mars Odyssey MARIE Experiment Data

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Abstract—

The Mars Radiation Environment Experiment (MARIE) was launched April 7, 2001, and inserted into orbit around Mars in October as part of the Mars Odyssey 2001 spacecraft payload. The purpose of the experiment is to evaluate the radiation environment in the vicinity of Mars in order to plan the design of future manned spacecraft and missions to that planet. The experiment consists of a charged particle telescope and has a resolution capable of measuring the flux of charged particles from about 20-450 MeV/A. The experiment experienced an equipment failure in August and has been inoperable since. However, some data were taken prior to that failure, and the analysis of those data is proceeding. Plans exist to attempt to restore the experiment to full functioning capacity when the spacecraft's orbit around Mars is stabilized after other mission-critical events have occurred. The original NASA PI for the experiment, Dr. Gautam Badhwar, tragically passed away last August, and there has been a transition in the responsible NASA personnel on the project. However, commitments have been reaffirmed to continue the involvement of the UH student supported in the project with ISSO funds as he continues to pursue his Ph.D. dissertation research.

IN THE EFFORT TO EXPLORE MARS, THE MARS ODYSSEY SPACECRAFT was launched on April 7, 2001, and arrived in orbit at Mars on October 23, 2001. The spacecraft then spent about two months aerobraking to achieve a two-hour circular science orbit. One of the three scientific instruments on board is the Mars Radiation Environment Experiment (MARIE), in which the University of Houston group plays a role in the analysis of the data. The principal function of MARIE is to characterize the space radiation environment of Mars and determine the risk it poses to human exploration. Primary radiation sources to be measured are surface and solar energetic particle events (SEPs) and galactic cosmic rays (GCRs). Data collected by MARIE will be used to model the effects of the atmosphere of Mars in order to predict radiation doses. MARIE is an energetic particle spectrometer that is described in the next section.

Instrument Description

The MARIE instrument functions much like a telescope, as shown in Fig. 1. It consists of six silicon detectors, two position sensitive detectors (PSDs), and a Cerenkov detector. Starting from the top in Fig. 1, detector A1 is a square silicon detector $25.4 \times 25.4 \times 1$ mm. Next are the position sensitive detectors PSD1 and PSD2, which are identical in design. Each consists of two silicon strip detectors placed one directly on top of the other, with the strips oriented perpendicular to one another for x - y position sensitivity. Each strip detector has 24 1-mm width strips, such that

dimensions of the PSDs are $24 \times 24 \times 0.3$ mm. The next detector, A2, is identical to A1. The four B detectors (B1, B2, B3, B4) are identical circular silicon detectors with a diameter of 63.5 mm and thickness of 5 mm. The last detector is the C detector complex, which consists of a Cerenkov detector, made of sapphire, (45 mm diameter and 10 mm thickness) followed by a reflector and a photomultiplier tube. In addition to these detectors there are four 0.001" brass sheets in the detector stack. There is one sheet located on each side of the two A detectors. This material was inserted to reduce the background noise.

The trigger for this instrument is an A1 A2 detector coincidence. This means that an ion or charged nucleus must enter the 60 degree field of view (FOV), in either the forward (top to bottom) or backward (bottom to top) direction, and have enough energy to penetrate the A1 and A2 detectors. It is not necessary for the particle to go entirely through both detectors, it only has to penetrate one and then deposit a small amount (enough to be detected by the electronics ~35 keV) in the other. If both A1 and A2 have a signal, then a reading from every detector is recorded to disk as a single event.

MARIE weighs 3.3 kilograms and uses seven watts of power. Its outside dimensions are $29.4 \times 23.2 \times 10.8$ cm. An isometric view is shown in Fig. 2.

Preliminary Data Results

Data were taken during the Earth-Mars transit phase from April-August 2001. During this time, MARIE was calibrated and several adjustments were made to the values for voltage bias in the spectrometer. These changes altered triggering thresholds which affected particle energy cutoffs.

Figure 3 shows a scatter plot of the measured energy loss in A2 and B1 for particles that did not completely penetrate B1. The solid lines are theoretical curves based on a best fit of the proton range-energy data of Janni¹ to a power law $R_p = kE^n$, where the values of k and n are material-dependent. The data spread above the solid lines are due to the path-length variation caused by finite opening-angle of the telescope. The solid line has been calculated using normal incidence, and thus minimum path length.

Figures 4 and 5 show the average measured charge from the four B detectors, for particles that have enough energy to penetrate all the silicon detectors. The charge measured in each detector is calculated using $Z = \sqrt{E/\alpha}$, where E is the measured energy loss, and is determined by forcing the proton peak to a value of $Z = 1$. The resolution of this plot will improve when the A detectors are included in the measurement.

References

¹J. Janni. "Proton Range-Energy Tables, 1 keV-10GeV, Part I and II," *Atomic Data and Data Tables* 27 (1982).

Publications

Cleghorn, T., K. Lee, L. Pinsky, C. Zeitlin, and G. Badhwar. "Initial Results from the 2001 Mars Odyssey Martian Radiation Environment Experiment (MARIE)," *Proc.*, 33rd Lunar and Planetary Science Conf., League City, TX, March 11-15, 2002

Presentations

Lee, K., L. Pinsky, G. Badhwar, T. Cleghorn, T. Beyers, R. Dunn, C. Chambellan, J. Bahr, F. Riman, J. Flanders and P. Delaune. "Measurement of the Galactic Cosmic Ray Particle Energy

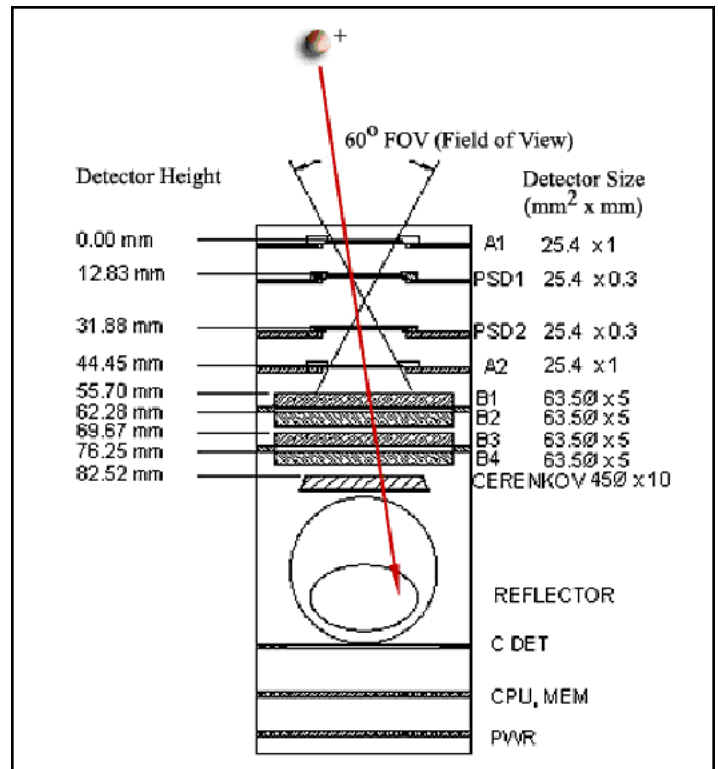


Figure 1. Detector array schematic of MARIE

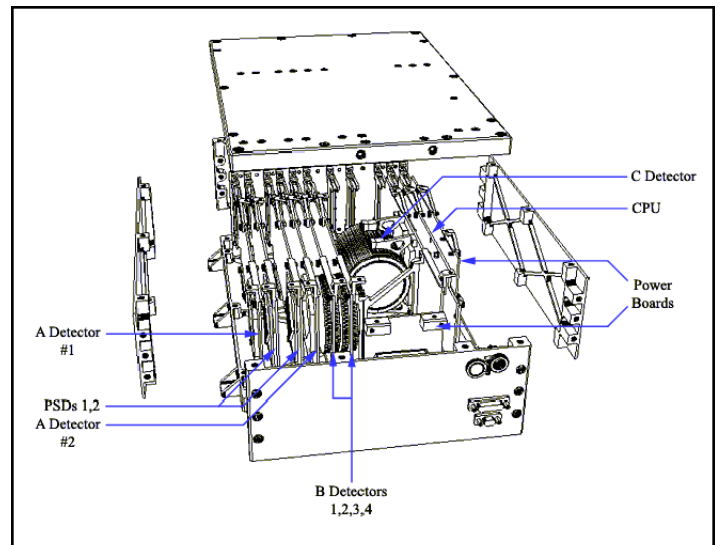


Figure 2. An isometric view of MARIE

Spectra in Earth-Mars Transit and Mars Orbit," Int'l. Conf. on Environmental Systems, San Antonio, TX, July 15-18, 2002.

Funding and proposals

"Analysis of Data from the Mars '01 MARIE Experiment." Aug. 1, 2001-July 31, 2002, NAG9-1347, \$25,894.

"Analysis of the MARIE Data Including A Study of the Radial Dependence of Solar Energetic Particle Events," July 1, 2002-June 30, 2005, NASA NRA-01-OSS-01=Mars Odyssey Participating Scientist, \$356,400; pending.

"Determining the Radial Dependence of Particle Intensities from Coronal Mass Ejections," Jan. 1, 2002-Dec.

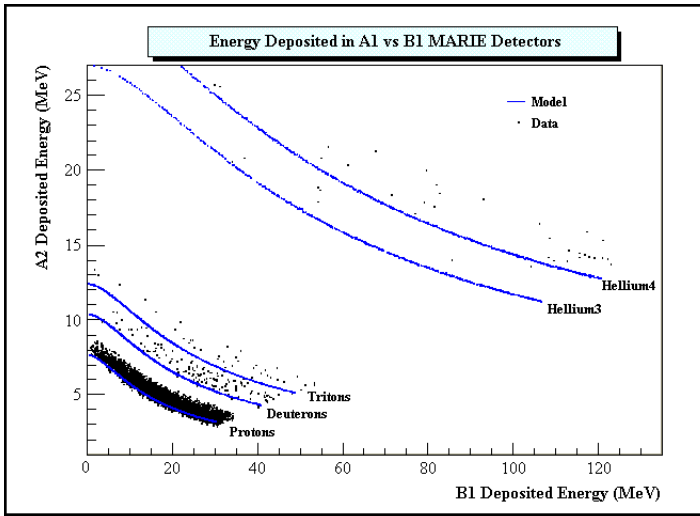


Figure 3. Particles stopping in detector B1.

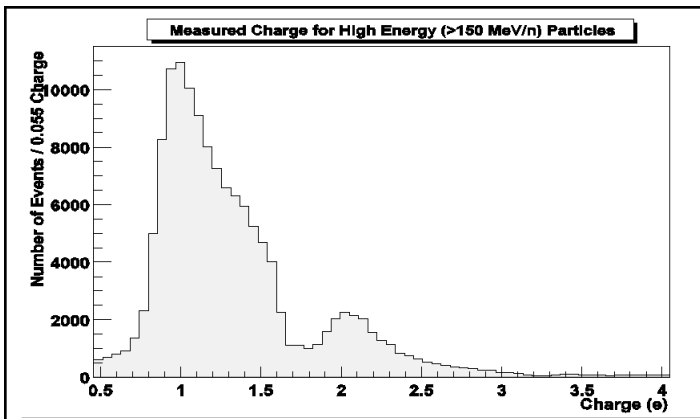


Figure 4. Charge plot showing *H* and *He*.

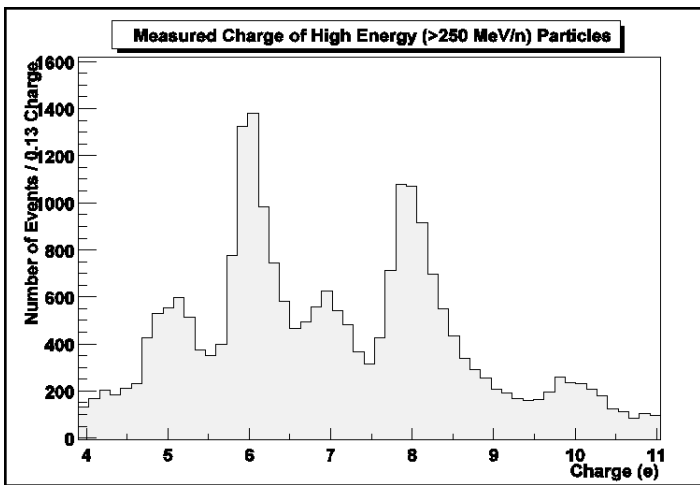


Figure 5. Charge plot showing $Z > 4$.

31, 2003, ARP, \$103,000.

Theses or student reports
 Lee, K. Dissertation in progress.

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