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Focusing on size and energy dependence of electron microbursts from the Van Allen radiation belts

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Focusing on Size and Energy Dependence of Electron Microbursts From the Van Allen Radiation Belts

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Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD), a space weather–targeted and goal-directed mission supported by the U.S. National Science Foundation, will launch into a high-inclination, low-Earth orbit in October 2013 as a secondary payload under NASA's Educational Launch of Nanosatellites program. FIREBIRD is a dual CubeSat mission that is designed to resolve the spatial scale size and energy dependence of electron microbursts from the Van Allen radiation belts. The FIREBIRD mission embodies the CubeSat ideal: high scientific return provided at low cost through focused and novel investigation of an unexplored yet important phenomenon in a region easily accessed by nanosatellites.

FIREBIRD provides a valuable opportunity for students to be involved in multiple aspects of an active space mission, its long duration allowing students to experience all phases from initial concept to final implementation and scientific analysis. Right from the beginning, students and young professionals at the University of New Hampshire and Montana State University played key roles in the development of FIREBIRD, in collaboration with senior scientists at The Aerospace Corporation and Los Alamos National Laboratory.

Relativistic electron microbursts appear as short durations of intense electron precipitation measured by particle detectors on low-altitude spacecraft, seen episodically when their orbits cross magnetic flux tubes that thread the outer radiation belt [*Lorentzen*, 2001a, 2001b]. Previous spacecraft missions (e.g., SAMPEX) have quantified important aspects of microburst properties (e.g., occurrence probabilities); however, other crucial properties (e.g., spatial scale) remain elusive owing to the space-time ambiguity inherent to single-spacecraft missions. While microbursts are thought to be a significant loss mechanism for relativistic electrons [*O'Brien et al.*, 2004], they remain poorly understood, thus rendering space weather predictive models of Earth's radiation belts incomplete. The so-called "killer" electrons in the radiation belt can produce deep dielectric discharging in spacecraft components, a significant concern for satellite health and operations. FIREBIRD's two-point, focused observations at low altitudes address three fundamental scientific questions with important space weather implications: (1) What is the spatial scale size of an individual microburst? (2) What is the energy dependence of an individual microburst? (3) How much total electron loss from the radiation belts do microbursts produce globally? FIREBIRD's unique microburst observations will significantly advance understanding of relativistic electron precipitation loss from the outer zone radiation belt, which, in turn, will provide insight not only into the current state of the belt but also potentially into future states.

Each FIREBIRD CubeSat (see Figure 1) possesses two solid-state detector charged particle sensors with different geometric factors optimized to cover electron measurements over the energy range from 0.25 to ~1 MeV in six differential energy channels. The detectors are read out by a custom application-specific integrated circuit (ASIC), designed by The Aerospace Corporation, called the Dual Amplifier Pulse Peak Energy Rundown ASIC. Onboard memory (~2 gigabytes) stores fast sample (~20 milliseconds) observations needed to resolve spatial structure; survey observations identify times of interest to download the highest temporal resolution data within the limited telemetry stream (~4 megabytes per day). While all data from the instruments are saved on board for 2 weeks, FIREBIRD telemeters a reduced event identification data product to the ground each day in order to select particular intervals with microbursts to download for scientific analysis.

The two FIREBIRD CubeSat packages will be delivered to California Polytechnic State University, San Luis Obispo, in April 2013 for integration into the Poly Picosatellite Orbital Deployer [*Puig-suari et al.*, 2001]. Both undergraduate and

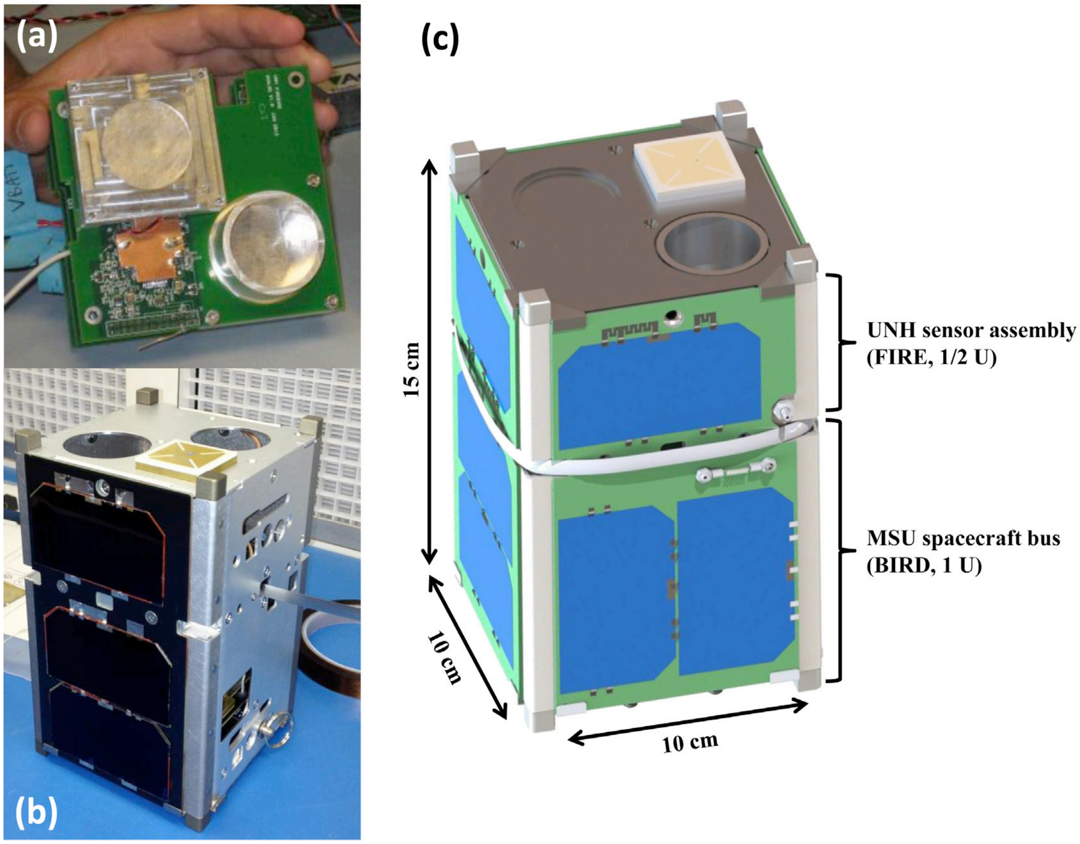

Figure 1. (a) A single engineering unit sensor assembly. The sensor assembly houses two solid-state detectors, one (bottom right corner) collimated and the other (top left corner) uncollimated. (b) Engineering model of a single FIREBIRD satellite. The sensor assembly detector apertures are seen on top. (c) A dimensioned computer-aided design drawing of a single FIREBIRD satellite. The CubeSat standard specifies a 10 × 10 × 10 cm cube (i.e., 1U); each FIREBIRD comprises a 1.5U structure with a mass of ~2 kg. The upper 1/2U comprises the sensor assembly (FIRE) developed by the University of New Hampshire; the bottom 1U comprises the spacecraft bus (BIRD) developed by Montana State University.

graduate students will analyze FIREBIRD data as part of their academic experience. After a short data validation period, all data will be available for public use.

The mission is highly complementary to large flagship strategic space missions such as the recently launched Radiation Belt Storm Probes mission [*Mauk et al.*, 2012] and the upcoming BARREL balloon mission [*Millan and the BARREL Team*, 2011].

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