MARIE: Current Status and Results from 20 Months of Observations at Mars. C. Zeitlin[1], V. Andersen[2], W. Atwell[3], T. F. Cleghorn[4], F. A. Cucinotta[4], K. T., Lee[2], L. Pinsky[2], P. Saganti[4] [1]National Space Biomedical Research Institute, One Baylor Plaza, Houston, TX 77030, email: cjzeitlin@lbl.gov; [2]University of Houston, Department of Physics, 4800 Calhoun Blvd. Room 617, Houston, TX, 77204-5005; [3]The Boeing Company, 13100 Space Center Blvd., Houston, TX 77059; [4]NASA-Johnson Space Center, 2101 NASA Road 1, Houston, TX, 77058.

Introduction: The MARIE instrument aboard the 2001 Mars Odyssey spacecraft detects energetic charged particles in the Galactic Cosmic Radiation (GCR) and during solar particle events (SPE) [1]. As of this writing (January 2004), MARIE has been turned off, after losing communication with the spacecraft during the large SPE of October 28, 2003. However, during the prior 20 months, MARIE collected data almost continuously, observing several solar events and the nearly-constant GCR. There is still a possibility the instrument can be recovered, and troubleshooting efforts are scheduled to begin in May 2004, following the completion of the primary missions of MER-A (Spirit) and MER-B (Opportunity). At present, Odyssey is acting as a telecommunications relay for the rovers and only routine science operations are permitted in this mode.

Here, we will discuss the current status of MARIE and review its achievements during the period of successful operation in 2002-3. Additionally, we will present a detailed study of the flux of helium ions recorded at Mars, as an example of the analysis we intend to perform with the full MARIE data set.

Loss of MARIE Communications: In late October of 2003, there were two large SPEs. The first began on Oct. 26 and was successfully recorded by MARIE. As particle fluxes appeared to be dropping back to their normal background (GCR) level on Oct. 28, a much larger, sharply-rising event began, and within two hours of the onset of this second event, MARIE was discovered by ground controllers to have a temperature exceeding its safe operating point. An attempt was made to switch MARIE into a low-power mode, but the instrument did not respond to the signal, and it was turned off. Subsequent commands sent to MARIE throughout the months of November and December 2003 failed to re-establish communication with the instrument. Several distinct failure modes are possible and are being investigated. Since MARIE had not accumulated a large dose of radiation at the time of the failure, a leading suspect is a component latch-up.

MARIE also experienced a communication anomaly during Odyssey's cruise to Mars, and as a result was turned off from Aug. 2001 to March 2002, at which time it was successfully recovered. It is hoped that a similar extended period of being powered down will allow annealing of any damaged or latched parts.

MARIE Achivements: MARIE has recorded the first energetic particle data in Mars orbit. These data are invaluable for the determination of dose and dose equivalent that would be received by astronauts on a Mars mission. In addition, with the data in hand, we can test the hypothesis that the GCR does not vary significantly from 1.0 to 1.5 AU. Also of considerable interest are the SPEs that have been observed [2]. Measurements at Mars can be correlated with those taken near Earth to yield insight into the mechanisms of particle acceleration in Coronal Mass Ejections.

MARIE Capabilities: MARIE's primary detection system is a stack of silicon diodes that measure deposited energy, ΔE. Charged particles traversing the silicon liberate charge by the process of ionization energy loss; this charge is collected, amplified, and digitized by local electronics. On a triggered event, defined as a coincidence of above-threshold hits in the A1 and A2 detectors, the digitized pulse heights from all detectors are read out and stored in the onboard computer.

The fluxes of particles in the GCR and SPE present many measurement challenges. The GCR in particular includes heavy ions that are very densely ionizing, owing to the Z^2/β^2 (charge squared over velocity squared) dependence of energy deposition, as well as high-energy protons that are very sparsely ionizing. To cover the full spectrum of energy loss, a particle detector needs a huge dynamic range, on the order of 10000:1. In a modest instrument such as MARIE – constrained to have a mass of only about 3.4 kg and a maximum power consumption of 7W – it is not possible to achieve this dynamic range. Because it is expected on theoretical grounds (as well as on sparse data) that the GCR flux at Mars should be very similar to that measured by near-Earth instruments such as ACE/CRIS, it was decided to set the gain of the instrument such that it would efficiently measure the spectrum of protons during SPE.

As a result of the realtively high gain settings, the electronics saturate when MARIE is hit by lower-energy (< 100 MeV/nucleon) ions of charge $Z \geq 5$, and even highly relativistic ions of $Z \geq 12$. Further, at the other extreme, noise limitations in the A1 and A2 trigger detectors prevent us from setting the thresholds low enough to efficiently detect high-energy protons.

Between the extremes, however, we find that MARIE is quite efficient at measuring helium with energy above 30 MeV/nucleon.

Flux Measurement: We identify helium ions using the pulse heights in the silicon stack. Low-energy helium ions produced in SPEs help us define the cut contours in two-dimensional scatter plots that are used to isolate the desired event sample. However, there is a non-trivial degree of overlap of distributions when comparing high-energy helium with medium-energy protons, and a correction must be applied to subtract the proton background that contaminates the helium sample.

Geometry factor. To determine flux, one needs to know the geometric factor *G* of the detector telescope. *G* is a complex function of the charge, mass, energy, and angle of the incident particle, as well as depending crucially on the distribution of mass around the detector. For MARIE, particles coming into the "top" of the detector stack (i.e., striking A1 first) are restricted to an angle of incidence of ± 30° with respect to the central axis. Particles entering at the top must pass through just 0.2 g cm^{-2} of mass (this contributes to the minimum energy requirement of 30 MeV/nucleon). This small amount of mass allows for a simple calculation of *G* for forward-going particles. However, it is also possible for particles to enter the MARIE telescope from the bottom of the stack, although they must traverse much more mass when coming from that direction.

Backward-going particles are, if sufficiently energetic, indistinguishable from forward-going particles. Thus one needs to know in detail how much mass particles must traverse along the different trajectories that lead to an acceptable event geometry (i.e., both A1 and A2 hit) in the telescope [3]. In its present state, our mass model can be used to give a rough estimate of the efficiency for detection of backward-going helium, and hence to correct the observed flux so that it corresponds only to forward-going particles for which the geometry factor is well known.

References: [1] Zeitlin, C. et al (2004) *Adv. Space Res.,* in press. [2] Cleghorn, T. F. et al. (2004) *LPS XXXV,* submitted. [3] Atwell, W. et al. (2004) *Adv. Space Res.,* in press. [4] Stone, E. C. et al., (1998) *Space Sci. Rev. 86,* 357-408.