SEED Instrument Overview

The Solid-State Energetic Electron Detector (SEED) instrument is located on the Space Test Program (STP) $\mathrm{Sat}-6$ spacecraft parked into a geosynchronous orbit around planet Earth. The details of the instrument and its ground calibration are found in the paper written by Cress, et. al. (2020). This manual is written to supplement the information from that paper with the details of how the data needs to be processed so as to enable a scientific understanding of the data.

STP Sat-6 is in geosynchronous orbit at approximately $-111°$ longitude. The detector itself faces in the ram (East) direction looking in the $90°$ pitch angle direction.

Available data products contain both counts and flux as functions of energy and time. Also available are the exact values of the geometric factor, energy channels, and the time (in nanoseconds since January 1, 2000) the data were acquired.

In general, it is not possible to convert these counts and flux values to a meaningful electron distribution function due to the fact that the full 4π steradians of space is never sampled. Therefore, moment quantities such as velocities and temperatures are not supplied.

There are two sets of data presented here. The first dataset is all of the processed data in as high a time resolution as possible. This dataset appears to have a systematic readout error within the hardware that has yet to be isolated and identified. The second dataset is labeled "Dt_15" and is a filtered subset based on sequential measurements that avoid the systematic hardware error.

Energy Bins and Resolution

In total, there are 904 energy bins which range from 13.7 through 146.0 (keV). The energy channel resolution is 0.1465 keV. The energy range is given (in Fig. 7 of the Cress paper) as $y = 0.1464 * x - 3.837$ where "x" is the energy bin number running from 0 - 1023. The first 120 channels, bins 0 - 119 are channels that are overwhelmed by noise and are excluded. This gives 1023 - 119 (or 1024 - 120) = 904 channels. Choosing x = 120 results in y = 13.743 keV and choosing x = 1023 results in y = 146.0 keV.

Temporal Resolution

The SEED electron data are recorded as counts per 15 second interval (5760 possible energy spectra per day). The data are integrated in time so that if 10 counts were detected in a 15 second interval and 12 counts were detected in the next 15 second interval, the counts recorded would be 10 and then 22. In order to back out the 15 second count rate, the data were differenced.

Some data were discarded. In particular, if one of the energy channels had a bad data point, then the entire spectra was discarded. This practice resulted in overall spectra numbers being on the order of 1000-2000 per 24-hour period. Also, this practice results in data points that are not evenly sampled every 15 seconds. For example, times between spectra could range up to 150 seconds or even more. In general, discarding spectra did not cause giant gaps in the daily coverage, but rather the discarded spectra were evenly distributed throughout the day.

The instrument was designed to reset itself once every 20 minutes to reduce the risk of single-event-upsets (SEU) due to the high radiation environment in the outer radiation belts. In principal the resets were not done at exactly 20 minutes (1200 seconds) but tended to be very close to the 1200 second period. Therefore, the counters reset approximately 72 times per day. These resets result in a zeroing of the counters. No spectra were taken during these reset periods.

A second potential issue is instrument rollover. This occurs when the counters contain more than 2^{32} counts. At that time the instrument counter rolls over. This does not seem to occur at all but is listed here as a part of the record.

During the period starting on day of year 149, 2022 and lasting until day of year 229, 2022 the instrument was not reset every 20 minutes but instead at approximately 40 minute intervals. The main outcome of this procedure was that the data during that set of days were significantly noisier and as a result, the number of usable spectra for these days was typically less than 1000.

The data were recorded in GPS time. That is, seconds since midnight of January 6, 1980. In order to convert this time to Coordinated Universal Time (UTC), 18 seconds were subtracted. This is because UTC accounts for leap seconds but GPS does not. In the data processing we convert GPS to UTC before converting to the NASA standard of TT2000 time. TT2000 time is defined as nanoseconds since midnight of January 1, 2000.

The data times in this data set are given in TT2000 time. If the user uses Matlab to access the ".cdf" files, then the times are automatically converted to Matlab's datenum variable.

One outcome of the conversion from GPS to UTC is that any time that is less than 18 seconds from the start of the day get converted into UTC seconds at the end of the day before. As a way to keep the analysis as simple as possible if data times were shifted back into the previous day they were simply dropped. This also means that at the end of any day there will be no events for the last 18 seconds of the day (in UTC).

There are two time variables associated with the SEED data. The description for these two data variables can be found in the META data section of Space Physics Data Facility (SPDF). They are precisely labeled as:

Epoch
TT2000 time for the electron detector. This can have at most $\frac{86400}{15} = 5760$ values.

SEED_Time_Dt15_Good
This is TT2000 time for the SEED detector for time intervals of $\triangle$t = 15 seconds only. The electron data for these intervals are the best in the data set. This time variable is a subset of the "Epoch" time events.

The data user would use the "Epoch" data variable in association with the data variables: **SEED Electron Counts for energy between 13.743 and 146.18 keV** and **Electron Flux at 904 energies (20 - 146 keV), scalar**.

The data user would use the **SEED_Time_Dt15_Good** data variable in association with the data variables: **SEED Electron Counts Dt15(Dt15 $\rightarrow$ Delta t = 15 seconds** and **SEED Electron Flux for time intervals of delta t = 15 seconds. Electron Flux at 904 energies (13 - 146 keV), scalar**.

Geometric Factor

The geometric factor from the paper *Cress et. al.* gave an energy dependent result that was determined over the energy range of approximately 15 keV to 30 keV but not over the entire energy range over which the instrument was operated. A linear extrapolation was performed from the data in the paper to determine the geometric factor for all energies.

The extrapolation is given as:

$$G(E) = mE + b,$$

where $m = 1.73 \times 10^{-7} \frac{\mathrm{cm^2 ster}}{\mathrm{keV}}$ and $b = -1.8 \times 10^{-6} \mathrm{cm^2 ster}$ and E ranges from 13.743 through 146.1 keV.

The following bolded items are an exact list of the data products available for the SEED electron detector instrument.

SEED Electron Counts for energy between 13.743 and 146.18 keV
This data product contains the counts for all 904 energy channels for all of the possible times in a given day. There are undetermined problems with this data set and analysis has shown anomolies that cannot be readily explained or understood. This data product would be used to investigate specific events over unspecified time intervals. Conversion to differential particle flux would be to divide the counts by the product of the delta energy, the delta time and the geometric factor.

Electron Flux at 904 energies (20 - 146 keV), scalar
This data product contains the differential particle flux$(\mathrm{Counts\ keV^{-1}\ s^{-1}\ ster^{-1}\ cm^{-2}})$

for all 904 energy channels for all of the possible times in a given day. These data were calculated from the SEED electron counts and are subject to the same caveats and restrictions as mentioned above.

SEED Electron Counts Dt15(Dt15 $\rightarrow$ Delta t = 15 seconds)
This data product contains the counts for all 904 energy channels for times in which the data cadence was exactly 15 seconds. These data are the most reliable data produced. This data product would be used to investigate specific events over unspecified time intervals. Conversion to differential particle flux would be to divide the counts by the product of the delta energy, the delta time and the geometric factor.

SEED Electron Flux for time intervals of delta t = 15 seconds. Electron Flux at 904 energies (13 - 146 keV), scalar
This data product contains the differential electron flux for all 904 energy channels for times in which the data cadence was exactly 15 seconds.

STP Sat-6 Falcon Dosimeter Users Guide

The dosimeter on the STP Sat-6 satellite is a four channel dosimeter with a sample rate of 1 sample per second. Only the first 3 channels are offered as data products. The dosimeter is a Teledyne Microdosimeter, model number (P/N UDOS001-C). All of the specifications can be found at the following website :

`https://www.teledynedefenseelectronics.com/e2vhrel/products/Pages/UDOS001 & Micro Dosimeter Datasheet - 23rd April 2021.pdf`

The conversion factors for each dosimeter channel were determined by the following procedure. The data was used to determine the average number of counts required to cause the channels to overflow. This value was then applied to the appropriate energy range of the specific channel. For example, figure 1 shows the results for the zeroth energy channel. This channel had an energy range of $0 - 3.6$ mrad. The average number of counts to overflow in the zeroth channel was 8925.11. Thus, the conversion from counts to dose was determined to be : $\frac{3.6 \text{ mrad}}{(8925.11 \text{ Count } \times 1000.0)} = 4.034 \times 10^{-7}\text{rads/Count}$. The same procedure was followed for the remaining channels.

The following bolded items are an exact list of the data products available for the Falcon-SEED dosimeter and temperature instruments. Each of these data products would be used in association with the SEED_Dosimeter_Time time variable.

SEED Dosimeter Counts
These data are the counts data taken on the spacecraft. The data were differenced in the same way as the counts data from the SEED detector and any counts that were recorded during the resets were thrown out.

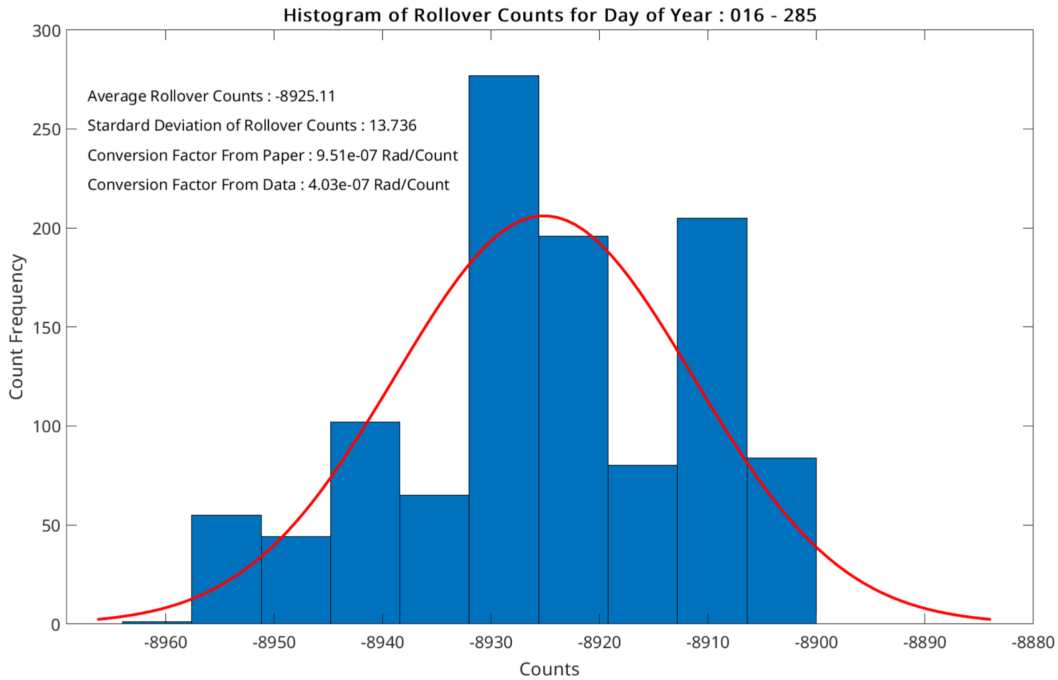

Figure 1: Histogram of dosimeter rollover counts.

SEED Dosimeter Dose
These data are simply the counts data from above with the conversion factor (Counts to Rads) applied to each channel. These data are dose per time interval.

SEED Temperature
This data set contains the temperature of the SEED instrument as a function of time. The data is sampled once per second and are presented as they are sent down from the spacecraft. No manipulation was preformed on these data.

The dosimeter data is also suspected of some errors and later versions of the data products will attempt to correct any errors.

Data analysis programs written in Matlab can be obtained from the author (John Williams) via email request.

References

Cress R., Maldonado C. A., Coulter M., Haak K., Balthazor R. L., McHarg M. G., Barton D., Greene K., Lindstrom C. D.(2020). Calibration of the Falcon Solid-state Energetic Electron Detector (SEED). Space Weather, 18. https://doi.org/10.1029/2019SW002345

For questions and further discussion please contact :

John Williams
john.williams@afacademy.af.edu
845-743-2384