

## 1. Contact Information

While the FIREBIRD-II data is freely available, please contact Harlan Spence ([spence@guero.sr.unh.edu](mailto:spence@guero.sr.unh.edu)), Dave Klumpar ([klumpar@montana.edu](mailto:klumpar@montana.edu)), John Sample ([john.sample2@montana.edu](mailto:john.sample2@montana.edu)), Mykhaylo Shumko ([msshumko@gmail.com](mailto:msshumko@gmail.com)) and Arlo Johnson ([arlotjohnson@gmail.com](mailto:arlotjohnson@gmail.com)) to get up-to-date with the FIREBIRD-II data caveats. As relevant, please consider including member(s) of the FIREBIRD-II team as coauthor(s) on any publication using FIREBIRD-II data.

## 2. Data Products

Two types of Data files are produced: HiRes and Context from the collimated and surface detectors in JSON headed ASCII format. The data is updated nightly and is available at [http://solar.physics.montana.edu/FIREBIRD\\_II/](http://solar.physics.montana.edu/FIREBIRD_II/). Data is gathered in campaign mode during times and with settings shown in Table 1. FIREBIRD-II operates in this mode due to the limited HiRes telemetry budget, but we almost always download all of the context data.

Flight Unit 3 (FU-3) has both the surface detector and collimated detector active, while Flight Unit 4 (FU-4) only has the collimated detector taking data. Energy boundaries of the channels and channel widths are described at the bottom. Nominal geometric factors of the 2 detectors are 9 and 23 cm<sup>2</sup> sr for the collimated and surface detectors respectively (analytically calculated). If uncertain hr0 refers to collimated detector, hr1 to surface detector.

### 2.1 Context

Context data is a 6 second cadence data product which is available for each campaign, lasting approximately one month each. The level 1 data product (L1) file has time, D0, D1 and Lat, Lon, Alt, Dipole L value, and a \*very crude\* magnetic local time estimate ("MLT") done from longitude and UT. D0 and D1 are count rates from two energies which are tabulated bellow. On FU3, D0 is from the collimated detector, and D1 is from the surface detector for campaigns 1-7 and from the collimated detector starting in campaign 8. On FU4, D0 and D1 are both from the collimated detector.

The level 2 data product (L2) files have Time, D0, D1 are unchanged, with magnetic coordinates added. The magnetic coordinates are magnetic local time (MLT), and McIlwain L shell parameters derived from the T89c magnetic field model.

### 2.2 HiRes

HiRes is the highest resolution event data. During 2015 it was taken at a 18.75ms time cadence. From 2016-01-15 to 2016-02-01, the cadence was 12.5 ms, and 2016-05-21 to 2016-08-30 the cadence was 50 ms. Due to the limited CubeSat telemetry budget, HiRes data availability is limited.

The level 1 data product contain UTC time, hr0 and hr1 are the 2 hires detectors (collimated and surface) counts per cadence interval, col and sur are the collimated and surface detector fluxes, normalized by the energy width of each channel. Where available, ephemeris files were used to populate with Kp, Lat, Lon, Magnetic Local Time, and McIlwain L shell parameter, derived from the T89c external magnetic field model and IGRF internal model.

Campaign	Start Date	End Date	HiRes Cadence	D0 (keV)	D1 (keV)
1	2015/2/1	2015/2/21	18.75 ms	FU3:1055 FU4:985	FU3:815

2	2015/3/21	2015/4/19	18.75 ms	FU3:1055 FU4:985	FU3:815 FU4:251
3	2015/5/16	2015/6/15	18.75 ms	FU3:1055 FU4:985	FU3:815 FU4:251
4	2015/7/3	2015/8/4	18.75 ms	FU3:1055 FU4:985	FU3:815 FU4:251
5	2015/8/8	2015/9/4	18.75 ms	FU3:1055 FU4:985	FU3:815 FU4:251
6	2015/11/15	2015/12/15	18.75 ms	FU3:1055 FU4:985	FU3:815 FU4:251
7	2016/1/15	2016/2/3	12.5 ms	FU3:1055 FU4:985	FU3:815 FU4:251
8	FU3:2016/5/20 FU4:2016/6/9	FU3:2016/6/14 FU4:2016/6/20	50 ms	FU3:1055 FU4:985	FU3:251 FU4:251
9	2016/8/12	2016/9/7	50 ms	FU3:1055 FU4:985	FU3:251 FU4:251
10	2016/12/21	2017/1/2	12.5 ms	FU3:1055 FU4:985	FU3:350 FU4:350
11	2017/5/1	2017/5/25	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
12	2017/7/1	2017/7/25	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
13	2017/11/19	2017/12/14	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
14	2018/02/26	2018/04/05	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
15	2018/04/19	2018/05/11	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
16	2018/6/24	2018/7/19	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
17	2018/7/30	2018/8/25	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
18	2018/9/17	2018/10/14	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
19	2018/12/15	2019/1/11	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
20	2019/1/23	2019/2/21	50 ms	FU3:1055 FU4:985	FU3:350 FU4:350
21	2019/03/15	2019/04/10	50 ms	FU3:1055 FU4:985	FU3:325 FU4:325
22	2019/05/04	2019/05/17	12.5 ms	FU3:1055 FU4:985	FU3:325 FU4:325
23	2019/07/04	2019/07/29	50 ms	FU3:1055 FU4:985	FU3:325 FU4:325
24	2019/09/10	2019/10/07	50 ms	FU3:1055 FU4:985	FU3:325 FU4:325

Table 1

### 3. Data Caveats

There is a potentially significant (on the order of a few second) independent offset between each of the two spacecraft clocks and ground time. MSU has developed algorithms to improve these uncertainties and they are included in the data under the column “Count\_Time\_Correction”. This correction has units of seconds and should be added to the time stamp. **This correction only applies to the count and flux data, spacecraft ephemeris is already correctly timestamped.** This correction is the best global estimate, but may still be subject to an error of up to 1 second and may be improved by a more in-depth look at a specific time. If a more precise correction for a given time is needed please contact Arlo Johnson.

The collimated detector experiences brief (a few data point) flux dropouts. While it’s still uncertain, we believe that they are caused by saturation affects. We have successfully developed an automated

algorithm that flag the dropouts. Please contact Mykhaylo Shumko if you wish to use it. The surface detector is prone to saturation during high fluxes; count rates above 600-900 in the lowest energy channels are often signs that saturation is possible, but there is no known threshold flux which saturates either detector.

During campaign 14 FU4 experienced an error in its time keeping causing data from March 9 to March 29 to be incorrectly timestamped. Unfortunately there is not enough information to correct these timestamps, so the FU4 data from this time period is effectively lost.

#### **4. Acknowledgments**

For refereed publications, to accurately acknowledge FIREBIRD funding, please include the following statement:

“FIREBIRD data was made possible by the National Science Foundation grant numbers: 0838034, 1339414”

#### **5. Detector Energy Bin Information**

The example boundaries between energy channels are shown below. The energy channel boundaries have changed during the mission, and are listed in the data headers. The highest energy channel has no defined upper bound and can be treated as an integral channel with a minimum energy given by the last number in the list. All energies are given in keV.

Channel Boundaries:

FU\_3:

Sur: 176.4, 240.9, 342.2, 480.3, 683.0, 950.1

Col: 231.0, 299.7, 407.6, 554.8, 770.7, 1055.2

FU\_4:

Col: 219.7, 283.4, 383.6, 520.3, 720.7, 984.95

The linear channel middles and widths are calculated from the boundaries above for the lowest 5 energy bins. All energies are given in keV.

Channel Middles:

FU\_3:

Sur: 208.7, 291.6, 411.3, 581.7, 816.5

Col: 265.4, 353.7, 481.2, 662.7, 913.0

FU\_4:

Col: 251.5, 333.5, 452.0, 620.5, 852.8

Channel Widths:

FU\_3:

Sur: 64.5, 101.3, 138.1, 202.7, 267.1

Col: 68.7, 107.9, 147.2, 215.9, 284.5

FU\_4:

Col: 63.7, 100.2, 136.7, 200.4, 264.25

#### **6. References**

When using FIREBIRD data in publications, please consider referencing publications that describe the mission science, mission implementation, and first science results:

- Spence, H. E., J. B. Blake, A. B. Crew, S. Driscoll, D. M. Klumpar, B. A. Larsen, J. Legere, S. Longworth, E. Mosleh, T. P. O'Brien, S. Smith, L. Springer, and M. Widholm (2012), Focusing on Size and Energy Dependence of Electron Microbursts From the Van Allen Radiation Belts, *SpaceWeather*, 10, S11004, doi:10.1029/2012SW000869, 2012.
- Klumpar, D., L. Springer, E. Mosleh, K. Mashburn, S. Berardinelli, A. Gunderson, M. Handly, N. Ryhajlo, H. E. Spence, S. S. Smith, J. Legere, M. Widholm, S. Longworth, A. B. Crew, B. A. Larsen, J. B. Blake, and N. Walmsley, Flight system technologies enabling the twin-CubeSat FIREBIRD-II scientific mission, Proceedings of the 29th Annual AIAA/USU Conference on Small Satellites, Technical Section V: Year in Review, SSC15-V-6, <http://digitalcommons.usu.edu/smallsat/2015/all2015/35/>, 2015.
- Crew, A., H. E. Spence, J. B. Blake, D. M. Klumpar, B. A. Larsen, T. P. O'Brien, S. Driscoll, M. Handly, J. Legere, S. Longworth, K. Mashburn, E. Mosleh, N. Ryhajlo, S. Smith, L. Springer, and M. Widholm, First Multipoint In Situ Observations of Electron Microbursts: Initial Results From the NSF FIREBIRD-II Mission, *J. Geophys. Res.*, DOI: 10.1002/2016JA022485, 2016.
- Breneman, A. W., Crew, A., Sample, J., Klumpar, D., Johnson, A., Agapitov, O., ... Kletzing, C. A. (2017). Observations directly linking relativistic electron microbursts to whistler mode chorus: Van Allen Probes and FIREBIRD II. *Geophysical Research Letters*, 44, 11,265–11,272. <https://doi.org/10.1002/2017GL075001>
- Shumko M., J. Sample, A. Johnson, J.B. Blake, A.B. Crew, H.E. Spence, D. Klumpar, O. Agapitov, and M.L. Handly. (2018), Microburst Scale Size Derived from Multiple Bounces of a Microburst Simultaneously Observed with the FIREBIRD II CubeSats, *Geophys. Res. Lett.*, 45. <https://doi.org/10.1029/2018GL078925>