Compact Half-Unit IES for CubeSat Operations

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Geophysical background

- Open and closed geomagnetic field lines
- Particles become trapped along closed field lines
- Electrons; however, ion populations of solar wind and ionospheric origin are also present
High Latitude Trapping Boundary

- Flux $\perp B$
- Flux $\parallel B$

Anisotropic Distribution
Isotropic Distribution
Polar Cap
Anisotropic Distribution

Magnetic Latitude
Scientific goals

1) Develop a better understanding of the motion of the HLTB and its relation to spaceweather activities.

2) Identify how scattering modifies the pitch angles of energetic particles within the HLTB.
Compact **Half-u IES for Cubesat Operations (CHICO)**

- Based on the Loss Cone Imager's (LCI), **Fixed Sensor Head (FSH)**

- CHICO provides the spaceweather community with a low cost, yet powerful instrument, for magnetospheric research

*CHICO AutoDesk CAD*
Basic Functionality

1) Detect particles in the range of 30 keV and 500 keV
2) Amplify and shape events
3) Digitize shaped events
4) Packetize and time-stamp data
Silicon detectors
Readout Electronics for Nuclear Applications 3 (RENA3)

- The RENA3 is a 36-channel pulse amplification and shaping Application Specific Integrated Circuit (ASIC)
- Each channel includes independently configurable gain, integration time and input polarity
- The RENA3 was used in the FSH for the LCI instrument
RENA3 channel block diagram
Instrument Block Diagram

- Telescope 1
- Telescope 2
- ADC
- RENA3
- XILINX FPGA

Connections:
- 12 V
- -200 V
- 3.5 V
- 2 V
- 1.2 V
- 1.8 V
- 3.3 V
- 5 V
- 12 V
- -12 V

Notations:
- Analog Output
- Digitized output /8
- RENA configuration and readout lines
- Diff. SCK
- Diff. SDA
- SCK
- SDA

27-pin intra-satellite connector
Completed IES in housing

Telescope 1

Telescope 2
Instrument highlights

- **Mass:** ~0.3 kg
- **Volume:** Smaller than 0.5 CubeSat Unit
- **Power:** Less than 2 W (5V, 12V, -12V)
- **FOV:** 120 degrees (180 degrees with appropriate rotation)
- **Particle energy range:** 30 keV to 500 keV
- **Unit cost:** <10k USD
Testing

- Preliminary instrument testing with Ortec research pulser
- Lower detection threshold \( \sim 30 \text{ keV} \)
- Instrument calibrated with internally generated pulse
- Future testing will include EU155 sources
RENA3 analog stages
RENA3 analog output
CHICO noise performance

- Full-width half maximum (keV) for shown data:

  - 50 keV: 8.64
  - 100 keV: 9.00
  - 200 keV: 9.20
  - 300 keV: 8.46
Angular resolution

- Three orders of magnitude rejection of scattered electrons when compared to the incident beam
- Plot shows counts versus incident angle measured for the LCI FSH
Twin Imaging of the Moving Electron boundary (TIME)

- Two student-built 1.5 U CubeSats
- 8 measurements of the HLBT per orbit
- Each CubeSat will fly a small, three-axis magnetometer and a GPS in addition to CHICO
- 6-month mission
Student Training

- TIME draws heavily from Boston University BUSAT program
- Aims to institutionalize student training in satellite development at BU
CHICO integrated into TIME
THANK YOU!

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“Spaceweathermen: CHICO”
at the Boston University ECE Day 2011
Extra Slides
Pitch angle and the loss cone

Particles with pitch angles that fall within the red area, called the loss cone, will likely be lost.
Particle motion

Diagram from Walt, 2005
Heritage IES

IES from Boston University
Student-satellite for Applications and Training (BUSAT)

IES-Fixed Sensor Head (FSH)
from the Loss Cone Imager (LCI) instrument
Analog Board

- Six layer board
- 12 detector pixel inputs
- Houses RENA3, 12-bit ADC and low-noise voltage regulators
- Complex grounding scheme for noise
Digital Board

- Houses Xilinx FPGA and flash PROM
- USB, UART and differential I2C (following the BUSAT inter-cube communication Space Plug and Play standard)
TIME configuration

- CHICO
- HMC2003 Honeywell Magnetometer
- GPS
- ClydeSpace EPS
- MSP430 Microcontroller
- Solar Panels (Spectrolab TASC cells)
- Comms System
- Attitude Determination & Control
- PCB torque coils