Development and Characterization of a High-Energy Proton and Electron Telescope (HEPT) for the Proposed Canadian Space Agency ORBITALS Satellite Mission

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Overview

The magnetosphere is a region of the Earth's atmosphere responsible for shielding the Earth from high-energy charged particles emitted by the Sun. The magnetosphere contains the Van Allen Radiation Belts which begin above low-Earth orbit where the International Space Station and Space Shuttle orbit and extend to geosynchronous orbit where our communications and Global Positioning satellites orbit. High-energy charged particles usually bombard the Earth at high densities varying on an 11-year cycle: the Sunspot cycle. These particles can easily damage our satellites and the only safe remedy is to power down the satellites during these solar storms. The next peak is due in 2011. Previous missions to study the magnetosphere and the nature of particle excitation has led to our understanding of the particle density and energy that correlates the most intense radiation with the solar flare cycle; however, recent studies have indicated that the magnetosphere can itself energize protons and electrons and the energies achieved can still be hazardous to our orbiting satellites. A mission to study this region around the time of the next sunspot maximum has been proposed to the Canadian Space Agency (CSA) as a Canadian small satellite mission called ORBITALS[1] and will be complemented by a similar NASA mission.

HEPT Development using the Cyclotron at the Cross-Cancer Institute

The High-Energy Proton Telescope (HEPT) is a critical part of the Canadian satellite mission proposal headed by Dr. Ian Mann in the Physics Department of the University of Alberta. The HEPT instrument development is led by Dr. Robert Fedosejevs and Dr. Ying Tsui in the Department of Electrical and Computer Engineering. The goal is to record the electric and magnetic field intensities and frequencies as well as the electron, proton and ion energies and densities before, during and after Solar Cycle 24 between 2010 and 2012. These data would be the first time all the parameters involved in particle energization will be measured simultaneously and a dynamic model of our magnetosphere can be developed.

The proposed HEPT detector for the ORBITALS satellite will consist of 2 telescopes capable of measuring protons over an energy range of 6 – 120 MeV and electrons with an energy range of 2 – 20 MeV. The first detector, the low energy head, will measure protons with energies between 6 MeV and 26 MeV and the high energy head will measure protons with energies between 26 MeV and 120 MeV and the full electron range. The detectors are sequential stacks of large-radius silicon diodes that measure the energy based on the amount of charge deposited in each of the silicon detectors by each of these particles. This charge-to-energy response needs to be calibrated and compared to existing models.

The initial development of HEPT requires the construction of a prototype. This prototype is a robust design capable of measuring proton energies up to 100 MeV. The cyclotron at the Cross-Cancer Institute will allow the HEPT team to measure and model the low-energy response of the HEPT detector for the ORBITALS satellite. Measurements of the prototype's response to protons at the Cross-Cancer Institute can be compared to Monte Carlo particle codes, such as GEANT4, used for developing such high-energy particle detectors.

It is proposed that the 19 MeV proton beam line at the Cross-Cancer Institute Cyclotron will exit the vacuum environment through a 37.5 μm HAVAR coupler and will spread out by about 33 mm per meter of travel. This spread is required to reduce the current entering the HEPT prototype since it is designed to handle a peak rate of 200,000 particles/sec. This rate is the expected peak flux during a solar flare. At around 10 fA (62,000 particles/sec), the signals from the three sequential detectors in the prototype will be recorded using a multichannel analyzer and an oscilloscope. The incident particle energy will be correlated to the recorded signal. The cyclotron radiates a significant amount of radio-frequency electromagnetic radiation and the ability to measure low-energy proton signals in this environment will be a test of the noise immunity in the prototype design.

Higher energy protons (above 50 MeV) will be measured at larger accelerator facilities, such as TRIUMF at the University of British Columbia in Vancouver. The cyclotron at the University of Alberta Cross-Cancer Institute will be used to develop the experimental protocols to ensure that the more costly experiments at TRIUMF will be successful. These measurements will help in achieving the deliverables for the Phase A instrument development phase of the ORBITALS satellite proposal.

References:

1. Mann, I. R., *et al*. **The Outer Radiation Belt Injection, Transport, Acceleration and Loss Satellite (ORBITALS): A Canadian Small Satellite Mission for ILWS**, *Adv. Space Res.*, COSPAR special issue on ILWS, **38**, pp. 1838-1860, 2006.