Chandra Flight Note

FLIGHT NOTE NO.	#572
SUBJECT	DEA Shutdown Anomaly Closeout
DATE	3/15/2016
AUTHOR	R. Edgar, G. Germain, K. Gage

ANOMALY

On September 15, 2005, at 2005:258:23:31:29, the DEA side A power supply switched off without external command.

OPERATIONAL RESPONSE

The engineering staff examined the SSR dump data in detail, and determined that the behavior of the system was consistent with a commanded turn-off. The event was very similar to the previous incidents in which the DPA side A power supply turned off, likely due to a spurious signal generated by an SEU within the PSMC (See **FN 394**)

Using CAP 980, the DEA-A power supply was turned on again on September 16, 2005, at about 2005:259:11:02. Chandra operations resumed with the next scheduled observation.

Over the following month or so, various pieces of evidence including an apparent decrease in the CTI of the FI chips, led the team to believe that the ACIS focal plane temperature was not being regulated, and that the reported temperature was 1.3 C warmer than the actual value.

The default power-up state of the A/D converters in the DEA, including the one reporting the focal plane temperature, is a low-resolution mode which is uncalibrated. The lack of regulation was noted, and after a series of CTI runs at various elevated temperatures, the -120 C focal point temperature thermostat setting was re-established, but suspicions that the focal plane was colder than advertised persisted. Warm booting the BEP may put the A/D converters into high-resolution mode, as explained in a memo by Dorothy Gordon (ACIS/MIT engineering team, dated 18 November 2005), so that was done via CAP 981 on October 16, 2005.

ANALYSIS

See attached memo by Richard J. Edgar and Gregg Germain (ACIS DEA_A Off anomaly, Sept 15, 2005; dated Feb 8, 2016)

CONCLUSION

The investigation reveals that the telemetry was consistent with a commanded turn-off. The event was very similar to the previous incidents in which the DPA side A power supply turned off, likely due to a spurious turn-off signal generated by an SEU within the PSMC: OCCcm03681 (2000:300, FN 394) and OCCcm05521 (2002:353, FN 417). While the hardware in this case is distinct, the design is very similar, and a plausible case was made that the root cause was the same.

Recommended recovery procedure as of this writing (early 2016) would probably be:

- Establish that telemetry indicates no hardware failure.
- Turn on the DEA-A, using SOP 61036. Verify telemetry is as expected. If anything fails to verify, try again. If it still fails, power down again and consider swapping to DEA-B.
- Using SOP ACIS WARMBOOT DEAHOUSEKEEPING, warm-boot the BEP and restart housekeeping.
- Set the parameters for the TXINGS patch. This step is not urgent, as the default parameters are adequate. The update can be done in the loads at a later date.
- Perform a CTI observation using a standard SI mode, as it is done during radiation shutdowns, if desired.

Further thinking on power system anomalies and recovery procedures exists in draft form here: acis.mit.edu/axaf/psmcanomtest/

This report is intended to close out the anomaly documented by DDTS OCCcm07374.

CHANDRA
X-ray Center 60 Garden St., Cambridge Massachusetts 02138 USA

MEMORANDUM

Date:	February 8, 2016
From:	Richard J. Edgar and Gregg Germain
To:	Chandra Operations Team
Subject:	ACIS DEA-A Off anomaly, Sept 15, 2005
Cc:	MSFC Project Science, CXC Director's Office
File:	`DEA-A-off_memo.tex`
Version:	`1.4`

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1 Abstract

On September 15, 2005, the ACIS DEA side A power supply switched off without external command. This memo describes the diagnosis of this anomaly, steps to recovery, and lessons learned.

This memo is presented to support closing item OCCcm07374.

2 Introduction

On September 15, 2005, at 2005:258:23:31:29, the DEA side A power supply switched off without external command. Subsequent investigation reveals that the telemetry was consistent with a spurious command, and the behavior of the system was consistent with a commanded turn-off.

The engineering staff examined the SSR dump data in detail, and determined that the event was very similar to the previous incidents in which the DPA side A power supply turned off: OCCcm03681 (2000:300, FN 394) and OCCcm05521 (2002:353, FN 417). While the hardware in this case is distinct, the design is very similar, and a plausible case was made that the root cause was the same.

Using CAP 980, the DEA-A power supply was turned on again on September 16, 2005, at about 2005:259:11:02. Chandra operations resumed with the next scheduled observation.

Over the following month or so, various pieces of evidence including an apparent decrease in the CTI of the FI chips, led the team to believe that the ACIS focal plane temperature was not being regulated, and that the reported temperature was 1.3 C warmer than the actual value.

The default power-up state of the A/D converters in the DEA, including the one reporting the focal plane temperature, is a low-resolution mode which is uncalibrated. The lack of regulation was noted, and after a series of CTI runs at various elevated temperatures, the −120 C focal point temperature thermostat setting was re-established, but suspicions that the focal plane was colder than advertised persisted. Warm booting the BEP may put the A/D converters into high-resolution mode, as explained in a memo by Dorothy Gordon (ACIS/MIT engineering team, dated 18 November 2005), so that was done via CAP 981 on October 16, 2005. This mechanism is not fully understood, so it may be necessary to repeat the warm boot after assessing the A/D data (voltages and the focal plane temperature).

Recommended procedure as of this writing (early 2016) would probably be:

- Establish that telemetry indicates no hardware failure.
- Turn on the DEA-A, using SOP 61036. Verify telemetry is as expected. If anything fails to verify, try again. If it still fails, power down again and consider swapping to DEA-B.
- Using SOP_ACIS_WARMBOOT_DEAHOUSEKEEPING, warm-boot the BEP and restart housekeeping.
- Set the parameters for the TXINGS patch. This step is not urgent, as the default parameters are adequate. The update can be done in the loads at a later date.
- Perform a CTI observation using a standard SI mode, as it is done during radiation shutdowns, if desired.

Further thinking on power system anomalies and recovery procedures exists in draft form here: `acis.mit.edu/axaf/psmcanomtest/`

3 Detailed Timeline

- 2005:258 **Thursday Sep 15, 2005**
- 2005:258:23:30:14 Best-fit time of anomaly from the engineering data archive (this work, 2016)
- 2005:258:23:30:22 Last exposure packet from Obsid 6221 recieved
- 2005:258:23:31:04–23:31:22 DEA-A turned off during this VCDU frame
- 2005:258:23:37:54 Science run 6221 terminated by watchdog timers.
- 2005:259 **Friday Sep 16, 2005**
- 2005:259:03:45 Regularly scheduled DSN communications pass. The OC & CC noticed the DEA side A was off during normal health and safety checks.
- 2005:259:06:29 02:29 EDT: first e-mail notice to the ACIS team
- 2005:259:13:00 09:00 EDT (time approximate): ACIS Ops and ACIS Engineering meet to review the data and plan a recovery procedure.
- 2005:259:15:47 11:47 EDT: Draft of CAP 980 out for review. The CAP review was at 12:15 EDT
- 2005:259:16:50–18:50 The next scheduled DSN communications pass.
- 2005:259:17:02 CAP 980 execution begins
- 2005:259:17:25 Changed obsid to 62825
- 2005:259:17:29 1DEPSAON command sent to turn on DEA side A. Telemetry verified.
- 2005:259:17:40 Start a CTI run using SI mode TE_00216
- 2005:259:18:05 First event data recieved.
- 2005:259:18:50 Loss of comm
- 2005:259:19:45 Stop science command in weekly loads terminates CTI run, obsid 62825

4 Data Analysis

When the SSR dump data were available, an analysis was undertaken to see if the event was similar to the two previous examples of DPA-A spontenious shut-downs, and to determine the time of the event.

The data are consistent with all power system changes happening at once, and the apparent dispersion in times results from the precise location of the telemetry items in the major frame. The following telemetry items changed: 1DEPSA, the DEA Power Supply on/off indicator, from ON to OFF. Note 1DEPSAX remained with status ENABLED. The DEA input current, 1DEICACU, changed from 0.91 to 0.14 amps. The A-side analog voltages changed as follows: 1DEP3AVO, the +28V supply, from +30.5 to +0.45 volts; 1DEP2AVO, the +24V supply, from 25.2 to 0.36 volts; 1DEP1AVO, the +15V supply, from 16.1 to 0.15 volts; 1DEN0AVO, the -6V supply, from -6.35 to -0.15 volts; and 1DEN1AVO, the -15V supply, from -16.1 to 0.38 volts.

1DE28AVO, the 28-volt input power voltage for the DEA power supply, showed a small uptick, as expected if the load suddenly drops to near zero. Note the variability in the input current 1DEICACU, and hence the power derived from it, is an expected feature of the current monitor and is unrelated to the anomaly.

We append plots of these items.

As a result of the DEA-A power down, all active video boards lost power, and so the science run was interrupted. After about seven minutes pass with no pixel data from the video boards reaching their FEPs, each of those watchdog timers ran out and reset its FEP, the BEP was unable to continue and therefore terminated obsid 6221.

The ACIS engineering staff convinced themselves that this was very similar to the DPA-A incidents that had happened twice before (see introduction for document references).

5 Recovery Plan

Given the similarity to the DPA-A power down incidents, it was decided to power the DEA-A up again, and CAP 980 was written for this purpose. The CAP assumed the spacecraft was in telemetry format 2. Each command or set of commands (except the hardware command 1DEPSAON) was uploaded to an SCS slot, and they were enabled and activated one at a time by ground command.

The steps to be executed were these:

- A vehicle deadman load, in the event of lost comm. This is a 2-hour delay followed by code to activate SCS-107.
- Stop Science, via ACIS command AA00000000.
- Power down all FEPs and video boards, via ACIS command WSPOW00000.

- Power up the DEA side A with the ACIS hardware command 1DEPSAON. Verify voltages and currents are as expected.
- Power up the S0 video board, to verify nominal performance with a relatively unimportant system. Command is WSPOW0103F. Verify telemetry.
- Perform an ACIS-I CTI measurement, using SI_mode TE_00216. This involved six ACIS commands. In 2005 these were: WSVIDALLDN, WSPOW0CF3F, WT00216014, XTZ0000005, RS_0000001 and RH_0000001.
- Verify proper performance of ACIS, by monitoring currents and voltages, and watching bias frames and event data when they come in.
- Clear and disable SCS slots used, including the deadman load.

If at any point telemetry failed to verify as expected, contingency steps were identified: Stop Science, via ACIS command AA00000000, power down all FEPs and video boards (via ACIS command WSPOW00000), and command the DEA-A off again with the ACIS hardware command 1DEPSAOF.

Note that more modern versions of the SI_mode used would include the commands WBTX_QUIET (to cancel any TXINGS trigger), and WT00217034 (with updated video offsets and without forced bias recompilation) in place of WT00216014.

The CAP was successfully run starting around 2005:259:17:00. All went well, and the first event data from the CTI run were seen at 259:18:05.

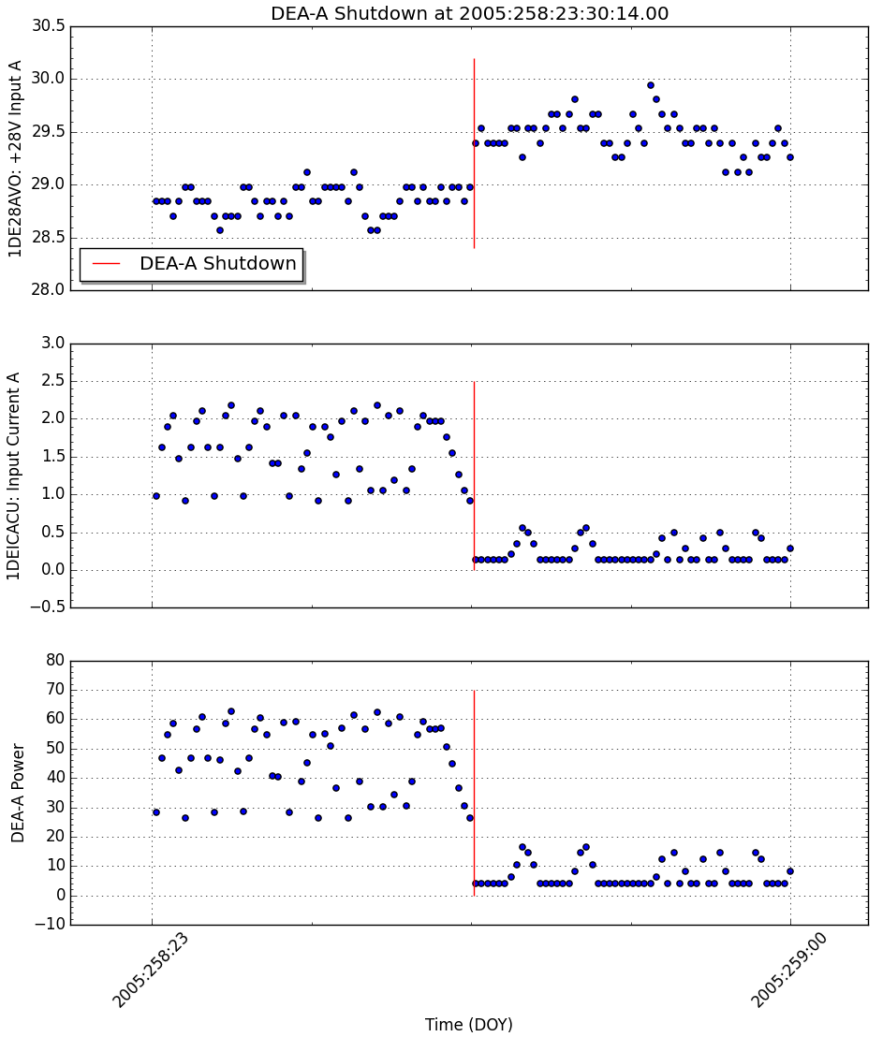

Figure 1: DEA side A 28v input voltage and current vs. time.

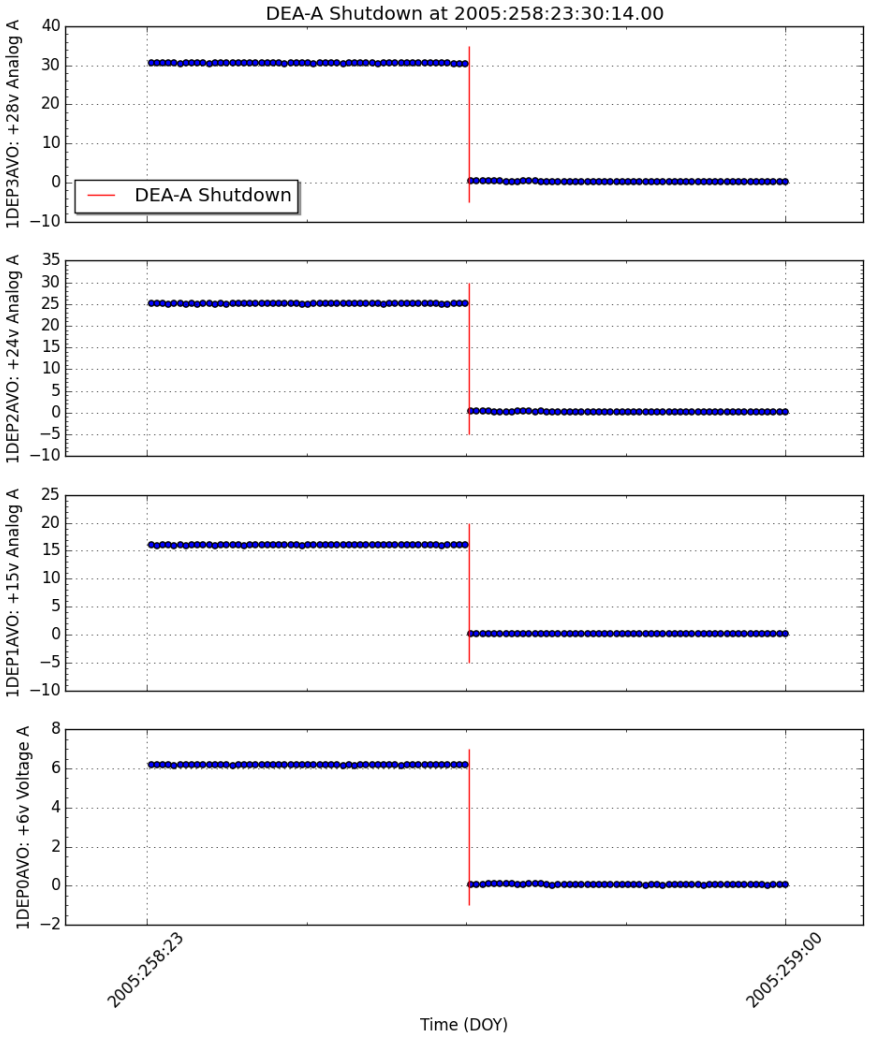

Figure 2: DEA side A positive analog voltages vs. time

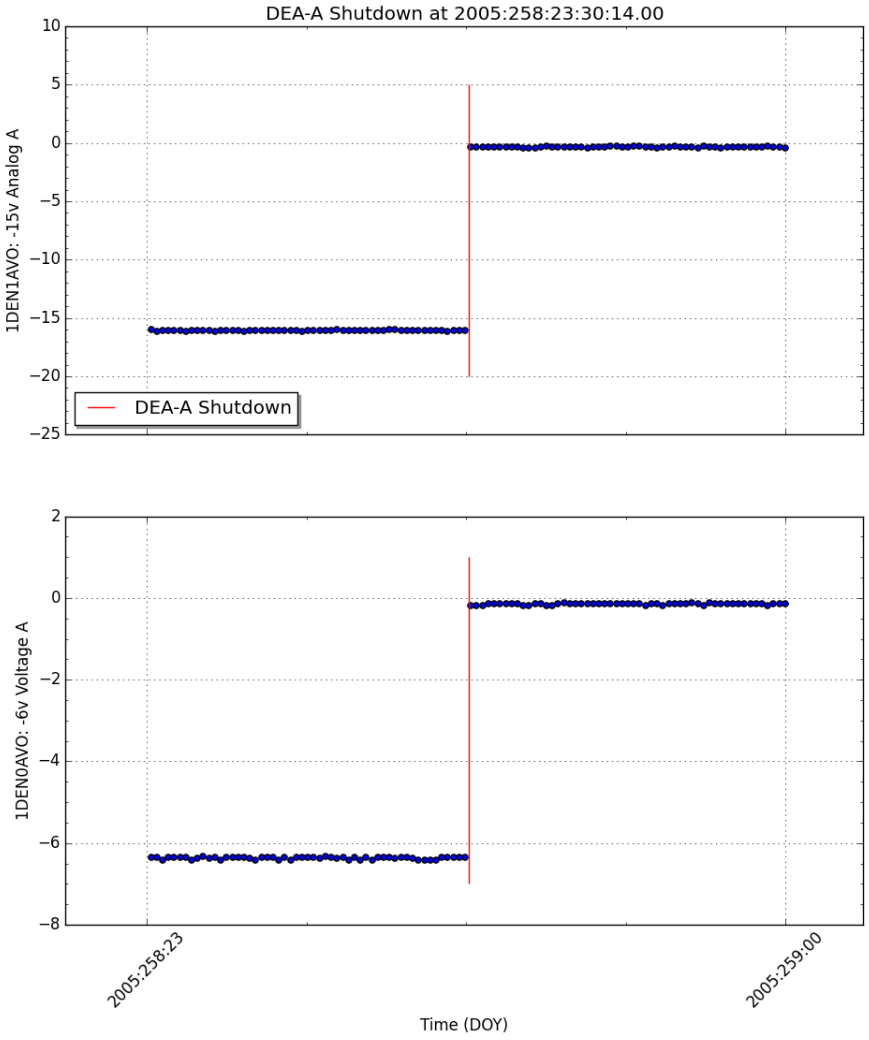

Figure 3: DEA side A negative analog voltages vs. time.

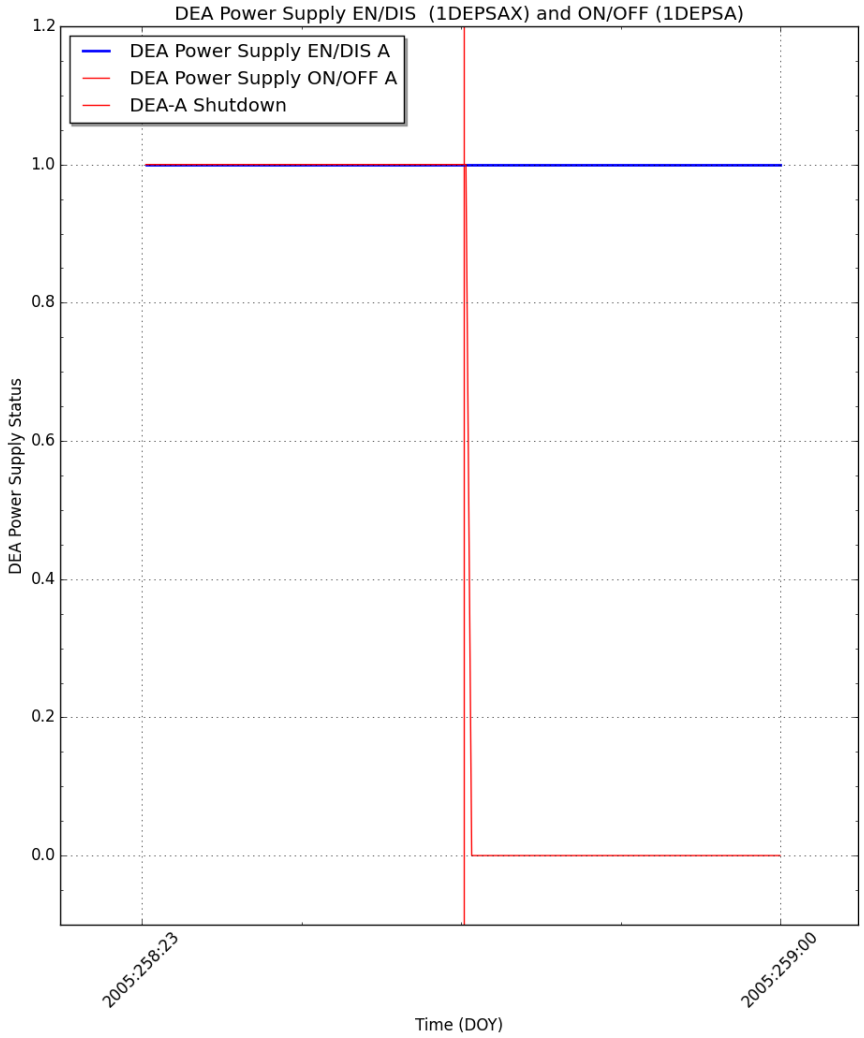

Figure 4: DEA side A power enable and on/off indicators. Note the power supply remained enabled.

6 Consequences

After a period of several weeks, the ACIS team began to suspect that something subtle had changed in the performance of the hardware. A timeline for this investigation follows.

- 2005:279 **Thursday Oct 6, 2005** First hints based on an apparent decrease in CTI that the FP temperature might be colder than expected. Other DEA housekeeping values such as currents and voltages were slightly but significantly different from pre-shutdown values as well.
- 2005:284 **Tuesday Oct 11, 2005** Focal plane temperature commanded setpoints verified to be as expected, following warm CTI tests (at -95C)
- 2005:287 **Friday Oct 14, 2005** CAP 981 review
- 2005:289 **Sunday, Oct 16, 2005**
- 2005:289:10:40–289:12:40 06:40–08:40 EDT: Scheduled DSN communications pass.
- 2005:289:11:00 Begin CAP 981
- 2005:289:11:02 Warm boot BEP using SOP 61070
- 2005:289:11:06 Start DEA housekeeping task using SOP 61010

It was determined that executing a warm boot of the BEP would likely reset the Analog to Digital converters in the DEA to their high precision, calibrated mode. Accordingly, CAP 981 was prepared to do that: it calls SOPs to warm boot the BEP, and to restart the DEA housekeeping task. This was successfully executed at 2005:289:11:00. ACIS operations returned to normal.

The mechanism by which the warm boot resets the A/D converters is not completely understood, and there may be an element of chance in the precise timing involved. Accordingly, it is recommended that the outputs of the DEA A/D converters be monitored to see if the results make sense in light of pre-anomaly values while conducting similar ACIS operations. The changes in the voltages can be quite subtle (roughly one sigma for an hour's worth of sampling), and the independent verification of the focal plane temperature requires monitoring the CTI over a period of weeks.

However, the A/D converter items reported on the ACIS PMON pages do show an immediate jump at the warm boot of the BEP. Most notable among those are the focal plane temperature (fptemp_11), and the DEA voltages (dea28volta, dea24volta, deam15volta, deap15volta, deam6volta, and deap6volta). These are stored as pseudo-MSIDs in the ska engineering database. For nearly identical circumstances before the anomaly, before the warmboot, and after the warmboot (i.e. the same SI mode was executing in a similar thermal environment), the focal plane temperature, and the +24 and +6 volt power supplies

in particular, returned to their pre-anomaly values after the warmboot, while exhibiting different values between the anomaly recovery and the warmboot.

We plot a few of these items near the time of the warm boot in figure 5.

This effect is even more clear in figure 6, kindly supplied by Peter Ford of MIT. Here the +15v analog power supply, as read out through the A/D converters in question, is plotted vs time for the period covering from 30 days prior to the DEA-A power anomaly, through 30 days following the BEP reboot. Points are color coded by the number of video boards powered, and whether they were clocking (as revealed by the 1STAT1ST status bit). This plot also gives an idea of the integration time required to be sure to detect an uncalibrated A/D converter.

It is recommended that the ACIS team monitor these values carefully following this kind of an anomaly recovery, to be sure the A/D converters are operating in their calibrated, high-resolution mode.

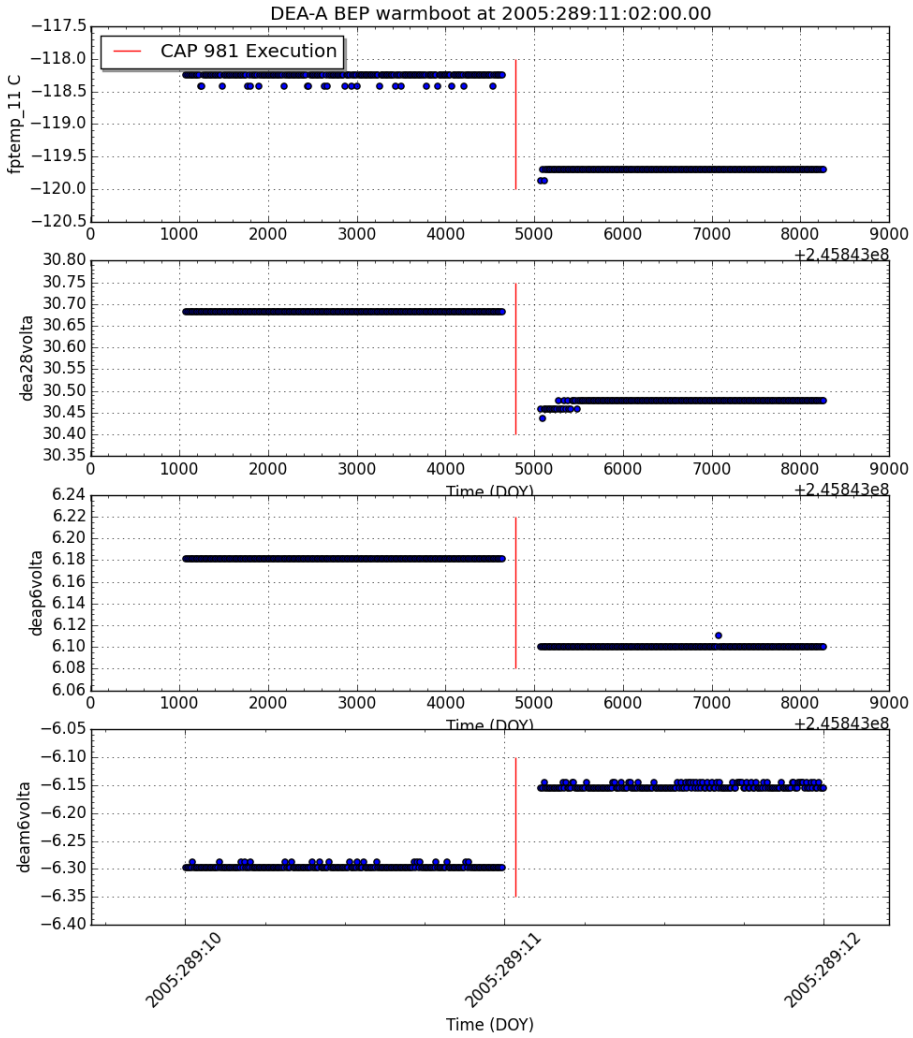

Figure 5: Selected A/D Converter data reported in the DEA housekeeping data, on the PMON page, around the time of CAP 981, rebooting the BEP. Note the perceptible jumps. These items returned to their pre-anomaly values after this CAP.

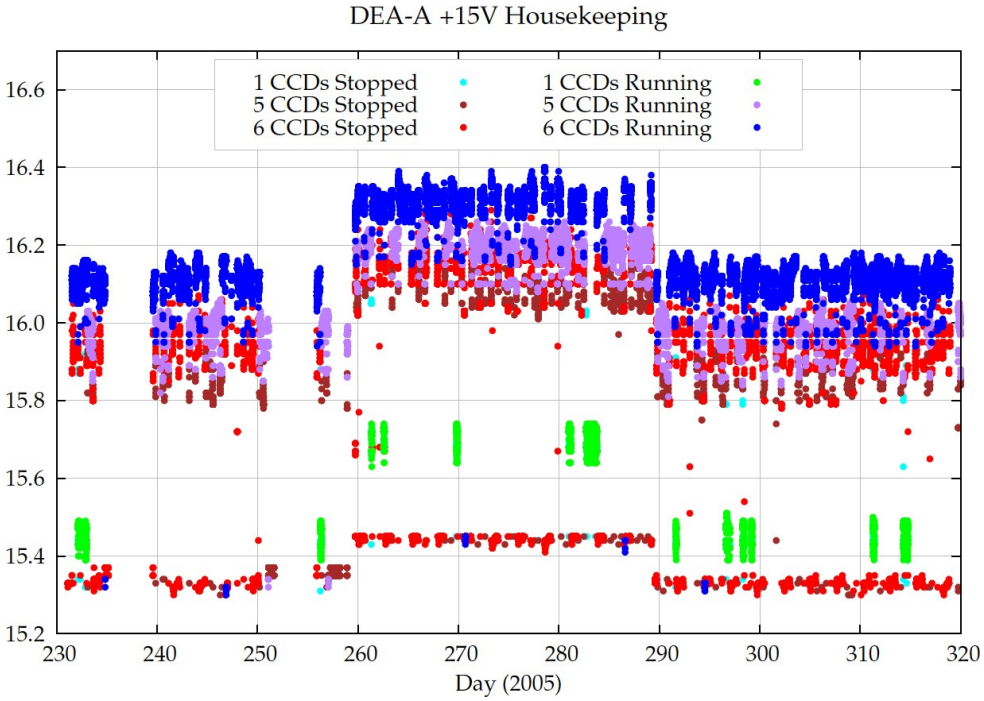

Figure 6: The DEA +15v analog voltage supply, from 30 days prior to the anomaly, through 30 days after the BEP reboot. Colors encode the number of video boards powered, and whether they were clocking (as seen by the 1STAT1ST status bit). Note the jumps at the time of the anomaly and at the BEP reboot.