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CASI

RE: Final Report on NAG 2-627, "Cosmic Ray Telescope Experiment (CRT), Pioneer 10/11 Program", Frank B. McDonald, Principal Investigator

In May 1996 the electrical power on Pioneer 10 was no longer adequate to support the Cosmic Ray Telescope Experiment (CRT). In March 1997 ground based operations for the mission were terminated. The 25 years of Pioneer 10 were a remarkable voyage of discovery as it ventured into a vast new unexplored region of space. These observations by the Pioneer experiments led in the development of a new discipline of space science — heliospheric physics. For cosmic ray studies it was an incredible era, leading to the identification of new energetic particle populations and processes and initiating the study of the dynamics and large-scale structure and began the study of the dynamics and large-scale structure of the outer heliosphere. A summary of some of the principal scientific findings of the CRT experiment over this period is given in the next section.

Even with the cessation of data from the Pioneer 10/11mission there remained a great deal of scientific analysis and data archiving that required on the order of an additional three years of effort on the part of the CRT team. We have tried to select those tasks where the P10/11 CRT data have an important role to play. Special emphasis is placed on long-term synoptic studies that make use of the extended temporal and spatial coverage of the missions and the full capabilities of the CRT experiment.

The major scientific objectives of this study are:

1) A phenomenological study of the modulation process in the heliosphere, thereby laying the foundation for developing a unified model of cosmic ray modulation over a complete 22 year heliomagnetic cycle.

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2) These modulation studies and the temporal changes in the cosmic ray intensities also provide information on the large-scale structure and dynamics of the outer heliosphere.
3) Use the galactic and anomalous cosmic ray data from Pioneer 10 to obtain a more accurate estimate of the distance to the modulation boundary and to the termination shock.
4) Use the results from (2) and from temporal variations to determine whether significant modulation occurs in the region of the heliosphere.
5) Study the acceleration and transport of low-energy solar/interplanetary energetic particles and their relation to solar activity and interplanetary phenomena.

While this final report emphasizes the role of the Pioneer 10 and 11 CRT experiment, the most powerful insight into understanding the physical processes of particle transport and acceleration and heliospheric dynamics is provided by the combination of data from Pioneer 10/11 and Voyagers 1 and 2, along with appropriate base-line observations at 1 AU which for the last 25 years have come from the Imp 7,8 Goddard MED detector system.Most of the studies made use of the data from all of these 5 spacecraft, which we have designated as the heliospheric cosmic ray network. The P 10/11 CRT detections have been carefully intercalibrated with the Imp 7 and 8 MED and with the Voyager 1 and 2 CRS experiment.

PRINCIPAL SCIENTIFIC CONTRIBUTIONS FROM THE CRT EXPERIMENT TEAM 1972-1996

1. The identification of Jovian MeV electrons in interplanetary space at distances extending many AU away from Jupiter and that these Jovian electrons were the source of the "quiet time electron increases observed at 1 AU.
[Journal of Geophysical Research 79, 25, 3615, 1974.]
2. Discovery of the anomalous cosmic ray component from the low energy spectra of oxygen and helium, the anomalous ratio of low energy oxygen to carbon and the positive radial intensity gradient of this new component.
[Astrophysical Journal Letters 187, L105, 1974.]
3. The discovery of interplanetary acceleration processes in the prediction of MeV ions.
[Astrophysical Journal Letters 203, L149, 1976].
4. The identification of radially outward propagating step-decreases as the dominant process in producing the long-term cosmic-ray modulation.
[Astrophysical Journal Letters 249, L171, 1981.]
5. The study of low energy solar/interplanetary energetic particle events in the distant heliosphere and their association with periods of very high activity.
[Journal of Geophysical Research 99, 14705., 1994]
6. The discovery of global merged interaction regions (GMIRs) and their role in producing the step decreases in cosmic-ray modulation and in controlling and continually accelerating the ions in the solar/interplanetary energetic particle events.
[Journal of Geophysical Research 98, 1243, 1991.]
7. The comprehensive measurement of the radial intensity gradients for galactic cosmic

rays and over 2 solar cycles of the negative latitudinal gradients of galactic and anomalous cosmic rays over the 1986-1988 solar minimum period of cycle 21.
[Journal of Geophysical Research 97, 1557, 1992.]

8. The discovery of anomalous cosmic ray hydrogen in the 1994/95 Pioneer 10 data.
[Astrophysical Journal Letters 446, L101, 1995.]

9. The study of significant differences in the energy spectra of galactic and anomalous cosmic rays over successive solar minima, leading to unambiguous identification of the effects of gradient and curvative drifts in the transport of these particles in the heliosphere.
[Journal of Geophysical Research 97, 1557, 1992.]

10. 1st detailed study of the composition of solar energetic particles leading to the conclusion that first-ionization potential effects were the same in solar and galactic cosmic rays.
[Astrophysical Journal 199, 482, 1975.]

11. The detailed exploration and study of energetic particles in the Jovian and Saturnian magnetospheres.
[Science: 188, 462, 1975; 207, 241, 1980]

PERMANENT ARCHIVING AND IMPROVED FORMATTING OF PIONEER 10/11 DATA

The unique nature of the Pioneer 10/11 missions makes their data of great value to future experimenters. While most of the CRT data is in the NSSDC, it is felt that significant improvements are possible both in making the system more user-friendly and providing the opportunity for the guest investigator to carry out new studies using the basic data from the experiment. In this phase we have 3 objectives: (i) permanent archiving of all the CRT data, (ii) ease of access, and (iii) improved documentation.

Our intention is to make all of the CRT data available on-line including rates, pulse height events, anisotropy information, etc. The basic time resolution–or granularity–of the data would be 15 minutes, although all individual rate readings would be available in these 15-minute packets. Our standard analysis programs would be available along with a more complete set of experiment documentation and a running commentary on changes in the experiment parameters over the 24.2 years of the P10 mission and for P11.

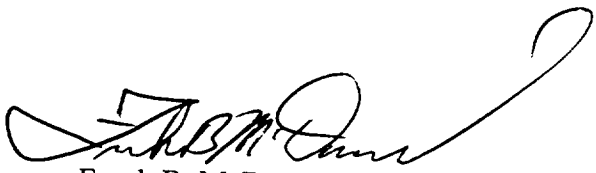
There will also be 24-hour and 26-day flux listings of such standard quantities as the "gradient fluxes" and H and He energy intervals used in spatial studies (26 days only). These latter databases will require much less effort by the G.O.'s. Over the coming three-year period it would also be possible to process special requests from G.O.'s just as we have done in the past.

The preparation of the more extensive documentation and putting the data "on-line" are major tasks that will require a significant effort. Much of this work is being done under the supervision of Dr. Nand Lal of Goddard Space Data and Computing Division, who is a Co-

Investigator on the CRT team. Dr. Lal wrote all of the CRT data processing and analysis programs and has been active in our modulation studies. The improved documentation will be prepared by the P.I. with assistance from Lal and from William R. Webber.

This phase of the P-10/11 CRT effort is being supported by an SRT grant from NASA Headquarters.

Precis: The funds from NAG 2-627 were fully expended on June 30, 1998. There are several major programs underway that are being carried out in collaboration with colleagues at NASA Goddard, Nagoya University, Japan, the Max Planck Inst. at Lindau, Germany, and Potchefstroom University in South Africa. The continuing Pioneer 10/11 Analysis and Archiving activities are being supported by an SRT grant from Headquarters.



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FBM/dm