National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

The 7th Community Coordinated Modeling Center (CCMC) Workshop

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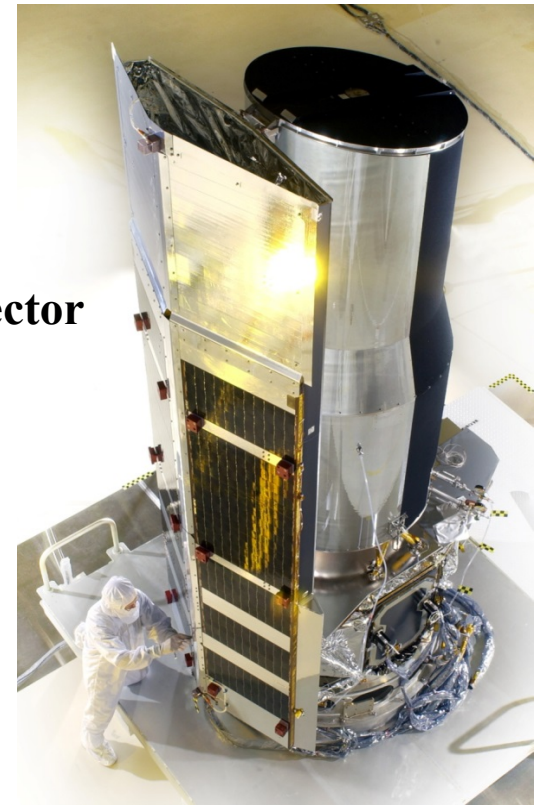
April 3, 2014



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Agenda

- **Mission Overview**
- **Driving Requirement (Space Weather)**
- **Space Weather Events**
- **Operational Space Weather Procedure**
- **Spitzer Mission Contribution for Space Weather**
- **Summary**

Mission Phases

- The Spitzer Space telescope was launched on 25 August 2003 with a prime Cryogenic Mission Requirement of five years.
- The helium depleted on 15 May 2009, ending the prime mission which started the Infrared Array Camera (IRAC) Warm Mission.
- First phase of extended mission - (FY 11 and FY 12).
- Second phase of extended mission - (FY 13 and FY 14).
- As of August 2013 Spitzer completed 10 years of Science Operations.
- A Third extended mission phase will be proposed spring 2014 for (FY 15 until FY 18).

Current Orbit Information

- Spitzer is in a heliocentric, Earth-trailing orbit. It follows the Earth around the Sun. Its orbit is slightly more elliptical than the Earth's, and most of the time it is farther away from the Sun than the Earth is, so it slowly recedes from Earth at about 0.1 AU/yr.

  - *Current Orbit Information (Geocentric)*
    - ***Distance* = 194136402.9639 km (1.298 AU)**
    - ***One-way light time* = *647.52 s (~10.792 min.)***
    - ***Right Ascension (EME J2000)* = 6.5192 deg**
    - ***Declination (EME J2000)* = 8.0261 deg**

Spitzer Observatory Telescope

- The primary mirror is 85 cm in diameter and made of beryllium.
- The field-of-view angle of the telescope is 32′ (32 arcminutes).
- The focal length is 10.2 m.
- The total mass of the spacecraft at launch was 950 kg, including 50.4 kg of liquid helium (cryogen).

Instruments

- Three science instruments
  - *IRAC – Infrared Array Camera*
    - Bands: 3.6 µm, 4.5 µm, 5.8 µm, and 8.0 µm
  - *MIPS – Multi-band Imaging Photometer*
    - Bands: 24 µm, 70 µm, and 160 µm
  - *IRS – Infrared Spectrometer*
    - Bands: 5.2 µm – 14.5 µm, 9.9 µm – 19.6 µm, 14.0 µm – 38.0 µm, and 18.7 µm – 37.2 µm
- In the Cryogenic Mission, only one instrument was on at a time for a sequence duration of one to three weeks.
  - *Primary mirror operates between 5.6 K and 12 K.*
- In the extended Warm Mission, only two bands of IRAC, 3.6 µm and 4.5 µm, will produce valid science data.
  - *Primary mirror operates at ~26 K*

Science Overview

- Cryo mission, the science objectives for the Spitzer mission were defined as:
  - *Deep surveys of oldest galaxies*
  - *Evolution and structure of ultra-luminous galaxies and quasars*
  - *Search for Brown Dwarfs*
  - *Evolution of stellar disks and planetary systems*

- Warm mission - IRAC, the science objectives are:
  - *Study properties of extra-solar planets*
  - *Study galaxies during the first one billion years after the Big Bang*
  - *Complete census of the galaxy for young stars*
  - *Determine cosmic distance scale in the local universe*
  - *Asteroid Hunter*

Driving Requirement (Space Weather)

Ground Segment Requirement

Space Weather event producing protons exceeding the 100 MeV energy level and particle flux greater than 100 pfu

Launch and Cryo Science Mission Phase

- The Ground Segment, using both local and telemetry information, shall decide the time at which the Observatory is to resume science operations after a solar flare
  - *real-time or stored sequence commands to accomplish this.*

- The Ground Segment shall recognize and respond to a solar flare event within 12 hours occurrence
  - *powering off non-essential loads as necessary to minimize radiation effects.*
    (For impacts to the IRS and MIPS due to common electronics)

Warm Mission Science Phase

- Monitor and annotate for S/C performance impacts and degraded science.
  - *No actions required from the ground*

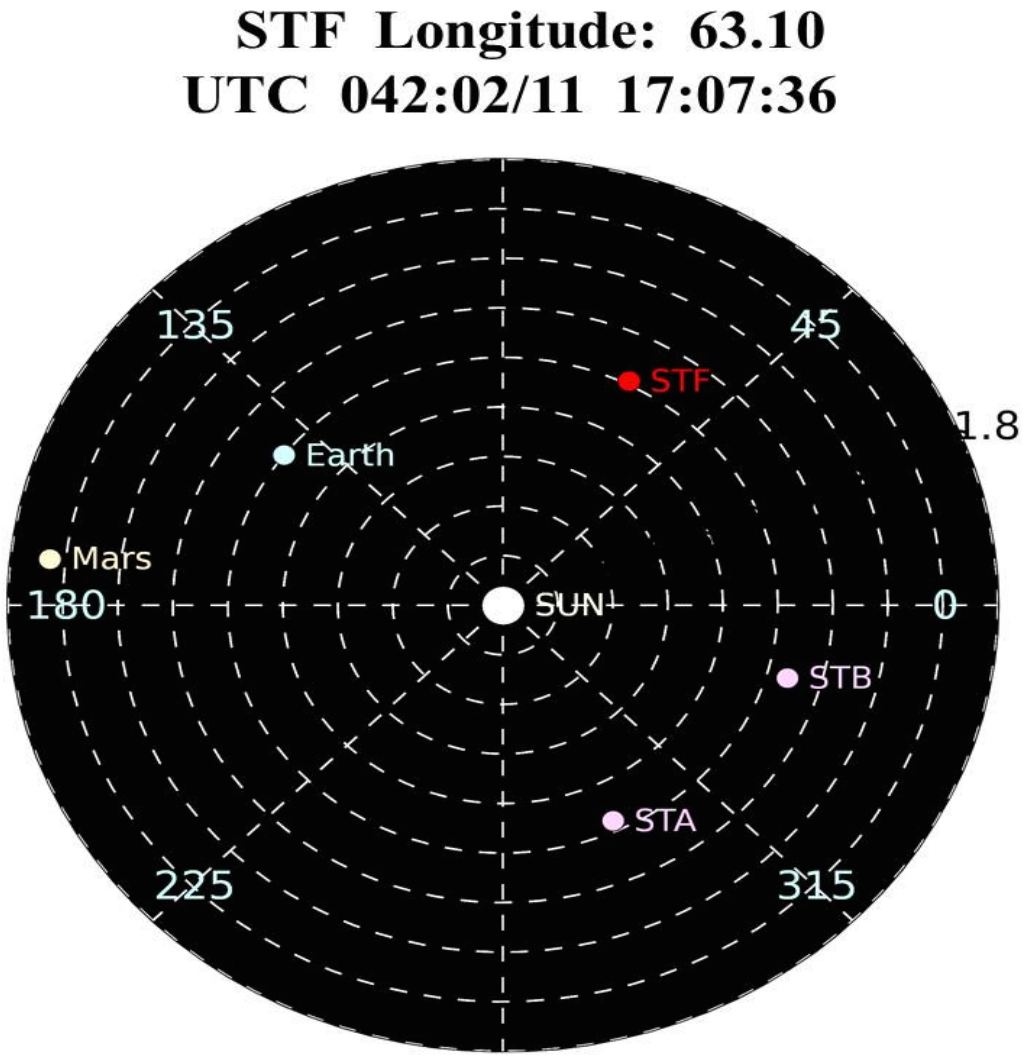
Space Weather Monitor Sources

- **NOAA GOES**
  - *NOAA Alerts (more relevant for near Earth orbit)*
  - *After more than ten years of drifting away from the Earth, Spitzer's distance from Earth is greater than 1 AU, and the GOES satellites no longer serve as a predictive tool for Spitzer engineers*

- **STEREO B**
  - *During Spitzer's prime mission phase, STEREO-B and Spitzer shared the same heliocentric Right Ascension; therefore, STEREO-B provided useful data to support alerts. Used in analysis for Spitzer of potential Space Weather impacts*

- **GSFC SWRC-Space-Weather-Research-Center**
  - *SWRC Alerts*
  - *SWRC Model with Spitzer's coordinates*
  - *SWRC Summary Reports*

Spitzer vs STEREO A/B



Space Weather Events

Subsystems Monitored for Space Weather Impacts

- **Mass Memory Card (MMC) Soft Scrub Errors**

  The EDAC continues to correct for single bit errors due to background radiation. The corrections are summed by the ratio of corrupted bits over time.

- **Power/Solar Array Panel**

  Continuous trending provides performance statics for the output power. All deviations are correlated and disposition.

- **Star Tracker**

  STA component-level fault protection utilizes a series of checks to test the component health. Values are set to monitor counters for fault persistence.

- **Infrared Array Camera (IRAC) Radhits**

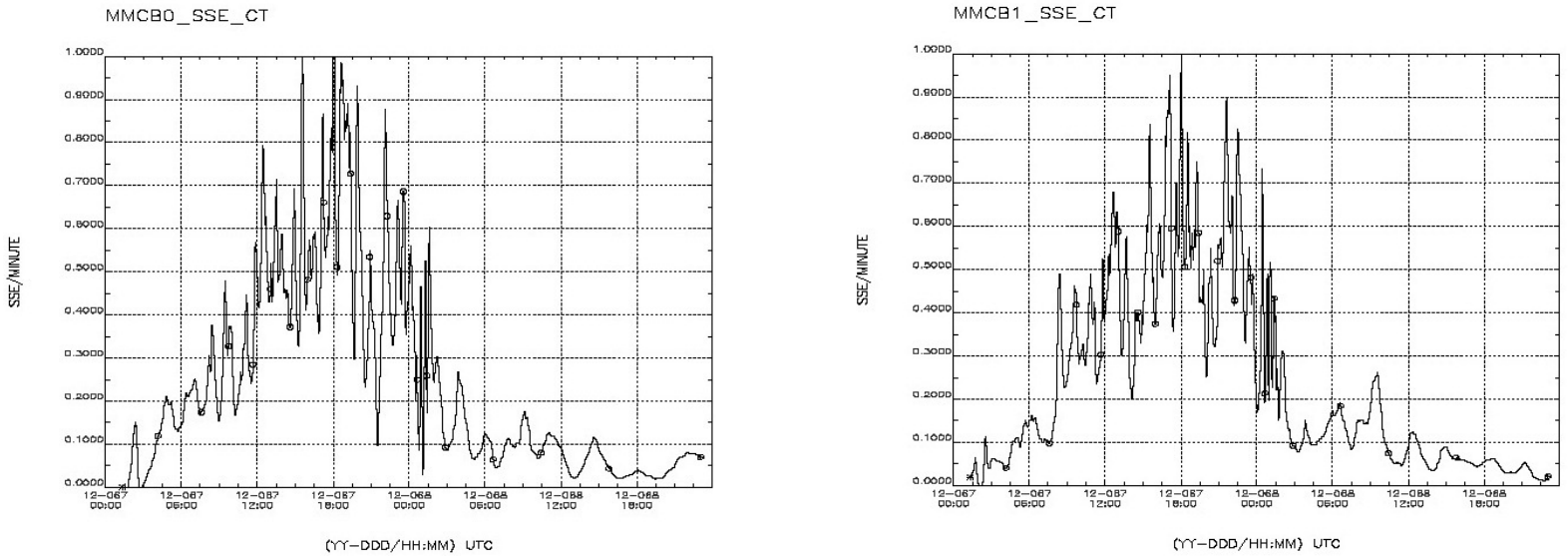
  In the benign space weather environment, based on the instrument exposure time the nominal observed Radhits are 4 per second with very little scatter.

Spitzer's Space Weather Impacts

- **Mass Memory Card (MMC) Soft Scrub Errors**

  The EDAC continues to correct for single bit errors due to background radiation. The corrections are summed by the ratio of corrupted bits over time.

  Increased background "noise" and the rapid changes in soft scrub error rates are indicative of space weather events.

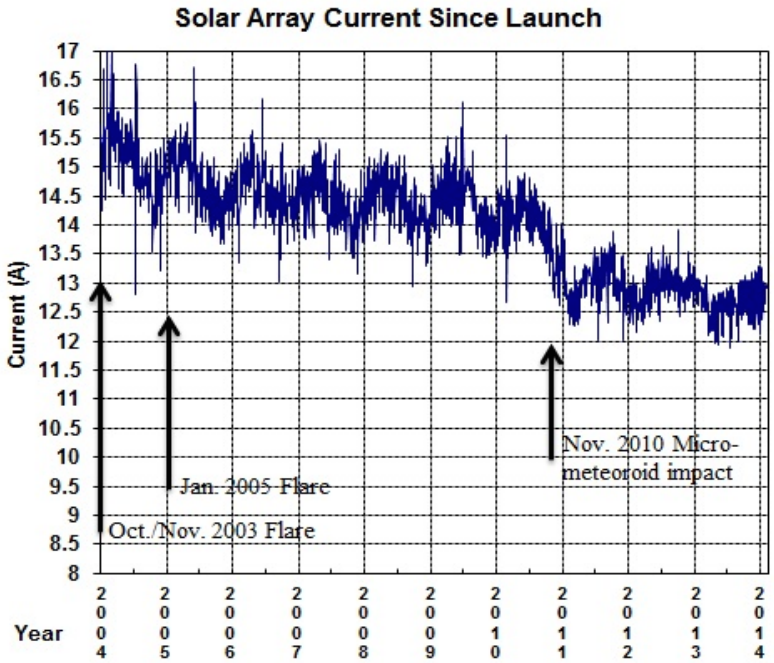


Spitzer MMC Board 0 and Board 1 Soft Scrub Error Counts during March 7-8, 2012 CME Event.

Spitzer's Space Weather Impacts

- **Power/Solar Array Panel**

  Continuous trending provides performance statics for the output power.

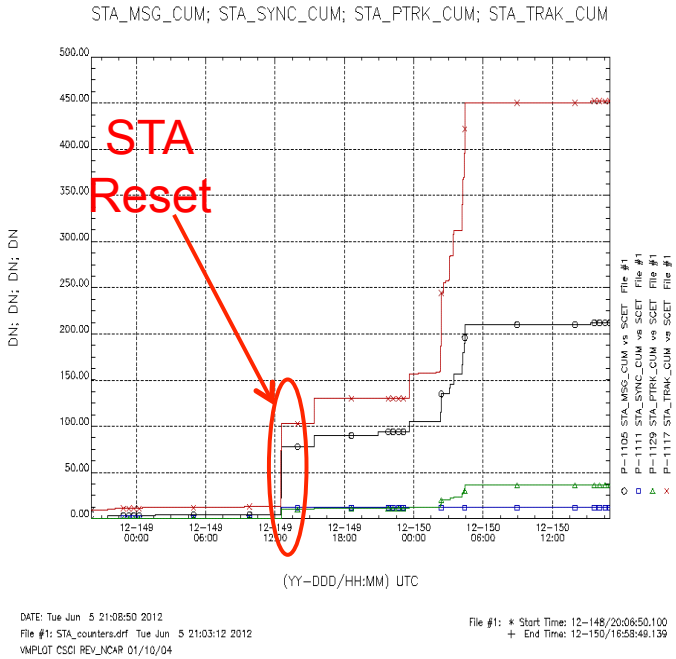


Major solar weather events in October-November 2003 and January 2005 reduced the solar panel assembly output by 4.7% and 2.8%, respectively. In addition, in early November 2010, a micrometeoroid impact damaged one of the solar panel assembly's strings, reducing the total power output by an additional 6.5%. The solar panel still operates well within the power output margin.

Spitzer's Space Weather Impacts

- **Star Tracker**

  STA component-level fault protection utilizes a series of checks to test the component health.

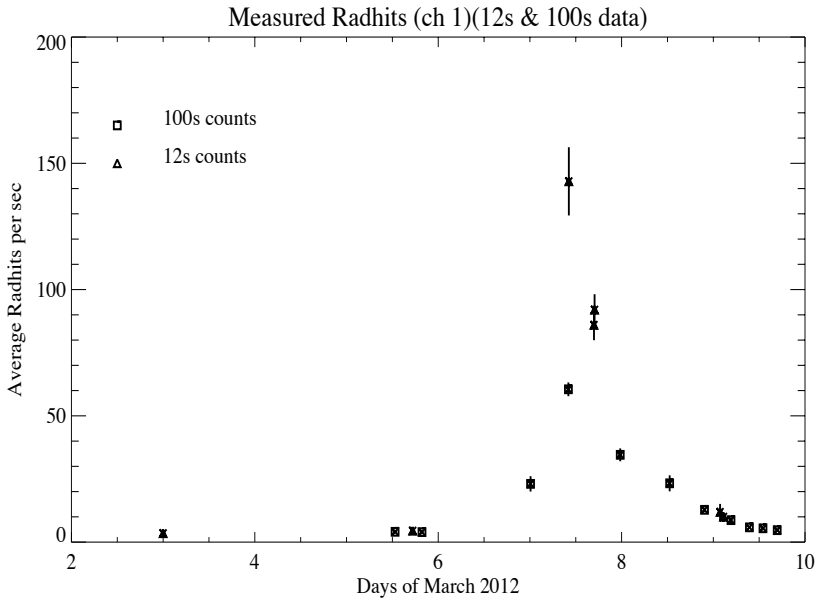


The accumulated and cumulative counts increased resetting the STA. This correlated with the May 2012 space weather event.

Spitzer's Space Weather Impacts

- **Infrared Array Camera (IRAC) Radhits**

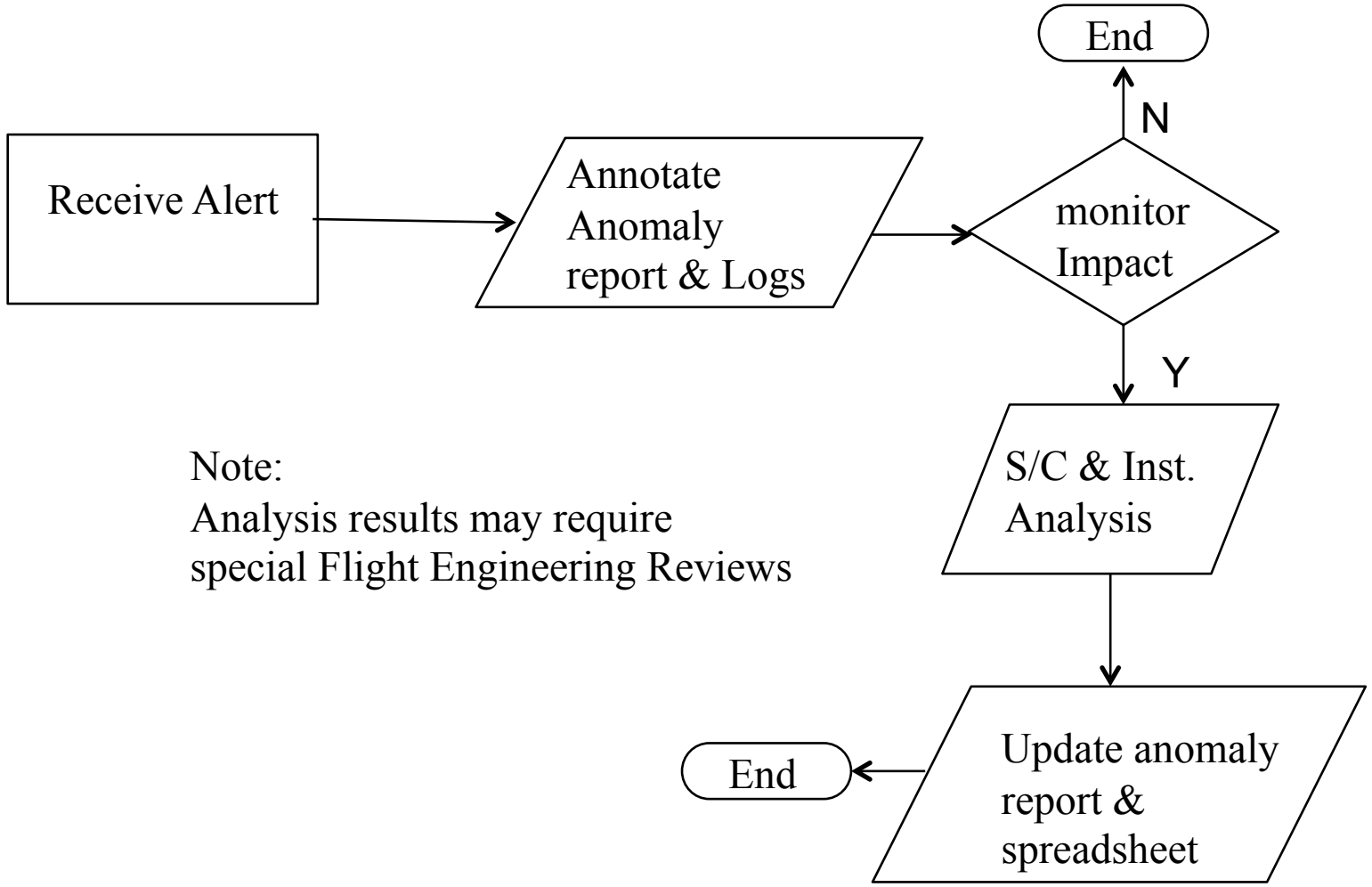
  Based on the instrument exposure time the nominal observed Radhits are 4 per second with very little scatter.



(No functional impact to the Instrument, however Loss of 69.6 hours of Science data for the space weather event on DOY 067/2012).

Operational Space Weather Procedure

Current Space Weather Procedure



Note:
Analysis results may require
special Flight Engineering Reviews

Master Space Weather Summary

Event		Description Section Space Weather Alert Message				Spacecraft Analysis Section				Instrument
Item #	Title	Message	Activity ID	Edge Time	Class	Alarms	MMC Soft Scrub Errors	Star Tracker	Power	IRAC
1	NSE_2012-0215_044	None	N/A	N/A	N/A	No	Board 1	No	No	No
2	SWE_2012-0307_067	ID: #20120307-AL-009	-----	069 / 0837	O	B1-DBE	Board 0 & 1	No	No	Plot (LS)
3	SWE_2012-0327_087	ID: #20120327-AL-003	-----	088 / 1726	O	Yes	Nominal	Printout	No	No
4	SWE_2012-0416_107	ID: #20120416-AL-001	2012-04-16T18:10:00-CME-001	109 / 1523	O	Yes	Nominal	No	S/A Plot	No
5	SWE_2012-0512_133	ID: #20120512-AL-002	2012-05-11T23:54:00-CME-001 2012-05-12T01:54:00-CME-001	135 / 1428	O C	No	Board 0	No	No	No
6	NSE_2012-0517_138	ID: #20120517-AL-004	2012-05-17T:01:48:00-CME-001	150 / 1140	O	Yes	Nominal	No	No	Plot
7	SWE_2012-0527_148	ID: #20120527-AL-003	2012-05-27T:06:24:00-CME-001	150 / 1140	C	Yes	Nominal	Timeline (FI)	No	No
8	SWE_2012-0614_166	ID: #20120614-AL-002	2012-06-14T14:09:00-CME-002	169 / 1704	C	No	Nominal	No	No	No
9	NSE_2012-0624_176	None	N/A	N/A	N/A	No	Board 1	No	No	---
10	SWE_2012-0712_194	ID: #20120712-AL-006	2012-07-12T16:54:00-CME-001	196 / 1356	O	No	Nominal	No	No	---
11	SWE_2012-0728_210	ID: #20120729-AL-001	2012-07-28T21:24:00-CME-001	213 / 1252	C	No	Nominal	No	No	---
12	SWE_2012-0831_244	ID: #20120831-AL-003	2012-08-31T20:36:00-CME-001	246 / 0054	O	No	Nominal	No	No	---
13	NSE_2012-0906_250	None	N/A	N/A	N/A	B1-DBE	Nominal	No	No	No
14	SWE_2012-0924_268	ID: # 20120924-AL-001	2012-09-23T15:12:00-CME-001	270 / 0008	O	No	Nominal	No	No	No
15	SWE_2012-0928_272	ID: # 20120928-AL-001	2012-09-28T02:25:00-CME-001	275 / 0156	O	No	Nominal	Spike	No	No
16	NSE_2012-1017_291	None	N/A	N/A	N/A	B0-DBE	Nominal	No	No	No
17	SWE_2012-1108_313	ID: # 20121108-AL-003	2012-11-08T11:09:00-CME-001	316 / 0012	O	No				
18	SWE_2013-0123_023	ID: # 20130123-AL-001	2013-01-23T14:55:00-CME-001	026 / 1126	C	No	Nominal	No	No	No

Master Space Weather Summary

Event		Description Section Space Weather Alert Message				Spacecraft Analysis Section				Instrument
Item #	Title	Message	Activity ID	Edge Time	Class	Alarms	MMC Soft Scrub Errors	Star Tracker	Power	IRAC
41	SWE_2014-0212_043	ID: #20140209-AL-001	2014-02-09T16:12:00-CME-001	043/ 1044	C	No	Nominal	No	No	No
42	SWE_2014-0221_052	ID: #20140218-AL-001	2014-02-09T01:25:00-CME-001	052 / 0946	C	No	Nominal	No	No	No
43	SWE_2014-0223_054	ID: #20140221-AL-001	2014-02-21T16:00:SS-CME-001	054 / 0824	C	No	Board 0 & 1	No	No	Plot
44										
45										

- LEGEND -
NSE - None Alert Space Weather Event
SWE - Space Weather Alert Event

(FI) - Functional Impact
(LS) - Lost Science .
DBE Double Bit Error .

3 of 3 - KS/JH - 3/31/2014

Spitzer Mission Contribution for Space Weather

Spitzer Mission Contribution

- In 2012, Spitzer was asked by the Mars Science Laboratory (MSL) Mission's Entry Descent and Landing (EDL) team to provide additional analysis into the level of possible solar energetic particle flux between the Sun and Mars
  - *MSL's request was due to Spitzer's position at the time of EDL, which was at an ideal location between the Sun and Mars*

- Space weather forecasts indicated a slow-moving CME advancing towards Spitzer, and heading towards Mars.

- MMC soft scrub error plots indicated no increase for the predicted event. The Spreadsheet data base also documented no reported anomalies on any other Spitzer subsystems.

- The Spitzer Space Telescope was designed without dedicated space weather radiation detectors.
  - *Its ability to help a NASA flagship mission, like MSL, in monitoring space weather was never envisioned by Spitzer's designers.*

Summary

Summary

•The Spacecraft continues to recede from Earth at about 0.1 AU/yr., we constantly re-evaluate the contingency plan and use other data to augment GSFC-SWRC, GOES and STEREO data.

- Spacecraft or IRAC instrument parameters may be used to assess space weather events.

•The Space Weather Analysis training and ISWA tool tutorial provided by the SWRC for the user community, has proven to be beneficial to Flight Projects.

•Can Alert notification be provided in a standard template?

- This could support user community tools (scripts or applications)

•An online subscription tool for the alert notification would streamline the process.

Acknowledgement

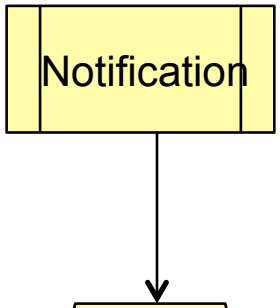
Thanks to Goddard's SWRC for its continued services which have provided outstanding support to the interplanetary user community.

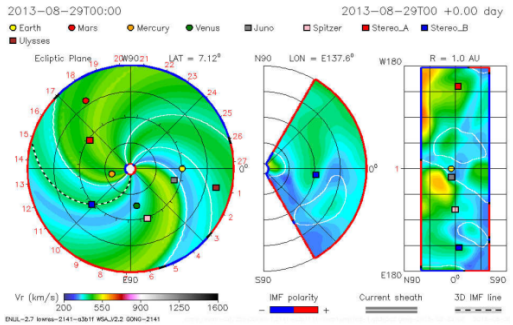
A large number of people from the Spitzer project, support organizations at the Jet Propulsion Laboratory, Lockheed Martin Space System Company, and the Spitzer Science Center at the California Institute of Technology contributed to the operations described herein.

Special Thanks:
Kennis Stowers – JPL
Patrick Lowrance – SSC
Andrzej Stewart – LMSSC
Paul Travis - LMSSC

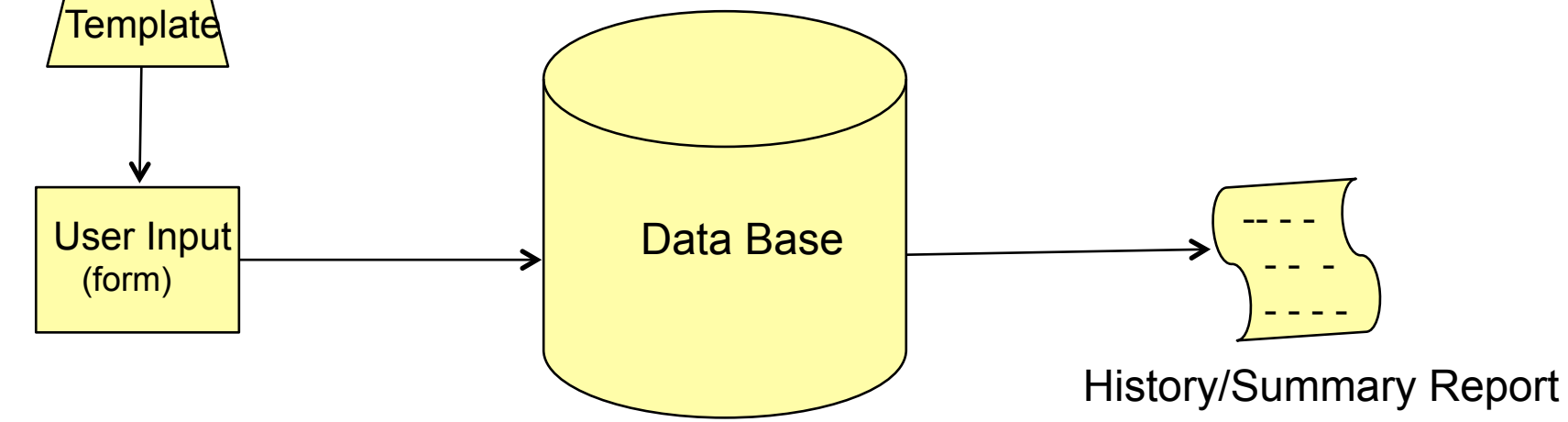
Back-up Material

Fill In Template





Event (Activity ID)	Missions STB	STA	Spitzer	Juno	….
1. 2013-08-10T02:48:00-CME-001					
2. 2013-08-20T02:48:00-CME-002					
3. 2013-08-30T02:48:00-CME-001					
n. 2013-09-30T02:48:00-CME-001					



Event Summary Request

- GSFC-SWRC Pre populated Template (all times in UTC)
  - *Message ID: ?? - AL- ??*
  - *Activity ID: (e.g., CME, SEP)*
  - *Type: (O, M, etc.)*
  - *Object: (S/C, Planet, etc.)*
  - *Time of Impact:*
    - Predicted: (Supplied by Model)
    - Actual: (Filled in by user)
    - ++
- Observed Effects: (User supplied by selected devices - all times in UTC)
  - *Spacecraft*
  - *Instrument*
  - *Attachments (e.g., graph, plot or table)*

MASTER ISA FORMAT

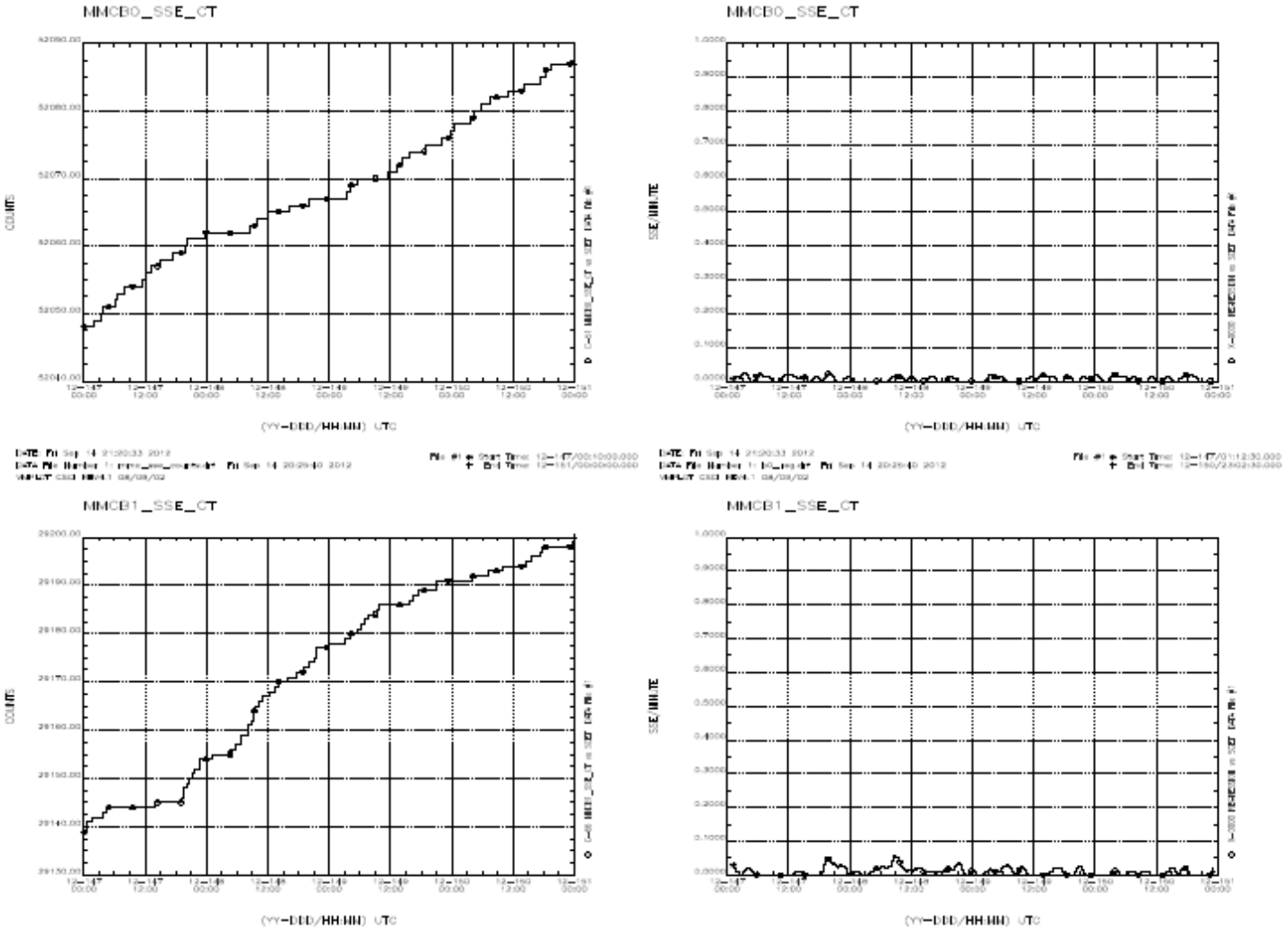
- **ISA #51348 Master Incident Surprise Anomaly (ISA) report for space weather related events.**
  - *Two types of entries*
    - Events with a weather alert message
    - Events without an alert message.

- **Event label format is "(Item Number) SWE_yyyy-mmdd_DOY“ or "(Item Number) NSE_yyyy-mmdd_DOY“**
  - *Item Number is a three digit number beginning 01 in parentheses.*
  - *SWE is short for Space Weather Alert Event*
  - *NSE is short for Non Alert Space Weather Event*
  - *yyyy is the year of the weather alert message*
  - *mmdd is the month and day of the weather alert message*
  - *DOY is the Day of Year for the weather alert message.*

- **The "Description of Incident" contains the alert message information with all data analysis information documented in the "Analysis and Impact" section.**

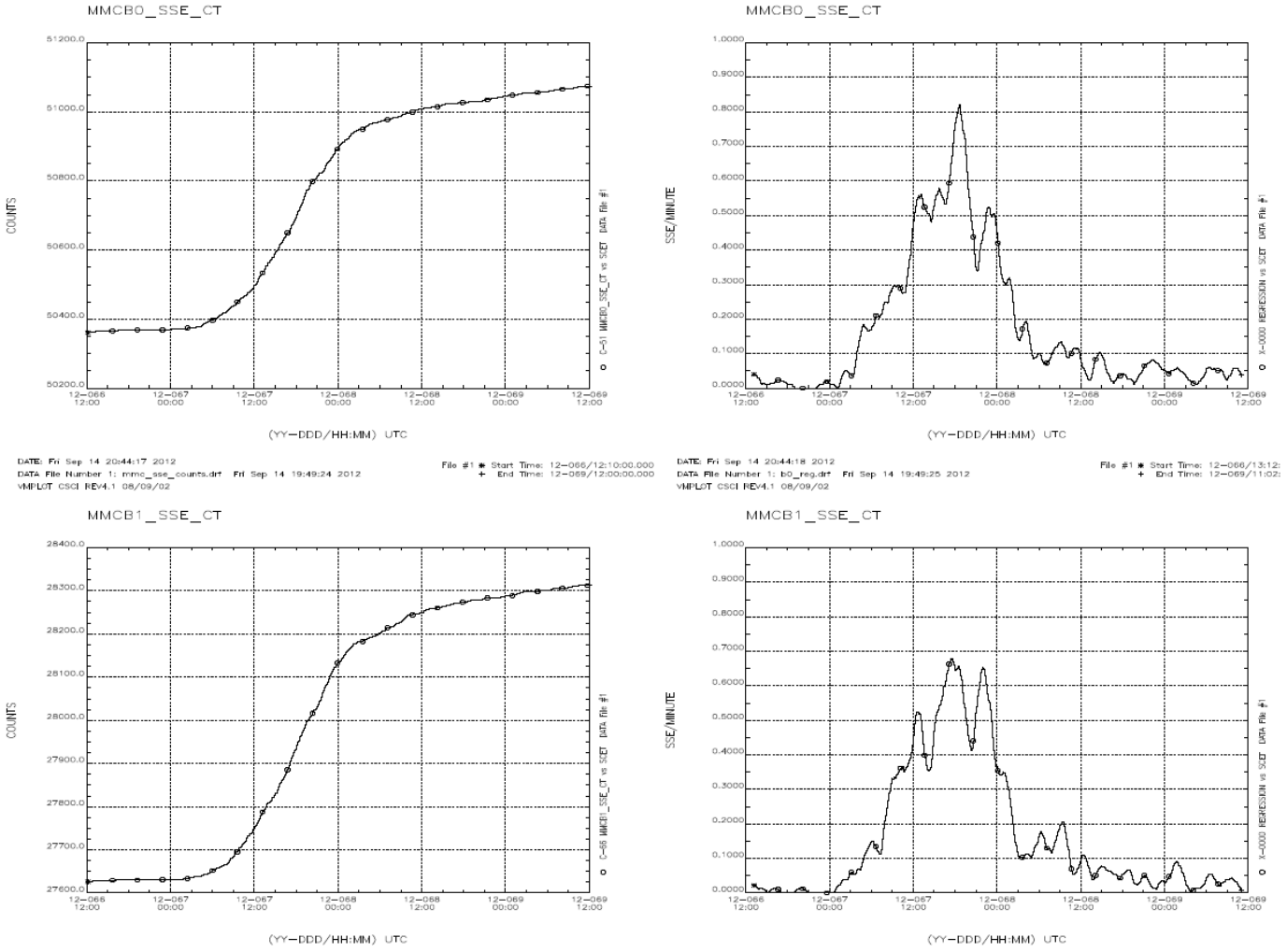
MMC Soft Scrub Errors

EI-006 SWE_2012-0527_148



MMC Soft Scrub Errors

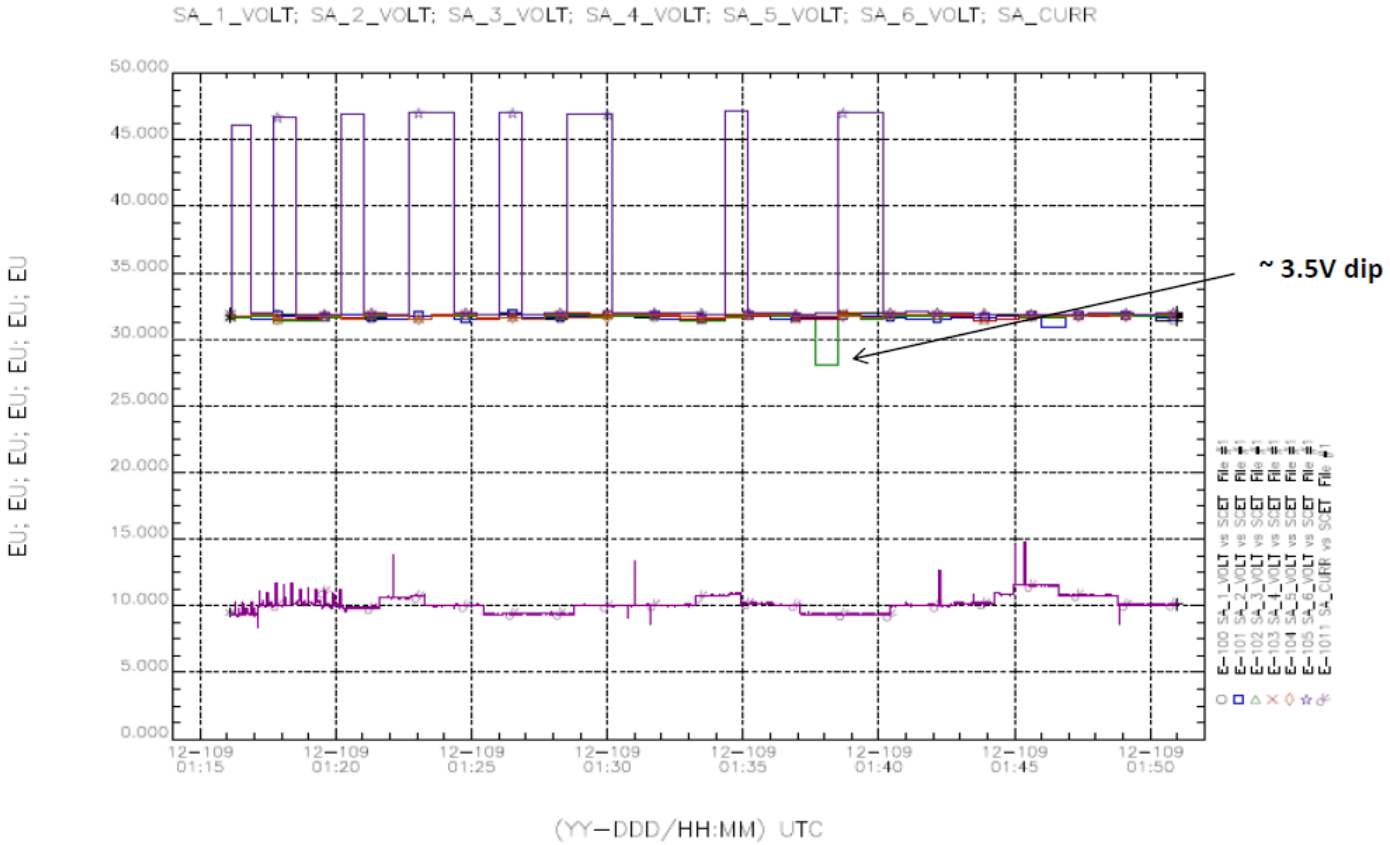
EI-002 SWE_2012-0307_067

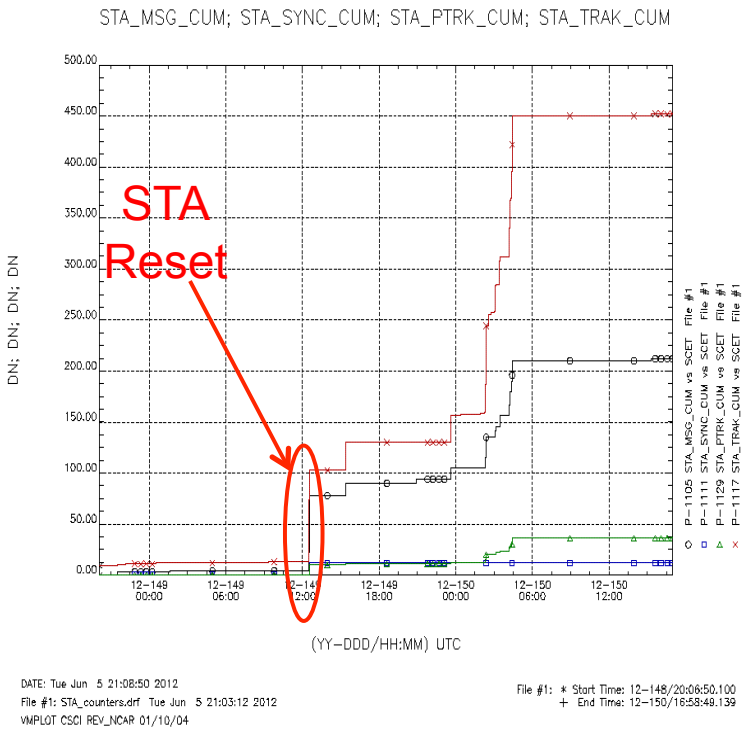


EI-004 SWE_2012-0416_106

S/A Voltage 1-6 DOY 109

- S/A String 3 Voltage E-0102 Measurement @ 12-109-01:47





Event Time: 12/149-12:30:56
Yaw (deg): -165.12
Pitch (deg): 27.42
Description: Ops Mode dropped from Windowed Track to Acquisition, then to Unknown, and then stepped back up through Acquisition, Full Field Track, and back to Windowed Track. Skipped Sync Strobe beats. Reset Indicator and Command Status indicate that a reboot occurred.

Modes:

12/149-12:30:56	Acquisition
12/149-12:31:50	Unknown
12/149-12:31:56	Standby
12/149-12:32:06	Acquisition
12/149-12:32:12	Full Field Track
12/149-12:32:17	Windowed Track

Accumulated and Cumulative Counts:

STA_MSG	74	78
STA_SYNC	12	12
STA_PTRK	10	10
STA_TRAK	90	103

Event Time: 12/149-15:24:44
Yaw (deg): -165.75
Pitch (deg): 27.38
Description: Ops Mode dropped from Windowed Track to Acquisition, and then stepped back up through Full Field Track and back to Windowed Track.

Modes:

12/149-15:24:44	Acquisition
12/149-15:24:58	Full Field Track
12/149-15:25:03	Windowed Track

Accumulated and Cumulative Counts:

STA_MSG	12	90
STA_PTRK	1	11
STA_TRAK	27	130

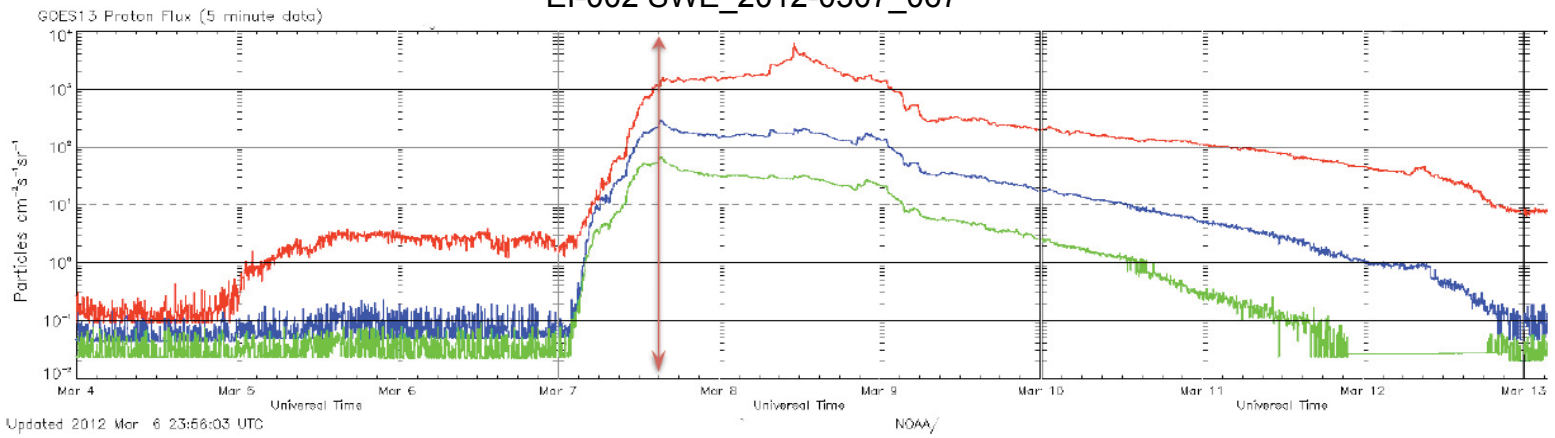
Event Time: 12/149-20:55:30
Yaw (deg): -75.10
Pitch (deg): 27.69
Description: Skipped Sync Strobe pulses, Faintest Star Magnitudes dropped to zero.

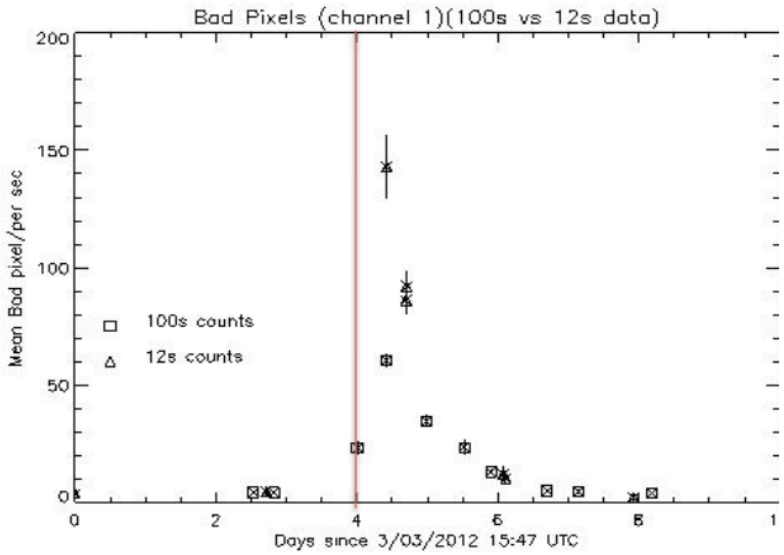
Accumulated and Cumulative Counts:

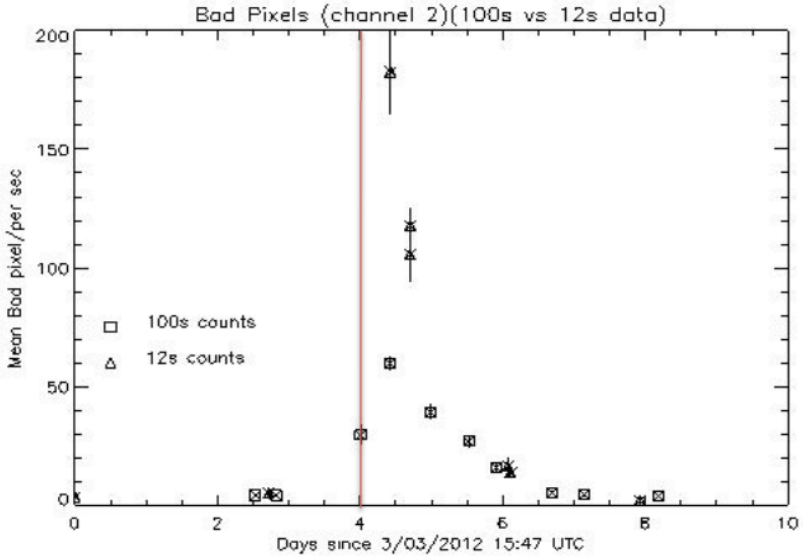
STA_MSG	4	94

IRAC Instrument Radhits

EI-002 SWE_2012-0307_067







10 Years Science Utilization Statistics

- **Currently for Spitzer: Unique PIs: 859, **Non-unique** CoIs: 11,512**
- **Count of Science Program AORs executed thru 26 Aug 2013: 82,915 AORs**
- **Science Time executed thru 26 Aug 2013: 67,900 hours**
- **Science time lost, all causes: 53 days (49 days Cryo mission, 4 days Warm mission)**
    - **equals 1.5% of the science time available over 10 years**

Public affairs statistics:

- **As of 8/22/2013, there have been 432 press releases/web news features posted on the Spitzer website over the course of the mission. Of these, 182 were NASA-led press releases.**
- **On the Spitzer website (spitzer.caltech.edu), in 2012 for example, we had, on average each month:**
    - **146,000 unique visitors**
    - **660,000 visits**
    - **2.3 million pages viewed**
    - **4000 GB of data (images, videos, etc) downloaded from the site**

Publication Statistics:

- **Over 5000 papers in the Spitzer bibliographical data base, which includes only refereed publications, as opposed to conference presentations or posters. That is more than one per day, given our 3650 day life time.**