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# Overview: The Dual-CubeSat FIREBIRD Mission

## (Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics)

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# Science Motivation

- Sporadic short time-scale electron dumping from the radiation belts into the upper atmosphere was discovered decades ago
- Beginning in 1992, low altitude observations from the SAMPEX Small Explorer satellite provided significant insight into the morphology of these electron microbursts.
- Electron microbursts occur in “clusters” consisting of  microburst region made up of many individual microbursts
- Single satellites, like SAMPEX are unable to discern the spatio-temporal behavior of electron microbursts at the cluster level and at the individual microburst scale.
- The global significance of electron microbursts as a loss mechanism for radiation belt electrons has not been quantified
- The two-satellite FIREBIRD mission will resolve the spatio-temporal variations of individual microbursts.

# NSF Sponsored 2-satellite Space Weather Mission

## Project start September 1, 2009

- Two 1.5U (10 x 10 x 15 cm) CubeSats
- each weighing up to 2 kg
- placed into a common high-inclination bead-on-a-string orbit.
- The two satellites will remain within a ~400 km of one another for up to four months, allowing characterization over the spatial scale regime from 10 – 300 km.
- Each satellite will carry an identical co-aligned pair of solid-state detectors sensitive to electrons from 30 keV to ~3 MeV with 10 msec time resolution.

- FIREBIRD (Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics):
  - A Dual Satellite Mission to Examine the Spatial and Energy Coherence Scales of Radiation Belt Electron Microbursts
- Three Critical Questions FIREBIRD will answer:
  - What is the spatial scale size of an individual burst?
  - What is the energy dependence of an individual burst?
  - How much total electron loss do bursts produce globally?



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# FIREBIRD Traceability Matrix

| Science Questions | Space Weather Impact | Measurement Goals | Instrument Requirements | Spacecraft Requirements | Mission Requirements | Science Closure |
|---|---|---|---|---|---|---|
| Are microbursts as localized in space as indicated? | Are microbursts an important local (small scale) or an important global (short duration) radiation belt loss mechanism? | Determine the temporal and spatial scale of magnetospheric microbursts | Fast sampling to resolve 5km (TBR) spacing | Accurate timing for each spacecraft and inter-spacecraft | Multiple spacecraft operating for at least 2 (TBR) months | Determination of formation mechanisms based on improved theory enabled by applicable measurements |
| Are microbursts as localized in time and indicated? | | | Fast sampling to resolve 200ms (TBR) time separations | | | |
| What are the energy spectra of microbursts? | Are microbursts an important loss mechanism across the whole radian belt energy spectra or specific energies only? | Determine the energy characteristics of magnetospheric microbursts | 3 (TBR) energy channels over the range from 200 keV (TBR) to 700 keV (TBR) | Data storage and selection to determine microburst event to fit into limited telemetry resources | Single spacecraft lifetime of at least 1 (TBR) month | Determination of total energy of radiation belts lost to microbursts |
| Does the energy spectra depend on plasma conditions or activity? | When are the losses different, what does this mean for forecasting the losses? | Determine energy spectra over time for a variety of conditions | None | Radiation tolerant enough to survive for a duration of 4 (TBR) months | Lifetime of at least one spacecraft of at least 4 (TBR) months | Determination of energy loss during different conditions. |
| What is the structure within the microburst? | | Within the spatial and temporal scales of the microburst determine what structure is present | 3 (TBR) energy channels over the range from 200 keV (TBR) to 700 keV (TBR) | | Multiple spacecraft operating for at least 2 (TBR) months | Improved understanding of formation mechanisms and particle scattering interactions in formation region. |
| | | | Fast sampling to resolve 200ms (TBR) time separations | | | |

# Implementation Concept

- Development of the FIREBIRD will focus on maximizing the scientific return of the mission first, with a seondary objective to provide hands-on workforce training for undergraduate and graduate students.
- Therefore:
  - The satellite bus and support systems will not be designed and built “from scratch”; rather, commercial subsystems will be procured whenever paractical.
  - Development focus will be on systems unique to the FIREBIRD mission, including:
    - Development of the sensor system
    - Development of a clean interface between payload and bus.
    - Control of intersatellite separations in orbit
    - Maximization of data downlink and scientific return
- Nominal mission lifetime is 4-months

# Implementation - Roles and Responsibilities

**Montana State University**

- Satellite Bus and subsytems
- Integration and test
- Tracking, command and telemetry from MSU ground station
- Science analysis and publication of results

**Boston University --> University of New Hampshire**

- Payload design and development
- Science Operations center
- Science analysis and publication of results

**The Aerospace Corporation (unfunded Collaborator)**

- Sensor development assistance
- Sensor calibration assistance
- Industry internship(s) for students

# Current Status

- Requirements flowdown nearly complete
- Payload/bus ICDs under development
- Bus trade studies under way
  - power system
  - telemetry system
  - GPS
  - separation control strategy
  - frequency allocationinputs (TODAY!)
- Oct 30, 2009: System Requirements Review iterated requirements
- Detectors identified, in stock Micron Corp.  NASA mission spares.
- November, 2009: Prototype Development hardware in house at MSU
- Planned System Concept Review:  February 8, 2010.



# Issues, Concerns

- Control over physical separation and separation rate (delta-V) - ideal along-track separation is 10 - 200 km (dictated by science) over duration of mission
- Instantaneous position knowledge of each s/c (relative)
- Relative timing between two spacecraft to ~10 msec
- Identifying frequency band and initiating license for spectrum use early enough to allow comm system development on schedule.
- Launch uncertainty (timeframe, launch location) -- scientifically meaningful orbit is 400 - 650 km, inclination at least ~50 degrees.

# Contact Us


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