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

Van Allen Probes SWG Telcon

4 March 2016

A scientific investigation sponsored by the National Science Foundation; launch provided by NASA

https://www.ssel.montana.edu/index.html Then navigate to Missions: FIREBIRD and FIREBIRD-II
The FIREBIRD-II Investigation Update

All four satellites returned excellent scientific data from orbit (FB-II continues)

**FIREBIRD-I Pair Launched December 6, 2013**
**FIREBIRD-II Pair Launched January 31, 2015**

- FB-II operating as a pair from immediately after turn-on (10-km separation) to present
- Month-long Campaigns: Campaign 7 finished; still downloading, Campaign 8 another 1-2 weeks away
  - Campaign duration set by quality and quantity of science data stored onboard satellites
    - Science data storage capacity allows northern hemisphere operation for ~4 weeks
    - Between campaigns selected high-value science data is downloaded to ground

<table>
<thead>
<tr>
<th>Campaign #</th>
<th>Dates (Approx)</th>
<th>Primary Science Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2/1-&gt;2/21/2015</td>
<td>Spatial Scale of Individual Microbursts</td>
</tr>
<tr>
<td>2</td>
<td>3/20-&gt;4/16</td>
<td>St. Patrick’s Day Storm</td>
</tr>
<tr>
<td>3</td>
<td>5/15-&gt;6/15</td>
<td>Van Allen Probes Conjunctions</td>
</tr>
<tr>
<td>4</td>
<td>7/1-&gt;8/1</td>
<td>July 4th Storm</td>
</tr>
<tr>
<td>5</td>
<td>8/7-&gt;9/3</td>
<td>BARREL Campaign Conjunctions</td>
</tr>
<tr>
<td>6</td>
<td>11/17-&gt;12/15</td>
<td>Conjunctions, Lightning induced precipitation</td>
</tr>
<tr>
<td>7</td>
<td>1/14-&gt;2/4/2016</td>
<td>12.5ms time resolution (EFW and Sample balloon conjunctions)</td>
</tr>
</tbody>
</table>
Happy Birthday, FIREBIRD-II!

31 January 2015
First Year of Operations

- 4 days from 1 full year of on orbit operations
- ~23,000 total spacecraft beacons downloaded
- 1000s of microbursts observed by both spacecraft
- Measurements at spatial separations from 10s to 1000s of kms
- Multiple conference presentations (GEM, Small Sat, AGU) + first results submitted to JGR

<table>
<thead>
<tr>
<th>Type</th>
<th>Samples</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>FU-3 Context</td>
<td>1,098,665</td>
<td>1,831.11</td>
</tr>
<tr>
<td>FU-3 HiRes</td>
<td>1,679,408</td>
<td>8.75</td>
</tr>
<tr>
<td>FU-4 Context</td>
<td>1,112,286</td>
<td>1,853.81</td>
</tr>
<tr>
<td>FU-4 HiRes</td>
<td>1,866,233</td>
<td>9.72</td>
</tr>
</tbody>
</table>
Now in New Science Mode

- **12.5 ms timing** enabled with beginning of campaign 7
- Looking to probe structure of individual bursts
- Better for exploring energy dispersion
Summary plot for first 5 campaigns with the >985 keV context channel on Flight Unit 4

- Can compare results with other LEO satellites or Van Allen Probes
- Data now converted to fluxes for differential channels
FB-II Quantifies Microburst Scalesize for First Time

- At ~7:49UT on 2 Feb 2015 the two FIREBIRD-II s/c are separated by ~11km in their nearly coplanar LEO orbits, passing through L ~ 5.9 (i.e., in the outer zone electron radiation belt)
- Occurs during early recovery phase of small magnetic storm
- Both spacecraft (Flight Unit 4 – top panel, Flight Unit 3 – bottom panel) observe remarkable richness of microburst activity
- Some microbursts are highly coherent (such as the train of three prominent tightly spaced bursts seen by both FU-3 and FU-4 starting at 07:49:34)
- Others are not (see highlighted ~1 sec interval starting at 07:49:26 when FU-4 observes a marked lull with no bursts while FU-3 sees prominent activity)
- Suggests that the inter-satellite separations at this time are at or near the microburst spatial decorrelation length scale
- Quantifying the microburst scalesize constrains their possible generation mechanisms (~ 11 km at LEO maps to ~117 km near magnetic equator where waves scatter electrons into loss cone)

Figure 3 from Crew et al., First Multipoint In Situ Observations of Electron Microbursts: Initial Results From the NSF FIREBIRD-II Mission, submitted to JGR, 2016.
Coordination with Van Allen Probes

• 12.5 ms timing enabled with beginning of campaign 7

• Storm (Minimum Dst -100) on 1/20 with many conjunctions between FIREBIRD and Van Allen Probes

• EFW measuring wave activity in heart of radiation belts, FIREBIRD-II measuring precipitating electrons below on same L-shells and local time sectors
Conjunction plot for RBSP-EFW and FIREBIRD-II for 1/20

FIREBIRD-II measurement of microbursts
Upcoming Science Meeting

- Hosting science meeting in LA March 21-23 with members of FIREBIRD, BARREL, Van Allen Probes, AC-6 teams
- Identified a number of events with measurements from multiple teams to collaborate on science results
- Comparison of wave and particle measurements as well as electron and x-ray measurements of precipitating population
FIREBIRD Summary

• **Enabling new science**
  - Spatio-temporal disambiguation of microbursts down to 1.5 seconds (~10 km) of dual spacecraft separation.
  - 12-point energy spectra of electron microbursts from 200 keV to ~1.1 MeV at high time resolution (12.5 msec)
  - Observation of relativistic electron dispersive bursts on Van Allen Radiation belt L-shells

• **Small space technologies demonstrated on-orbit**
  - Compact, low-power packaging of sensor system enabled by The Aerospace Corporation’s “Dapper”, an ASIC performing fast coincidence logic and pulse-height analysis. First on-orbit demonstration. (Now flying on NASA MMS mission)
  - Inverted Metamorphic Multi-Junction (IMM) high efficiency solar cells (~34%) (Vanguard Space Technologies, Inc. (VST))
  - Thin Integrated Solar (THINS™) photovoltaic panel technology: Proprietary solar cell cover glass solar panels at TRL9 (VST, Inc.)

• **Recent Presentations/Publications:**
  - H. E. Spence, J.B. Blake, D. Klumpar, and A. B. Crew, Multipoint Measurements of Earth’s Radiation Belt Dynamics from NASA’s Van Allen Probes and NSF’s FIREBIRD Missions, submitted for presentation at AOGS Meeting