Chandra X-ray Observatory

HRC Anomaly on 24 August 2020

Plan of action following the anomaly re-occurrance

Chandra Community Briefing

28 August 2020

HRC Operations Team

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CENTER FOR ASTROPHYSICS

HARVARD & SMITHSONIAN

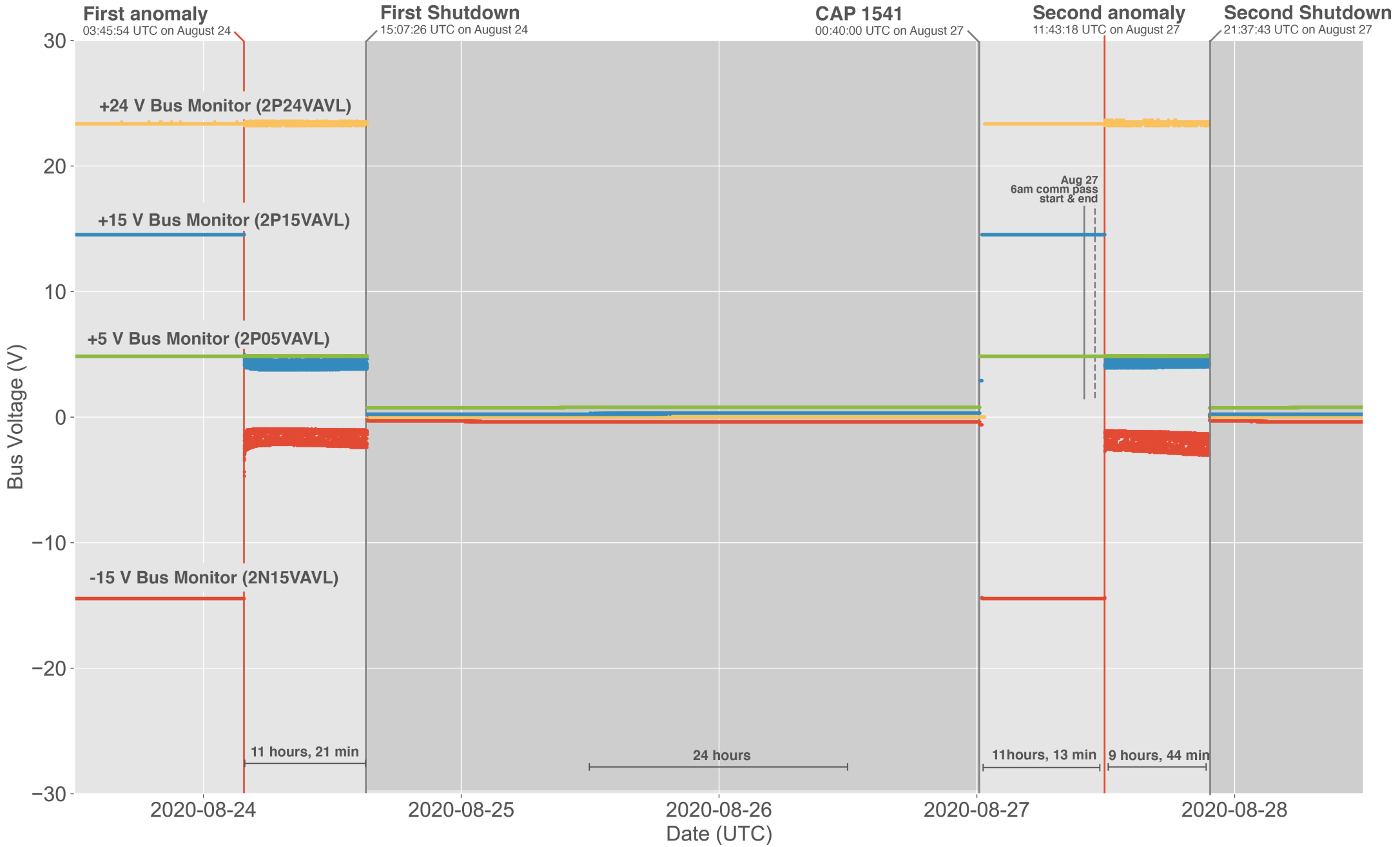
The re-appearance of the HRC anomaly

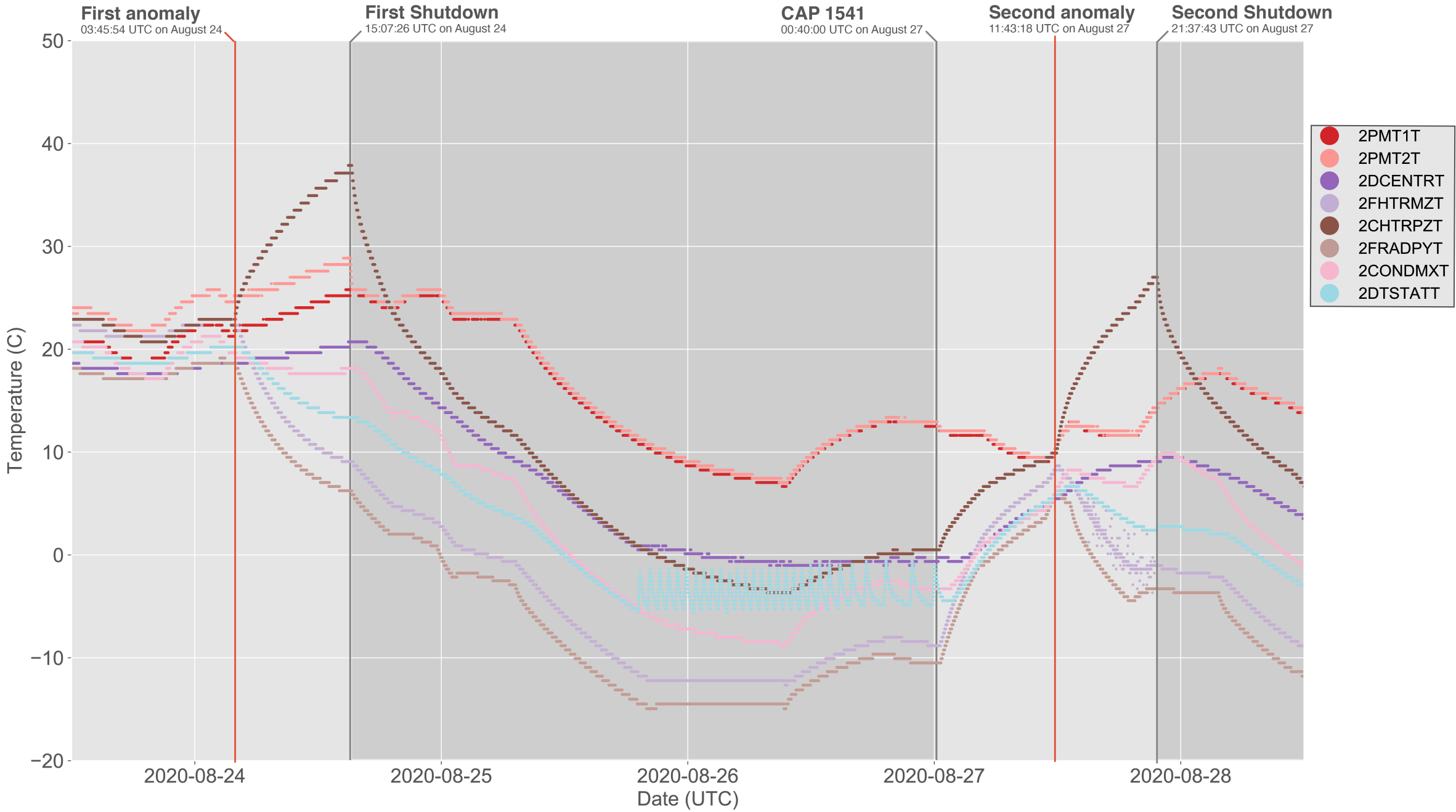
- In response to the initial HRC anomaly that began on Monday morning, the HRC Team recommended that we **attempt a reset of the Side A power supply bus**.
    - A summary of this initial anomaly and first response plan can be found in our two prior community briefings, found here and here.
- On Wednesday night, **we executed CAP 1541 to reset the power supply bus** during the 8:05pm EDT pass.
- **The CAP execution was *technically* successful**, and returned the HRC bus voltages to their nominal states. Those nominal states were persistent and stable for 11h 13 min, including through the 6am comm pass yesterday morning.
- **At the start of the 5:20 pm (BOT, EDT) comm pass yesterday evening, the HRC Team noted that the +/-15 V voltages had returned to the same off-nominal values encountered during the first anomaly.**

Timeline of the reappearance

- The anomaly returned yesterday at 11:53:19 UTC (7:53:19 EDT), i.e. 53 min, 19 seconds after the end of yesterday's 6am comm pass.

- The return of the anomaly was noted immediately at BOT of the 5:20pm comm pass last night. We successfully shut down the instrument via SCS 41 at 5:37pm local time.


First anomaly
03:45:54 UTC on August 24
First Shutdown
15:07:26 UTC on August 24
CAP 1541
00:40:00 UTC on August 27
Second anomaly
11:43:18 UTC on August 27
Second Shutdown
21:37:43 UTC on August 27
+24 V Bus Monitor (2P24VAVL)
+15 V Bus Monitor (2P15VAVL)
+5 V Bus Monitor (2P05VAVL)
-15 V Bus Monitor (2N15VAVL)
Aug 27
6am comm pass
start & end
11 hours, 21 min
24 hours
11hours, 13 min
9 hours, 44 min
Bus Voltage (V)
30
20
10
0
−10
−20
−30
2020-08-24
2020-08-25
2020-08-26
2020-08-27
2020-08-28
Date (UTC)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CAP 1541
00:40:00 UTC on August 27
Second anomaly
11:43:18 UTC on August 27
Second Shutdown
21:37:43 UTC on August 27
50
40
30
20
10
0
−10
−20
Temperature (C)
2020-08-24
2020-08-25
2020-08-26
2020-08-27
2020-08-28
Date (UTC)
2PMT1T
2PMT2T
2DCENTRT
2FHTRMZT
2CHTRPZT
2FRADPYT
2CONDMXT
2DTSTATT

Hypotheses

- The rapid reoccurrence of the anomaly **now disfavors a single event upset (SEU) scenario.**

- Timescales argue that **the thermal environment is one potential driver of whatever is causing the anomaly.**

Plan of action

- **The HRC Team now recommends that we swap to redundant Side B electronics**
  - The HRC Team has been reviewing, analyzing, and discussing the commanding and procedures necessary to make this change.
    - This includes shift reports from orbital activation, early logs and notes, etc.

- While prioritizing operational activities, the HRC team is actively investigating potential causes of the anomaly.

EXTRA SLIDES

Top level diagram to switch from Side A on the Prime Bus to Side B on the Redundant Bus

Power down HRC

Activate SCS #41 - Power-down HRC

turn off primary bus

turn off redundant bus

Reconfigure HRC

power configure HRC to use CEA B with redundant power

turn on redundant bus

(using redundant bus is one less relay to switch)

Power up HRC

power up HRC on CEA B

configure for HRC-I on CEA B

or

configure for HRC-S on CEA B

Needed operational changes

make explicit reference to side A or B:

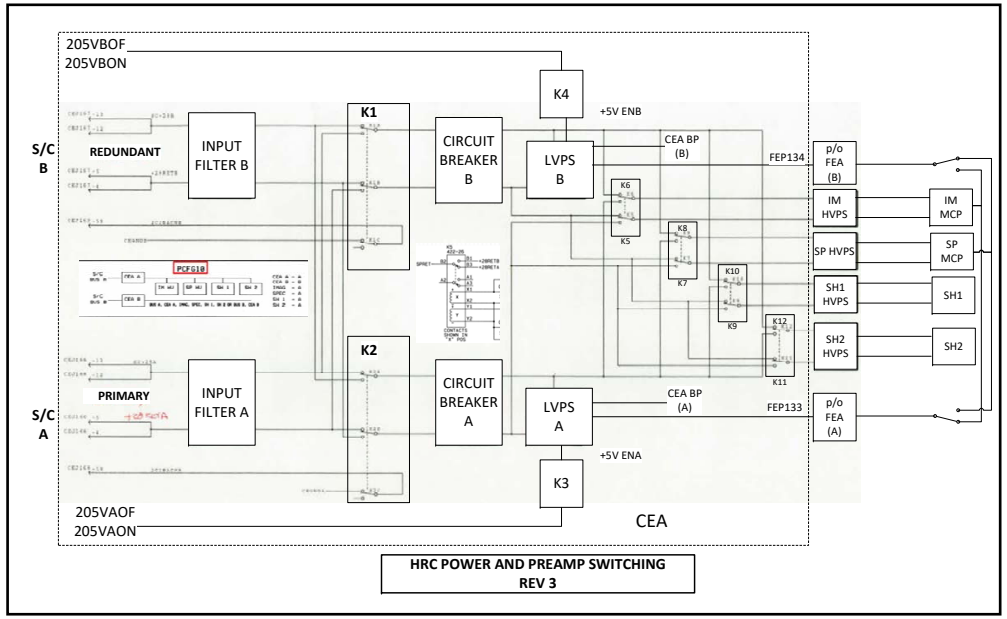
SCS 69 (maybe)

2_I_DEFAULTS.ATS

2_S_DEFAULTS.ATS

(preliminary)

HRC Power Switching



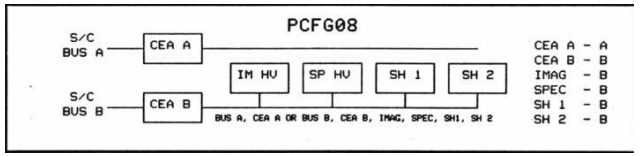
Post-power up HRC

turn on PMT#2

turn on HRC-I/S HV

ramp up HRC-I/S HV - point at blank sky

Swap to side B on redundant bus is represented by power configuration PCFG08



Hypotheses from 8/26 tagup

- The anomaly is due to a problem **with the +/- 15 V power supply bus** on **Side A**

  - **A problem in the +15 V bus *would also take out the -15 V power supply due to DC-to-DC design***
    - A problem in the -15 V bus would not cause issues with the +15 V bus

  - **There could be a fault in the electronics on this bus**
    - A load fault that is transient in nature (e.g. an SEL). This should clear with a power cycle.

… *or* …

    - A failed component that is dragging down the +15V bus. This would not clear with a power cycle and would require an A/B swap.

… *or* …

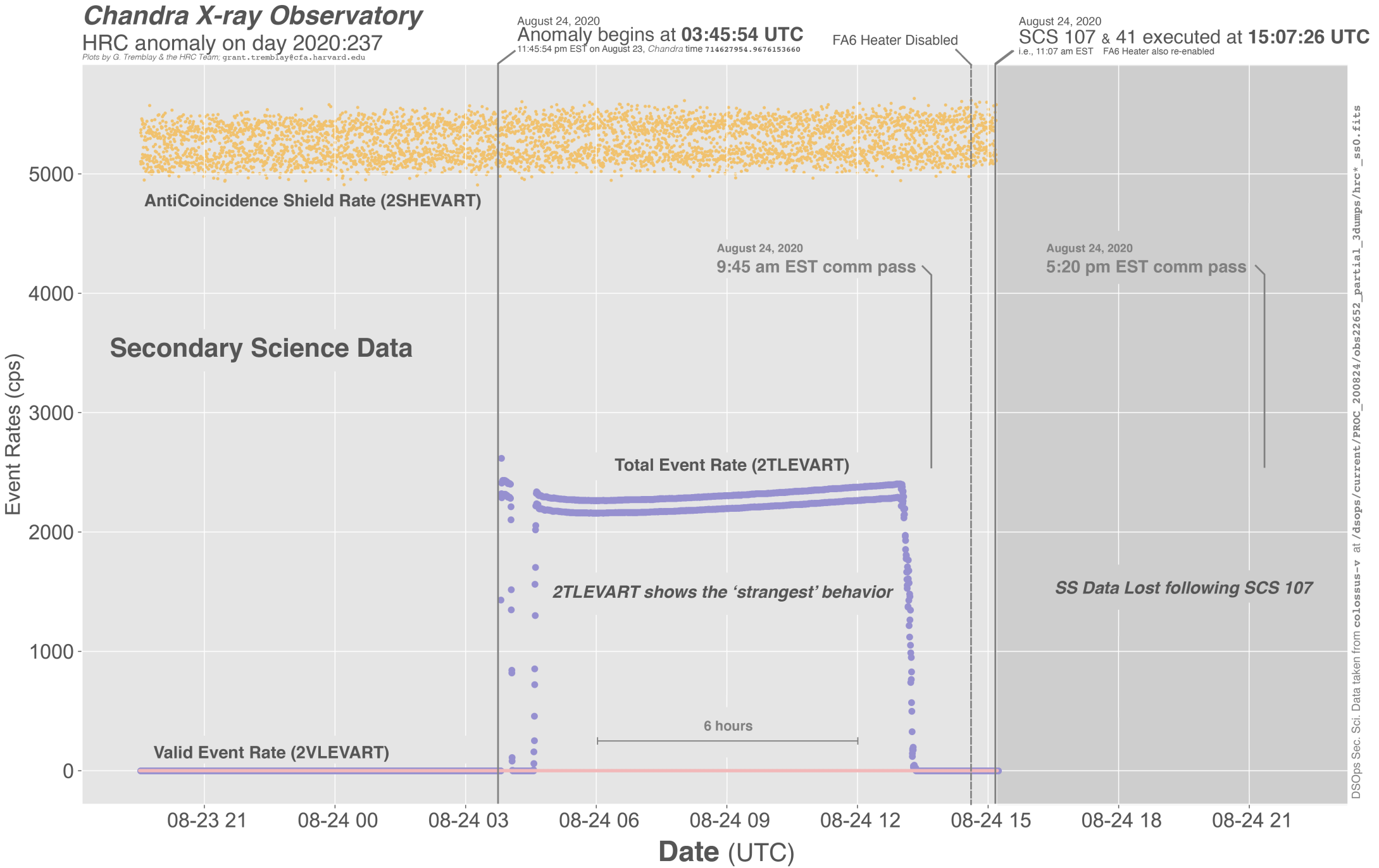
    - A latched-up component downstream of DC-DC converter may clear with power cycle. Otherwise an A / B swap is indicated.

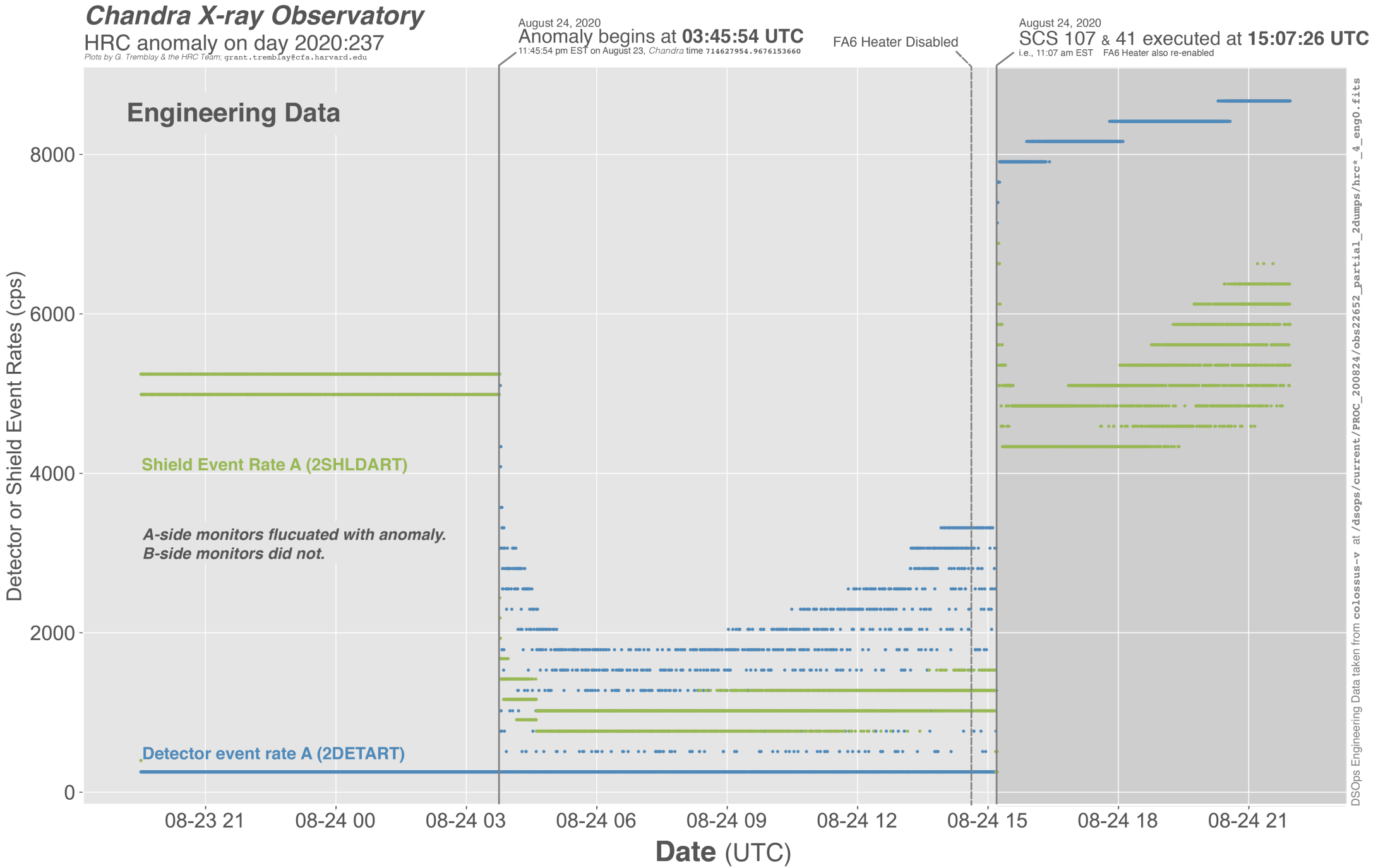
Decision tree during CAP execution

- Following CAP **Step 2** (**`205VAON`** with telemetry verifier **`2PS5AON=ON`**):
  - **Success:** We expect to see the +5 V bus return to a nominal value (i.e. around +5 V and stable for several frames).
  - **Failure**: The +5 V bus does *not* return to a nominal value, or only stays there for a very short period of time before returning to an off-nominal value.
  - If this step is successful, we will proceed to the next step. If it is not successful, we will execute contingency steps 6 and 7 in the CAP to safely shutdown the instrument. The CAP will end there.

- *Assuming the above step is successful,* following CAP **Step 5** (**`215PCAON`** with telemetry verifier **`215PCAST=ON`**):
  - **Success:** We expect to see the +15 V and -15 V bus monitors return to nominal values (i.e., *roughly* -14.5 V to -15 V for the -15 V monitor, and +14.5 V to +15 V monitor. Note that these thresholds are *not* exact. **Important note**: it is *possible* that we will see some secondary sciencex corruption in the telemetry. This is not surprising and will not necessarily constitute a failure. The HRC Team will decide if the exact returned values can be considered “nominal”.
  - **Failure**: One or both of the +15 V and -15 V monitors do *not* return to their expected values.
  - If this step is successful, we will proceed to the next step. If it is not successful, we will execute contingency steps 6 and 7 in the CAP to safely shutdown the instrument. The CAP will end there.

- *Assuming the above step is successful,* following CAP **Step 8** (**`224PCAON`** with telemetry verifier **`225PCAST=ON`**):
  - **Success:** We expect to see the +24 V return to a nominal value of *roughly* +24 V. The HRC Team will decide if the exact returned values can be considered “nominal”. Agan, some SSC might be present, and this does not necessarily mean failure.
  - **Failure**: The +24 V monitor does *not* return to its expected values.
  - If this step is successful, we will proceed to the next step. If it is not successful, we will execute contingency steps 6 and 7 in the CAP to safely shutdown the instrument. The CAP will end there.


Chandra X-ray Observatory
HRC anomaly on day 2020:237
Plots by G. Tremblay & the HRC Team; grant.tremblay@cfa.harvard.edu
August 24, 2020
Anomaly begins at 03:45:54 UTC
11:45:54 pm EST on August 23, Chandra time 714627954.9676153660
FA6 Heater Disabled
August 24, 2020
SCS 107 & 41 executed at 15:07:26 UTC
i.e., 11:07 am EST FA6 Heater also re-enabled
AntiCoincidence Shield Rate (2SHEVART)
August 24, 2020
9:45 am EST comm pass
August 24, 2020
5:20 pm EST comm pass
Secondary Science Data
Total Event Rate (2TLEVART)
2TLEVART shows the 'strangest' behavior
SS Data Lost following SCS 107
6 hours
Valid Event Rate (2VLEVART)
Event Rates (cps)
5000
4000
3000
2000
1000
0
08-23 21
08-24 00
08-24 03
08-24 06
08-24 09
08-24 12
08-24 15
08-24 18
08-24 21
Date (UTC)
DSOps Sec. Sci. Data taken from colossus-v at /dsops/current/PROC_200824/obs22652_partial_3dumps/hrc*_ss0.fits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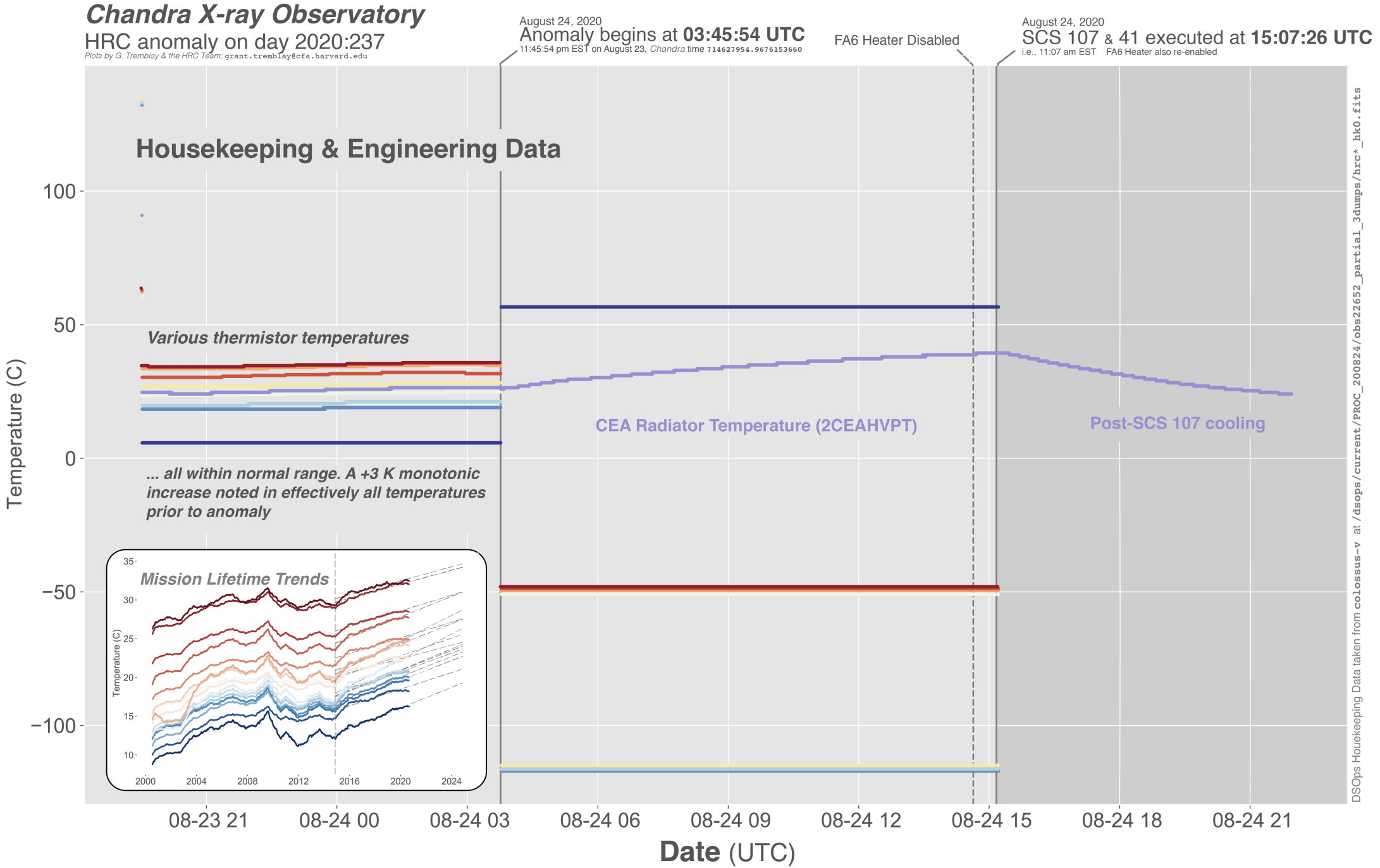
Engineering Data
Shield Event Rate A (2SHLDART)
A-side monitors flucuated with anomaly.
B-side monitors did not.
Detector event rate A (2DETART)
Detector or Shield Event Rates (cps)
0
2000
4000
6000
8000
08-23 21
08-24 00
08-24 03
08-24 06
08-24 09
08-24 12
08-24 15
08-24 18
08-24 21
Date (UTC)
DSOps Engineering Data taken from colossus-v at /dsops/current/PROC_200824/obs22652_partial_2dumps/hrc*_4_eng0.fits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FA6 Heater Disabled
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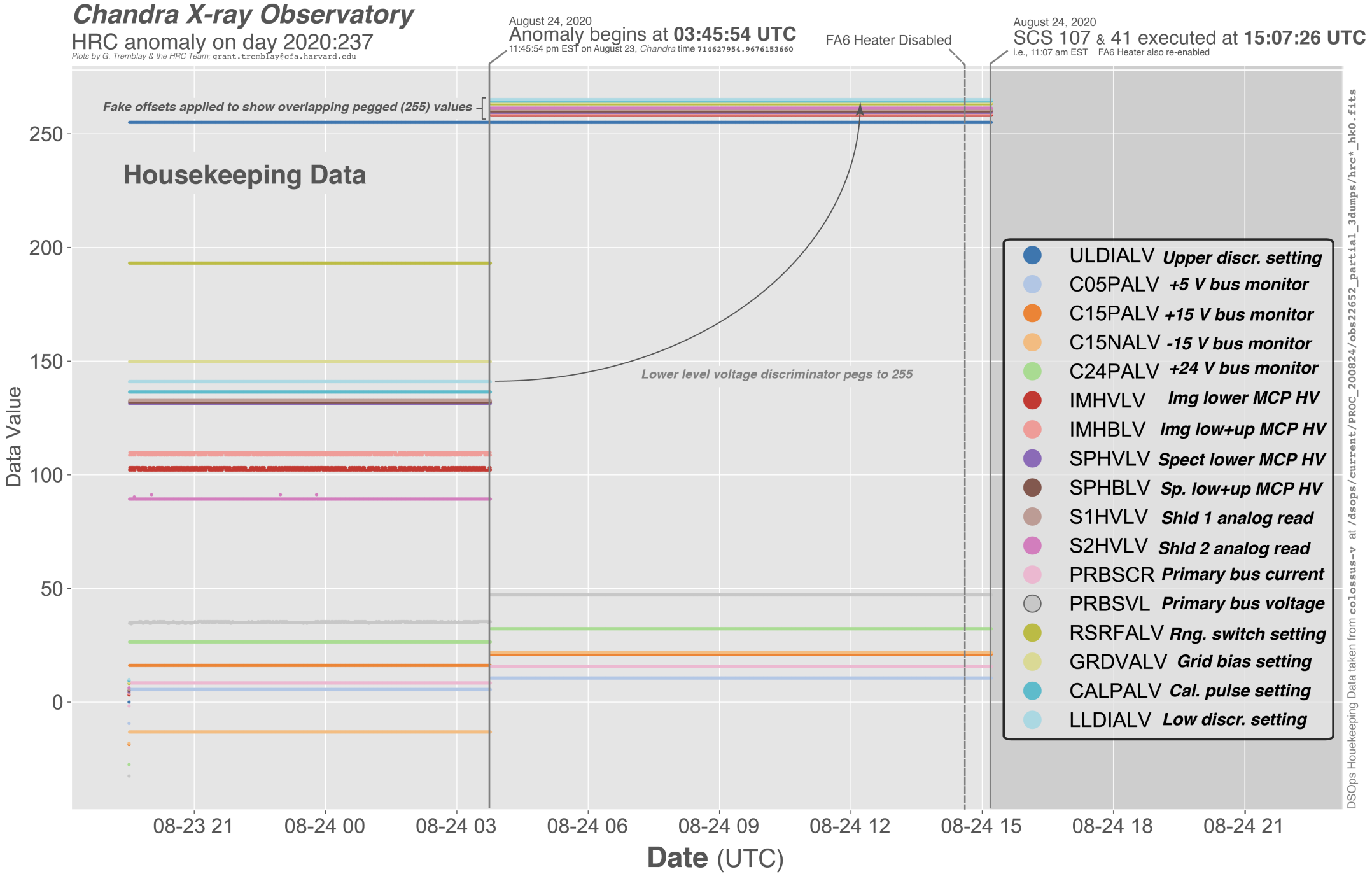
i.e., 11:07 am EST FA6 Heater also re-enabled
Housekeeping & Engineering Data
Various thermistor temperatures
... all within normal range. A +3 K monotonic increase noted in effectively all temperatures prior to anomaly
CEA Radiator Temperature (2CEAHVPT)
Post-SCS 107 cooling
Mission Lifetime Trends
Temperature (C)
100
50
0
−50
−100
08-23 21
08-24 00
08-24 03
08-24 06
08-24 09
08-24 12
08-24 15
08-24 18
08-24 21
Date (UTC)
DSOps Houekeeping Data taken from colossus-v at /dsops/current/PROC_200824/obs22652_partial_3dumps/hrc*_hk0.fits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FA6 Heater Disabled
August 24, 2020
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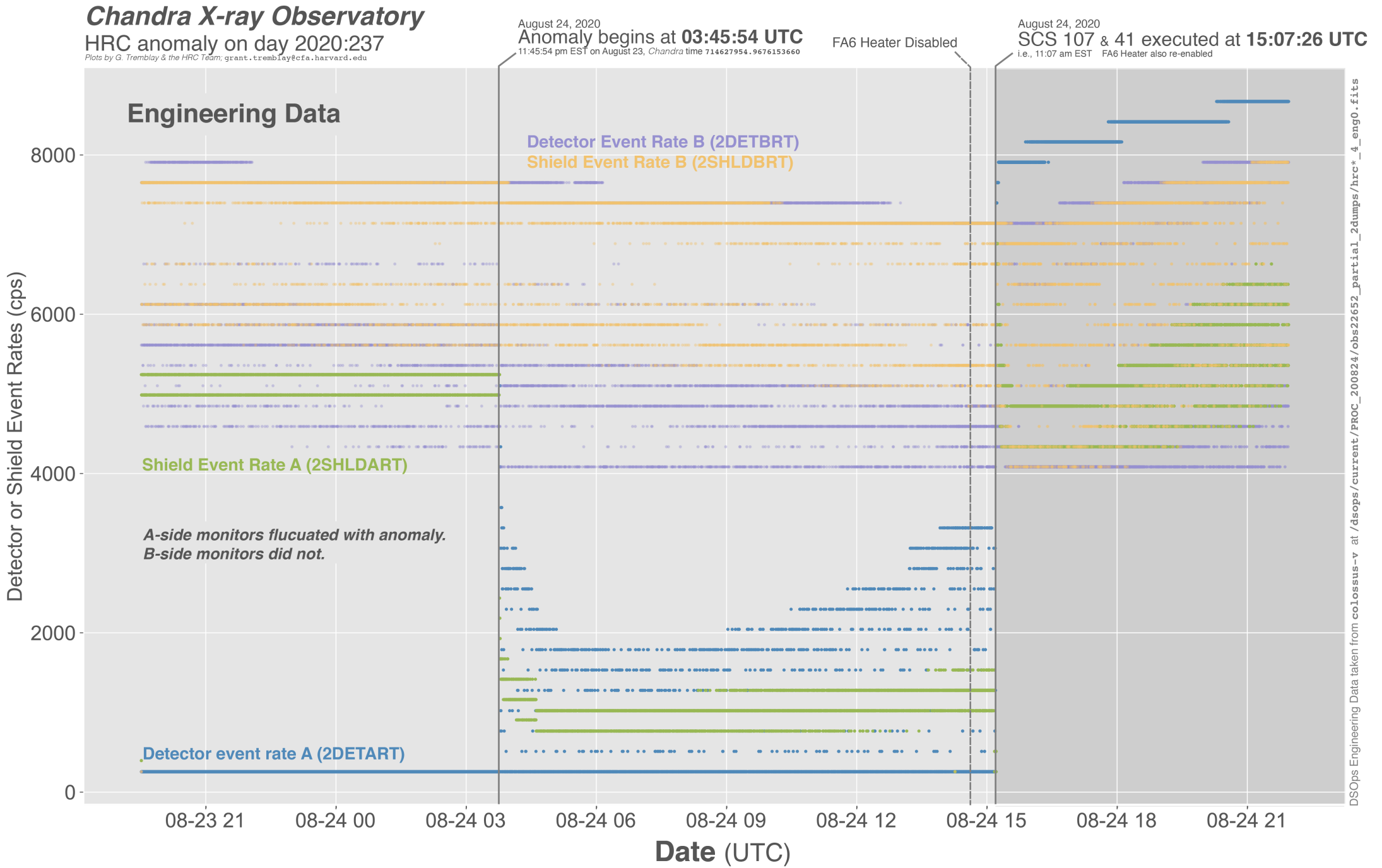
i.e., 11:07 am EST FA6 Heater also re-enabled
Fake offsets applied to show overlapping pegged (255) values
Housekeeping Data
Lower level voltage discriminator pegs to 255
Data Value
250
200
150
100
50
0
08-23 21
08-24 00
08-24 03
08-24 06
08-24 09
08-24 12
08-24 15
08-24 18
08-24 21
Date (UTC)
ULDIALV Upper discr. setting
C05PALV +5 V bus monitor
C15PALV +15 V bus monitor
C15NALV -15 V bus monitor
C24PALV +24 V bus monitor
IMHVLV Img lower MCP HV
IMHBLV Img low+up MCP HV
SPHVLV Spect lower MCP HV
SPHBLV Sp. low+up MCP HV
S1HVLV Shld 1 analog read
S2HVLV Shld 2 analog read
PRBSCR Primary bus current
PRBSVL Primary bus voltage
RSRFALV Rng. switch setting
GRDVALV Grid bias setting
CALPALV Cal. pulse setting
LLDIALV Low discr. setting
DSOps Houekeeping Data taken from colossus-v at /dsops/current/PROC_200824/obs22652_partial_3dumps/hrc*_hk0.fits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Engineering Data
Detector Event Rate B (2DETBRT)
Shield Event Rate B (2SHLDBRT)
Shield Event Rate A (2SHLDART)
A-side monitors flucuated with anomaly.
B-side monitors did not.
Detector event rate A (2DETART)
Detector or Shield Event Rates (cps)
8000
6000
4000
2000
0
08-23 21
08-24 00
08-24 03
08-24 06
08-24 09
08-24 12
08-24 15
08-24 18
08-24 21
Date (UTC)
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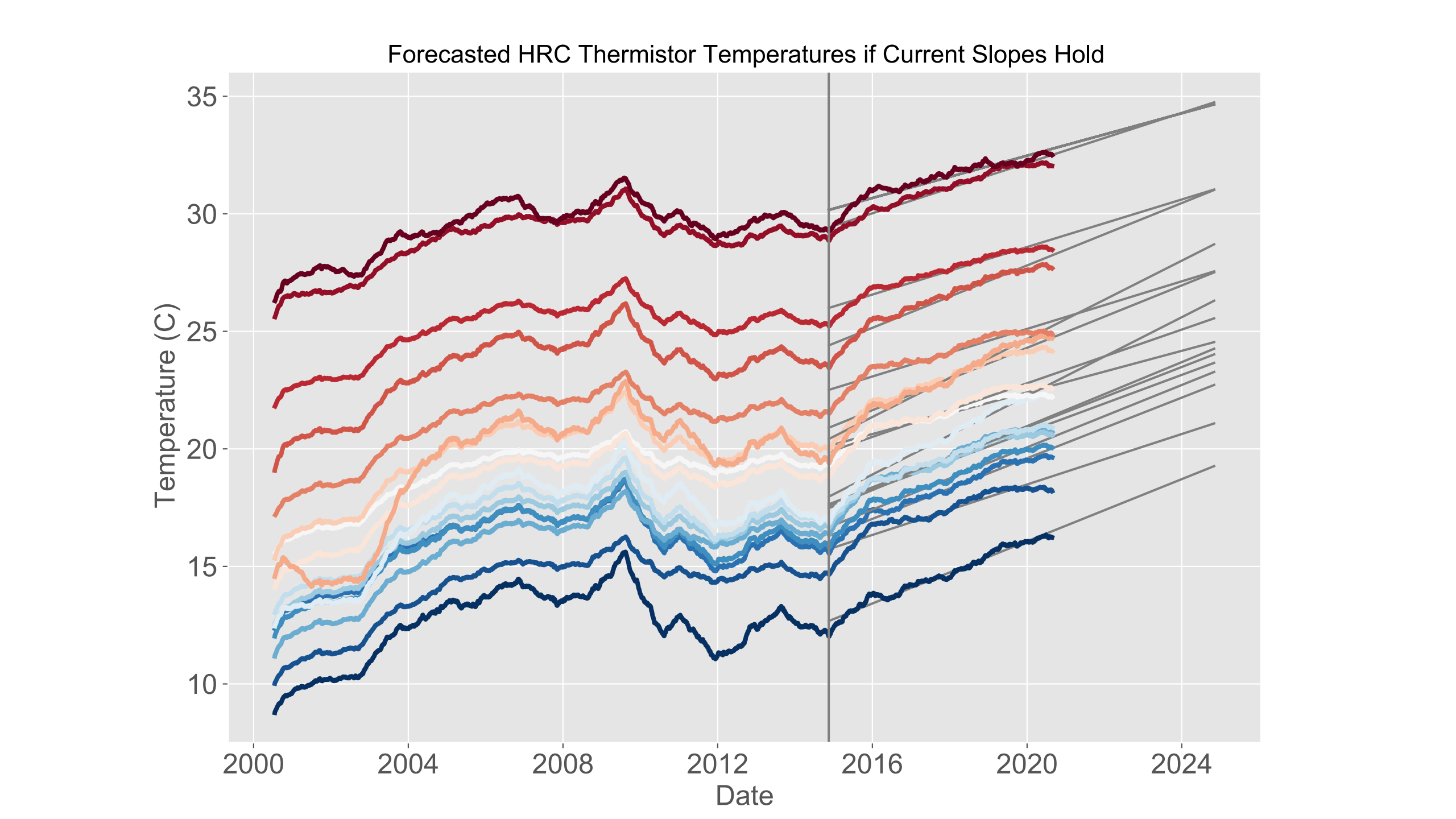
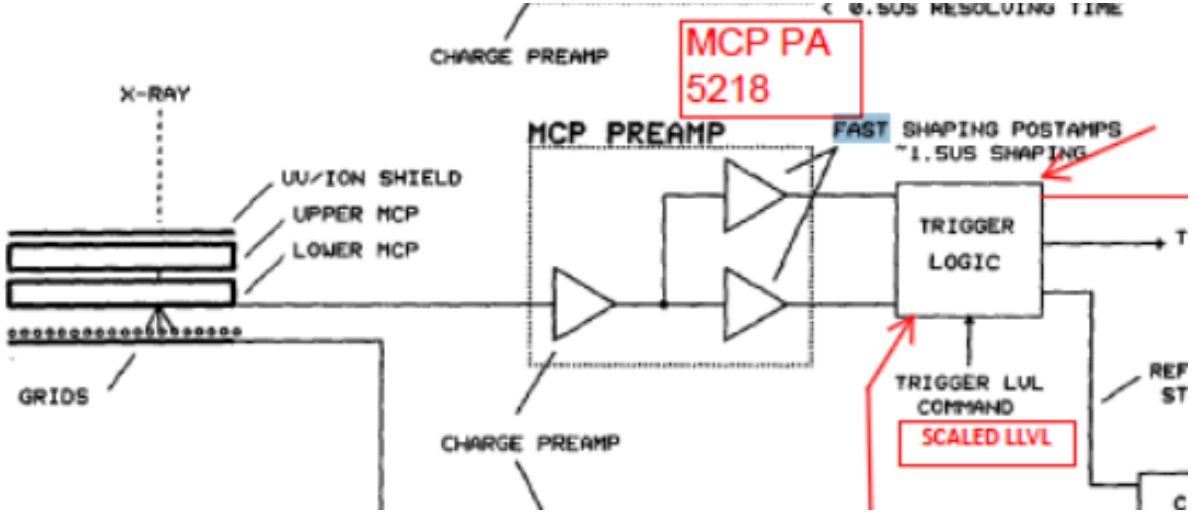
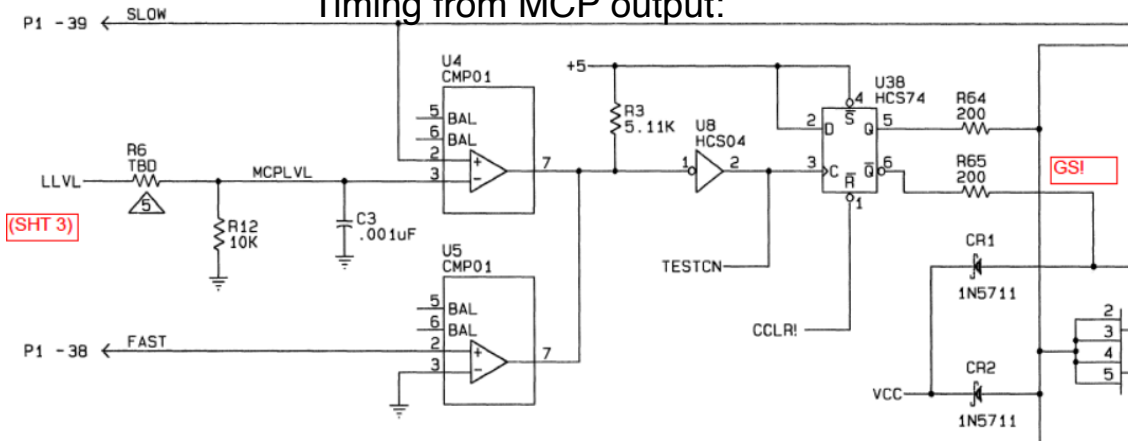

Forecasted HRC Thermistor Temperatures if Current Slopes Hold
Temperature (C)
35
30
25
20
15
10
2000
2004
2008
2012
2016
2020
2024
Date

Explanation of trigger noise
(T. Gauron)

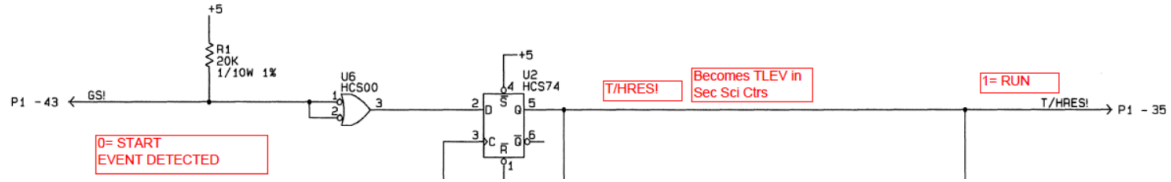
Top Level Trigger from MCP output:



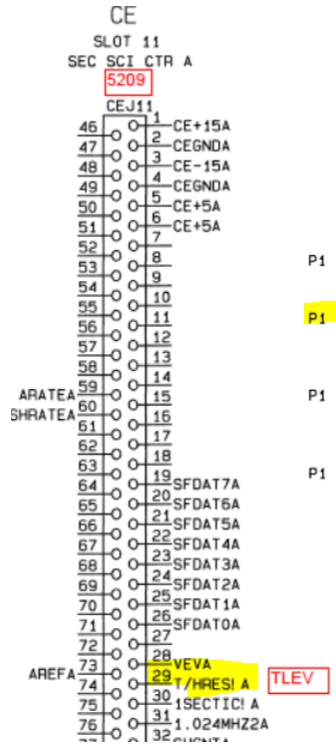
Timing from MCP output:



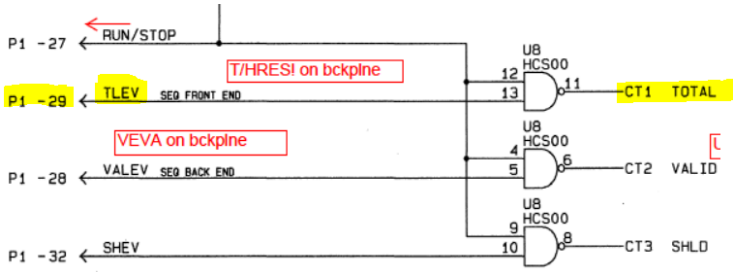
GS! is synced with S/C clock and becomes T/HRES! in SEQUENCER



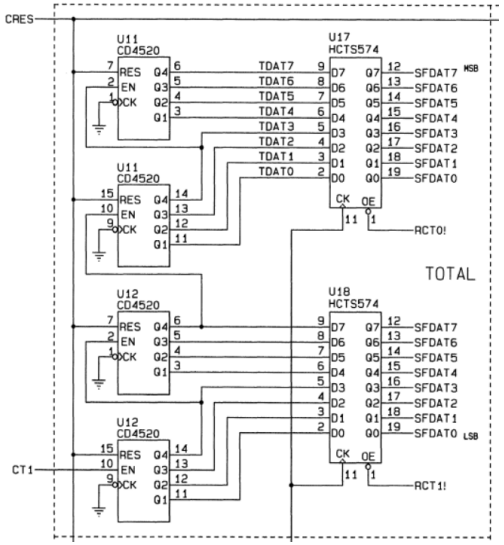
T/HRES! Routes to SEC_SCI_CTR pin 29 on backplane



It's called TLEV on the SEC_SCI PWA



…and gets counted for TOTAL EVENTS



Why is a Side A reset preferred?

- **Resetting Side A offers *lower risk* than swapping to Side B.**
  - The HRC team ***cannot find any plausible scenario*** **in which turning on the 5 and 15 V would cause any damage to the single stream components (e.g., MCPs, crossed grid array, etc.)**
  - This is a **straightforward procedure** derived from an SCS
  - This addresses the possible “single event latchup” hypothesis
- **Swapping to Side B is more complicated and risky.**
  - It requires switching of latching relays which we haven’t activated in 20 years.
  - It requires shutting the 28 V bus power to the HRC off.
  - B-side electronics have not been used in 20 years
  - It entails significant alteration of all HRC commanding, including protected SCSs, ATSs, and support software
  - It would require a complete calibration of the detectors

Explanation of trigger noise
(T. Gauron)

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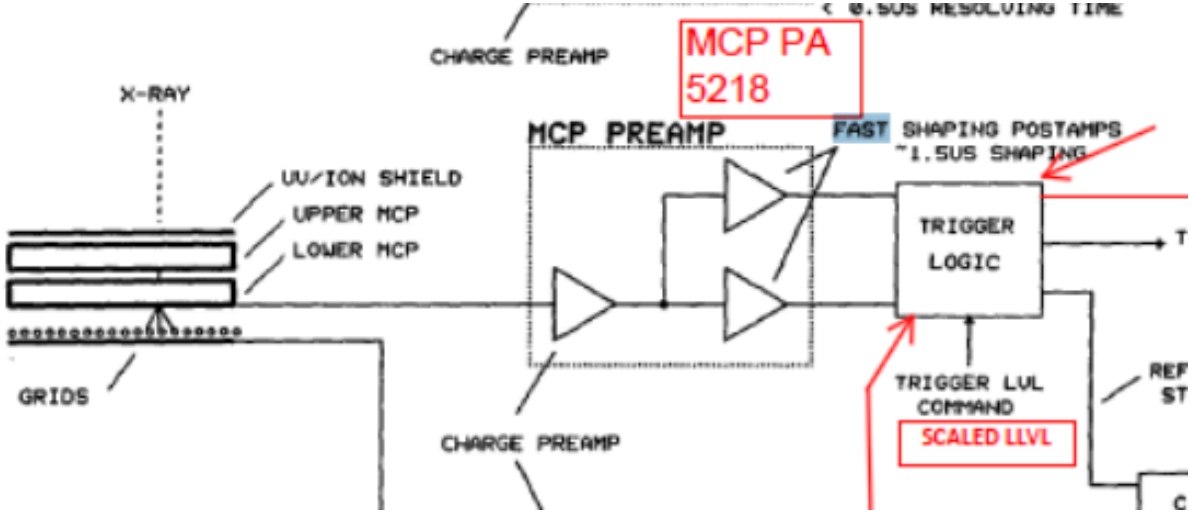

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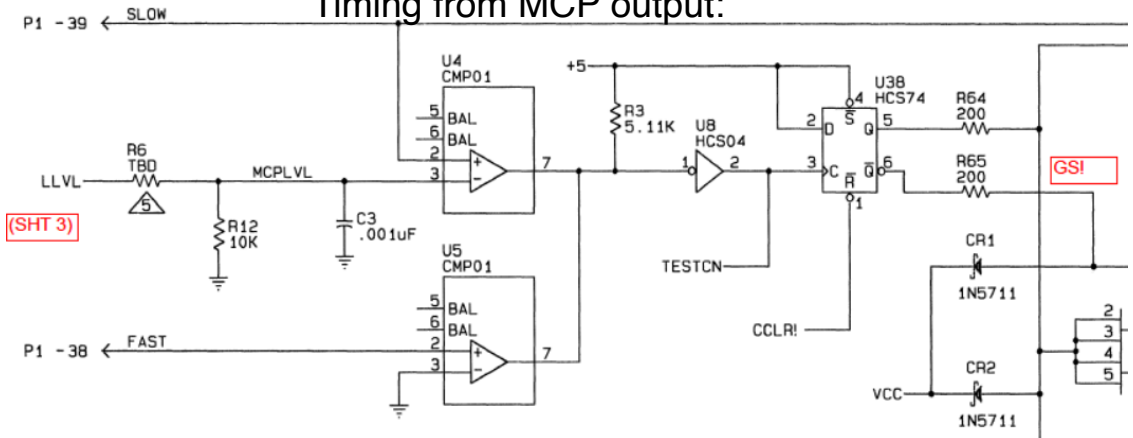

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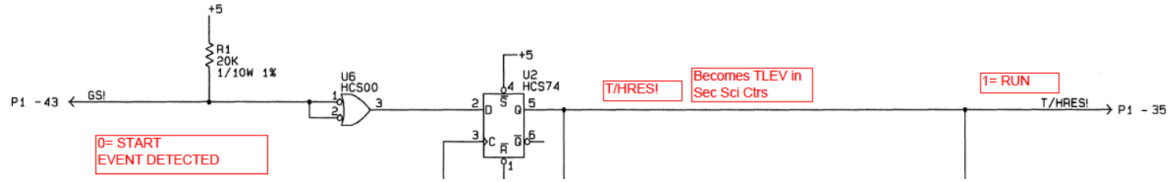
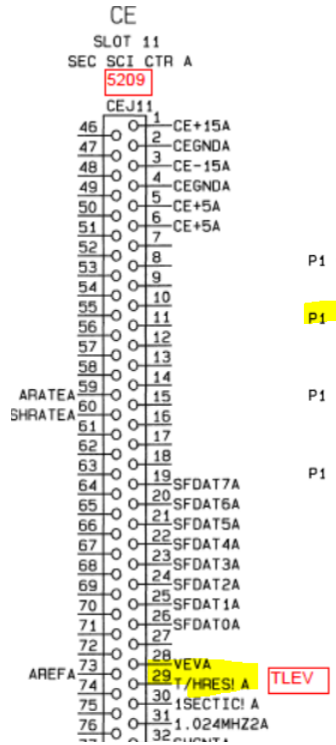


T/HRES! Routes to SEC_SCI_CTR pin 29 on backplane



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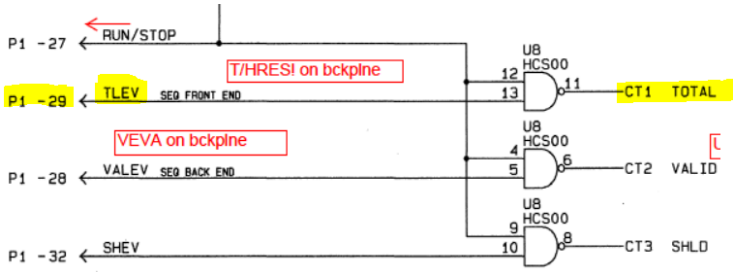

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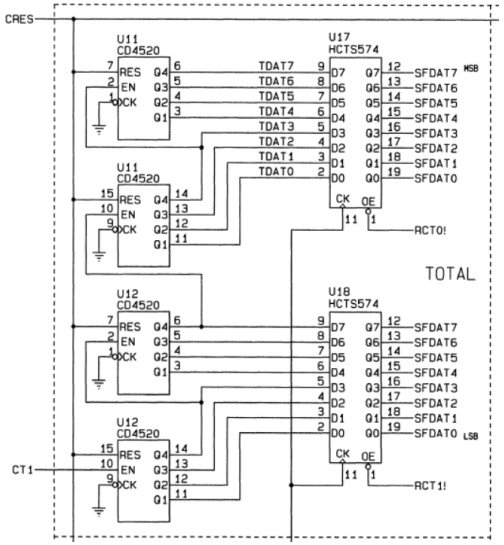

Prime and redundant side wiring

(T. Gauron)