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Preliminary Results of the CPDS Instruments Aboard the ISS

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The low-Earth orbit (LEO) radiation environment has been directly observed by the IV and EV charged particle directional spectrometers (CPDS) aboard the International Space Station (ISS). The EV instrument is mounted on the S0 truss of the ISS, and was activated in late April 2002. The IV instrument is placed inside the USA Laboratory module of the ISS and it was activated on April 21, 2001. These instruments continue to take data up to the present time and are used as operational radiation dose level indicators, but these instruments are also capable of particle and energy identification. These data can provide information about the composition of the lower radiation belts, shielding provided by Earth's magnetosphere, and differences in the radiation environments inside and outside the ISS. We present a preliminary look at the ISS radiation instrumentation data with an overview of what we expect to be able to measure.

1. Introduction

The Extra-Vehicular (EV) and Intra-Vehicular (IV) Charged Particle Directional Spectrometer (CPDS) instruments are aboard the International Space Station (ISS). The IV-CPDS instrument is located in the US lab module and consists of a single CPDS telescope shown in Figure 1 (left). The EV-CPDS instrument is located on a boom attached to the S0 truss and consists of three CPDS telescopes (EV1, EV2, and EV3) pointing in different directions, as shown in Figure 1 (right).

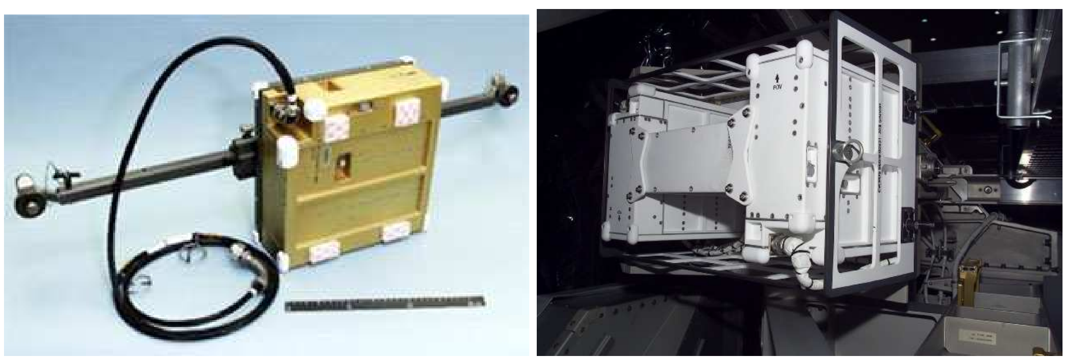

Figure 1. (left) Picture of the IV-CPDS instrument and (right) a picture of the EV-CPDS instrument on the S0 truss of the ISS.

The IV-CPDS instrument was sent to the ISS aboard STS-102 in March of 2001. It was installed in the US Lab Module pointing in the forward direction (direction of ISS velocity vector). The daily operational glitches were worked out over the next year and more routine and reliable operation began in June 2002.

The EV-CPDS instrument was sent to the ISS aboard STS-110 in April of 2002 at the same time the S0 truss was installed. It was activated in late April of 2002 and began nominal operation in late 2002. EV1 stopped functioning in April 2003, and has yet to be recovered. The orientation of each of the CPDS units comprising EV-CPDS are as follows: EV1 points in the forward direction, EV2 points towards zenith and EV3 points aft.

Each CPDS contains a silicon detector stack, which is illustrated in Figure 2. This stack will be described from top to bottom. A1 is a 1 mm thick square detector with 30.0 mm sides. PSD1 and PSD2 are identical square position sensitive detectors with 24 mm sides and are 300 μm thick. Each PSD is divided into 24 strips on top and bottom, which are orthogonal to one another, and this gives x-y position information. The A2 detector is identical to A1 and these two detectors define the trigger for event coincidence which yields a geometry factor of 3.2 cm^2-sr. Next are six B detectors mounted on three cards. Each B detector is a 5 mm thick lithium drifted [Si(Li)] cylindrical silicon detector with a physical diameter of 63.5 mm and an active diameter of 58.4 mm. Below the B detectors is PSD3, which is identical to the two previous PSDs. Next is A3, which is identical to A1 and A2. Last is the C detector complex, which consists of a 10 mm thick, 50 mm diameter piece of sapphire, where Čerenkov light is produced, and a Hamamatsu photo-multiplier tube (PMT), which converts the light to an electronic signal. Both the sapphire and PMT are enclosed in a light tight aluminum "can".

The individual detector cards are identical in design to those used on the MARIE instrument [7]. The only real differences in the CPDS units and MARIE is the location of the C detector complex and the CPDS units have one additional A,B and PSD detector card.

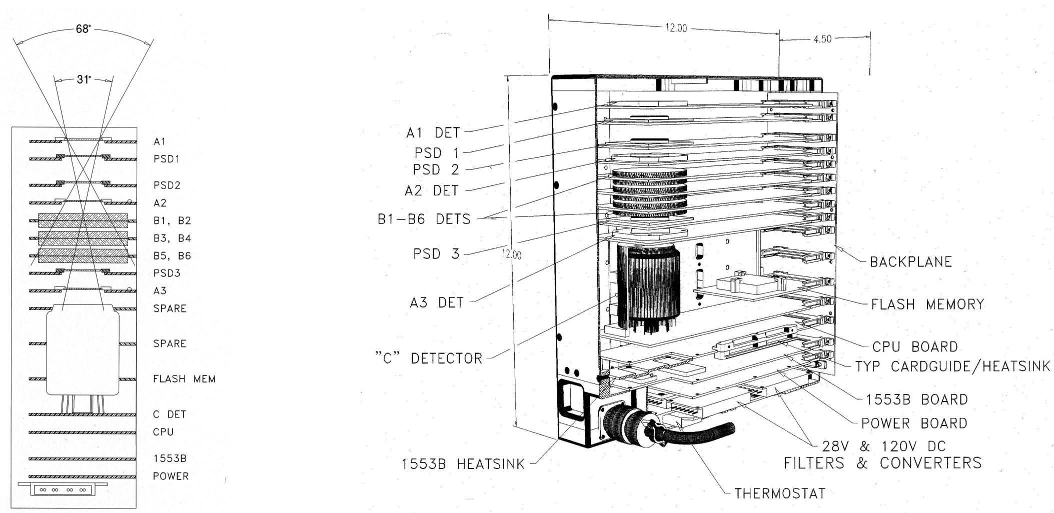

Figure 2. (left)CPDS detector stack and (right) CPDS isometric cut away, which shows the detectors, cards, and other components.

The data that can be expected from these instruments is similar to that of the MARIE instrument [4, 5, 7], although the CPDS instruments have additional silicon detectors, therefore, the energy spectrum can be extended up to about 400 MeV/n. Charge separation is possible up to about $Z = 12$, but the energy spectrum is only available for $Z < 4$.

2. Discussion

The data shown in this paper is only the most recent data from January to May of 2005. This data was chosen since it is devoid of any hardware threshold, high voltage, or software changes. Making this selection removes the EV1 instrument data since it only operated through April 2003.

The instruments were all calibrated using in-flight, low energy ($30 < KE < 200$ MeV/n) proton data and comparing it to fits of proton data tables [3] and instrument simulations performed by FLUKA [1, 2]. This calibration procedure is the same as that used for the MARIE instrument and is described in detail elsewhere [6].

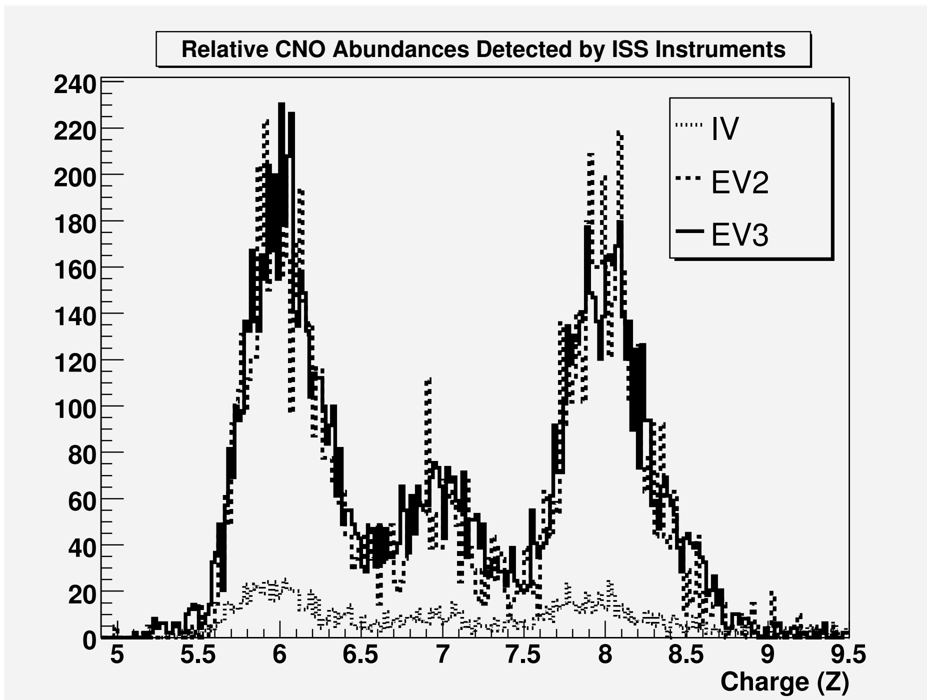

Figure 3. Relative abundaces of Carbon, Nitrogen, and Oxygen ions detected by IV(dotted line), EV2(dashed line), and EV3(solid line).

Figure 3 shows the relative abundances of CNO detected by IV, EV2, and EV3. This plot clearly shows that the ISS shields a large majority of these heavy ions. The heavy ions that are not seen in the ISS are either being stopped completely or are fragmenting, therefore, increasing the flux of low Z particles inside the ISS. Preliminary analysis shows that indeed the IV instrument is detecting more hydrogen ions than the EV instruments.

This work has just begun so there is still much to do in understanding the data reported by these instruments, but our experience with the MARIE instrument will guide us. A complete monte carlo simulation of each of these instruments will be performed, which will test the current LEO radiation environment models. Comparisons, of the CPDS data with ACE and GOES will be done during SPE and solar quiet times, which will test our current understanding of charged particle interactions with the magnetosphere.

3. Conclusions

The IV-CPDS and EV-CPDS instruments offer a great opportunity to study the charged particle space radiation environment in LEO. Not only can these instruments be used for operational safety for the ISS crew, but they can offer long term particle spectra observations that can be used to test the understanding of the lower region of the trapped radiation and the GCR-magnetosphere interactions. These data can also offer additional data points for observing the dynamics of the magnetosphere during solar particle events (SPE). Our models of the LEO radiation environment must become more accurate as we begin sending more humans to space. Improved models will allow for safe operations in space for both the crew and radiation sensitive hardware. Prediction of single event effects (SEE) in electronics must become more reliable as the electronic components used in space decrease in size and become more susceptible to SEE. We expect that these data will yield advances in our understanding of the LEO radiation environment and what effect the Sun has on it.

4. Acknowledgements

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