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

Seventh NASA Space Weather and Robotic Mission Operations Workshop

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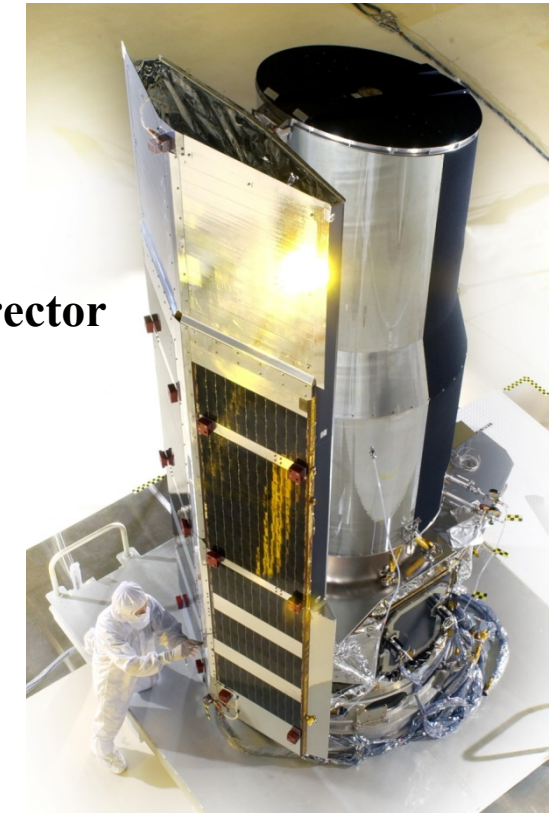


Agenda

- **Mission Overview**
- **Subsystems Monitored for Space Weather Impacts**
- **Operational Space Weather Process**
- **Summary of Key Events**
- **Summary**

Mission Overview

Spitzer Space Telescope

Salient Features

- *Heliocentric orbit trailing the Earth,* (1.383 AU)
- *85 cm Beryllium telescope operating at 26K*
- *2 arrays with 3-5 micron wavelength coverage operating at ~28.7K*
- *Launch date: August 25, 2003, Spitzer warm mission began July 27, 2009*
- August 2015 Spitzer completed 12 years of Science Operations.
- *Observing time avail. to general community: 100%*

Stellar Sparklers That Last

NGC 1333 is a star cluster populated with many young stars that are less than 2 million years old. Data from Chandra and Spitzer show X-ray brightness mainly depends on the size of the star. In other words, the bigger the stellar sparkler, the brighter it will glow in X-rays.

Science

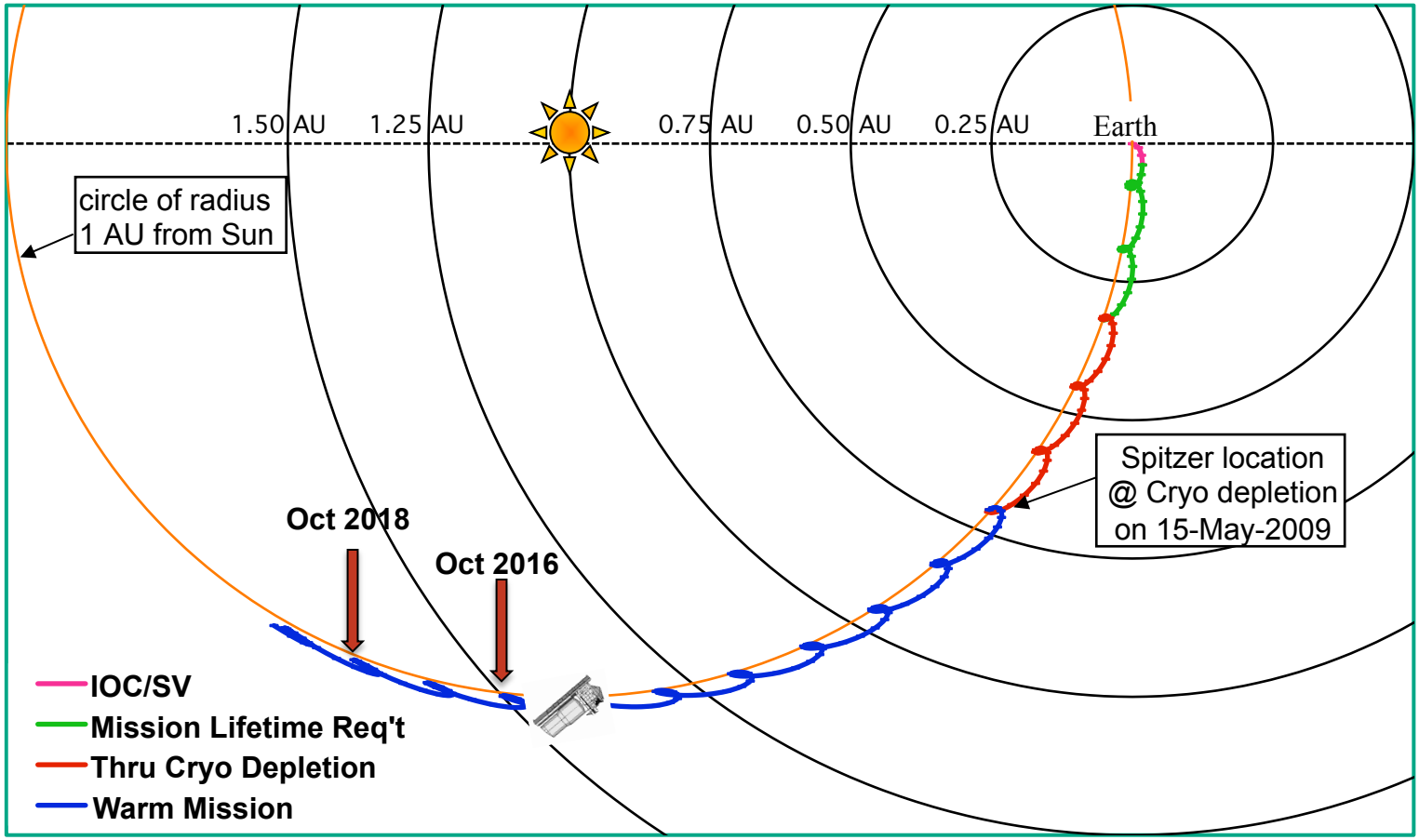
- *To study the properties of extrasolar planets and search for super-earths around nearby solar-type stars*
- *To study galaxies as they were when the Universe was less than 1 Gyr old, and to understand how galaxies and clusters of galaxies have evolved with cosmic time.*
- *To complete the census of the Galaxy for young stars, star forming regions and dusty post-main sequence stars, and search for new classes of brown dwarfs and super-planets.*
- *To determine the cosmic distance scale in the local Universe with unprecedented precision by the first systematic application of mid-infrared observations to this critical problem.*

08.20.15 **Colorful Calendar Celebrates 12th Anniversary of NASA's Spitzer**

http://www.spitzer.caltech.edu/news/1796-feature15-10-Colorful-Calendar-Celebrates-12th-Anniversary-of-NASA-s-Spitzer

Spitzer Orbit

Geometry drives operational challenges



Spitzer follows the Earth around the Sun. Its orbit is slightly more elliptical than the Earth's and it slowly recedes from Earth at about 0.1 AU/yr.

Ground Segment Requirement

Warm Mission Science Phase

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

Launch and Cryo Science Mission Phase

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

- 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.*

Space Weather Monitor Sources

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

- **NOAA GOES**
  - *After more than twelve years of drifting away from the Earth, Spitzer's distance from Earth is ~1.38 AU, and the GOES satellites no longer serve as a predictive tool for the S/C however, may provide ground transmission possible impacts.*

- **STEREO A/B**
  - *During Spitzer's prime mission phase, STEREO-B and Spitzer shared the same heliocentric Right Ascension ,no longer applicable. STEREO-A is approaching in right Ascension and could provided useful data to support alerts.*

- **SPITZER**
  - *Power Subsystem, Star Tracker, Mass Memory Card and IRAC instrument have proven to exhibit behavior that directly correlates to space weather events.*

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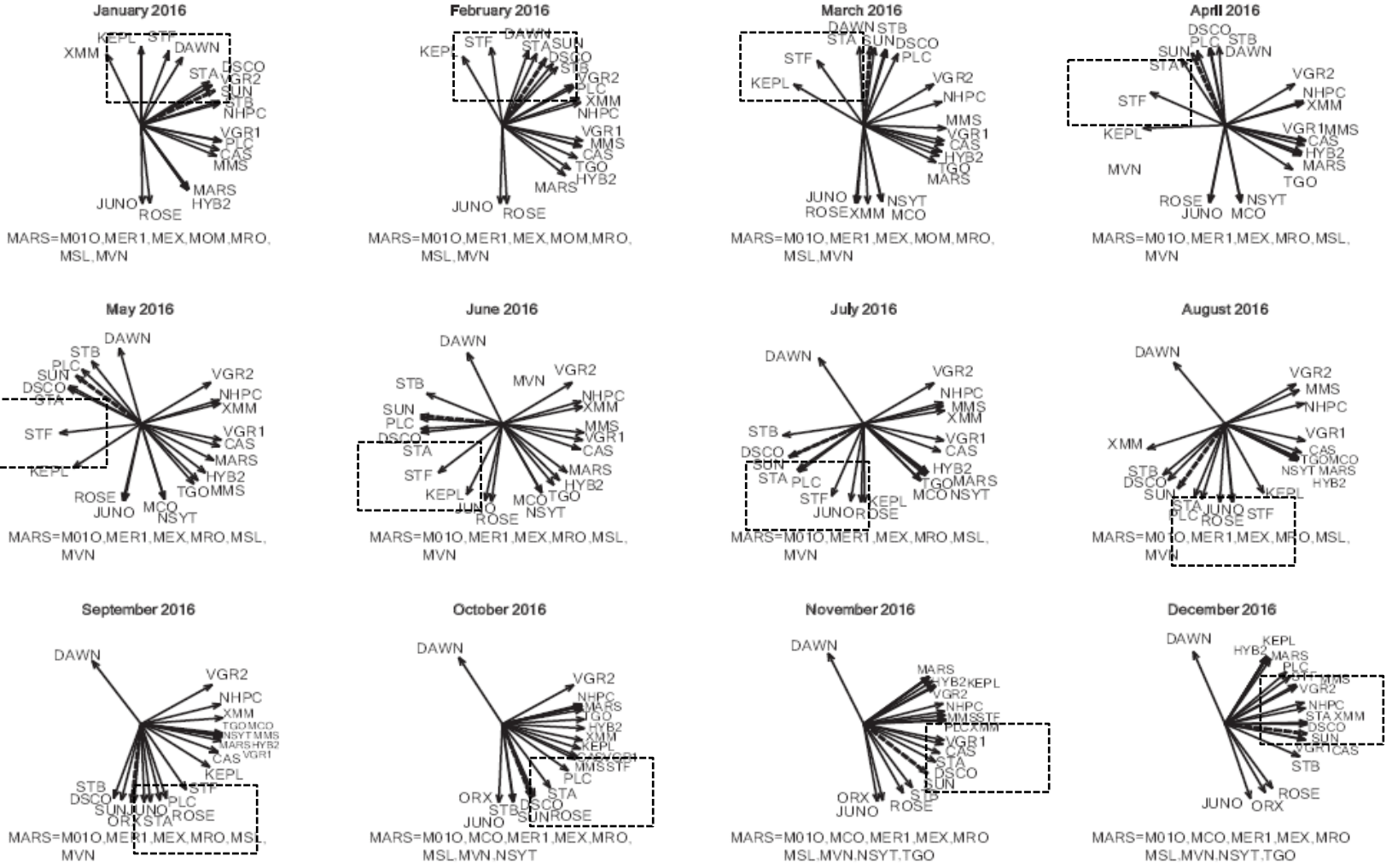
Spacecraft Right Ascension 2016



As of June 2015

The spacecraft right ascension figures show the positions of the spacecraft in the sky relative to each other on the 15th of each month for the year indicated. Right ascension is commonly measured in hours, with 1 hour = 15 degrees. The arrow indicates the center of a spacecraft view from earth. Extend 60 degrees on both sides of the arrow to calculate an eight (8) hour view period.

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**

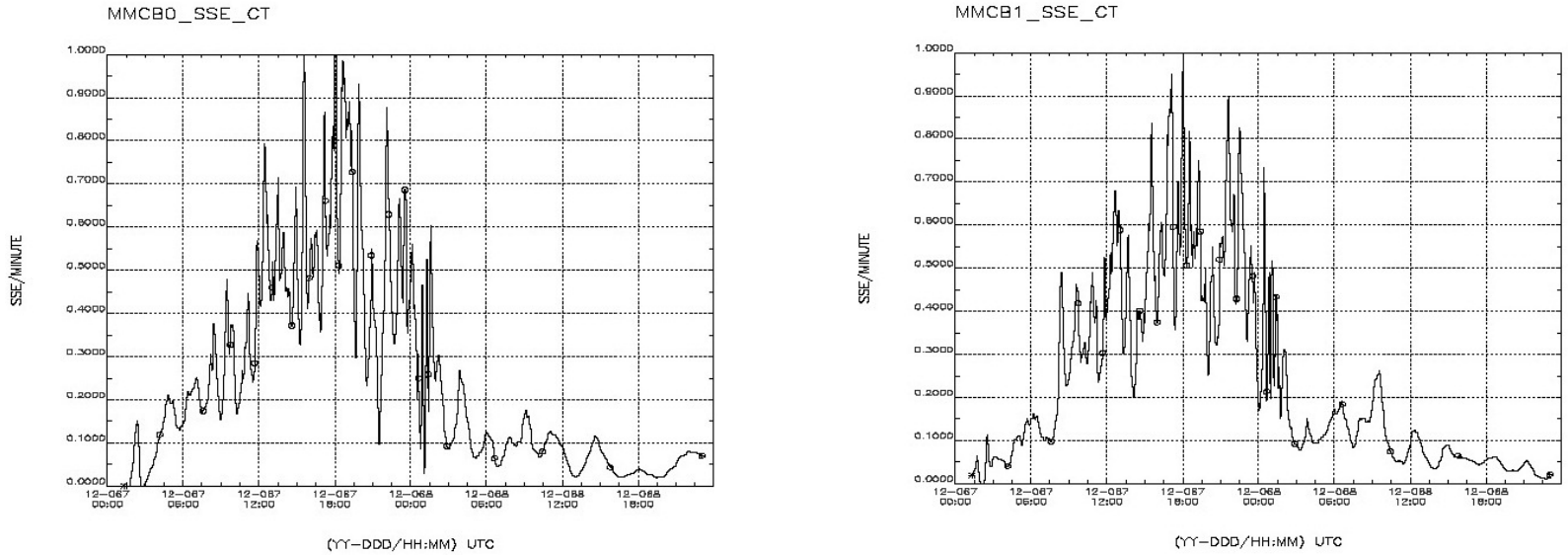
  In the benign space weather environment, based on the instrument exposure time the nominal observed Radhits are 4 per second with very little scatter.

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.

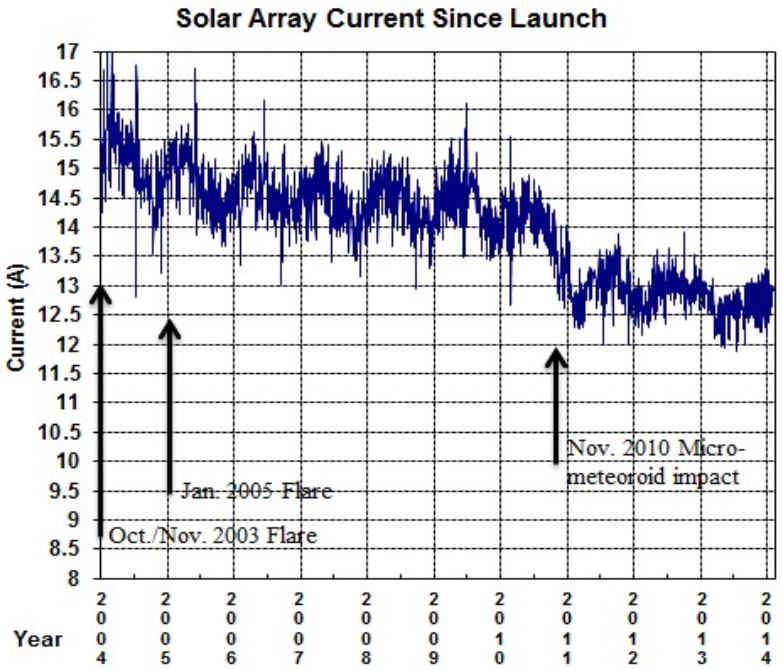


Spitzer MMC Board 0 and Board 1 Soft Scrub Error Counts during March 7-8, 2012 CME Event.

Spitzer's Space Weather Impacts

- **Power/Solar Array Panel**

  Continuous trending provides performance statics for the output power.

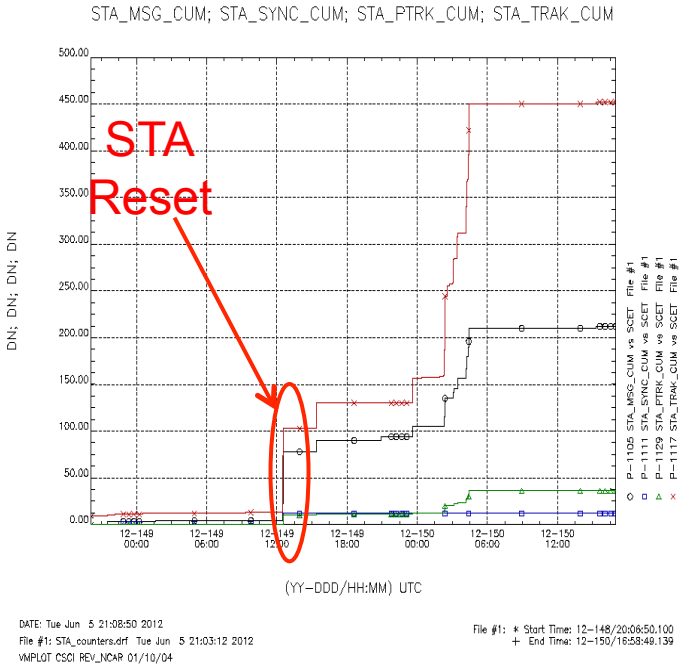


Major solar weather events in October-November 2003 and January 2005 reduced the solar panel assembly output by 4.7% and 2.8%, respectively. In addition, in early November 2010, a micrometeoroid impact damaged one of the solar panel assembly's strings, reducing the total power output by an additional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

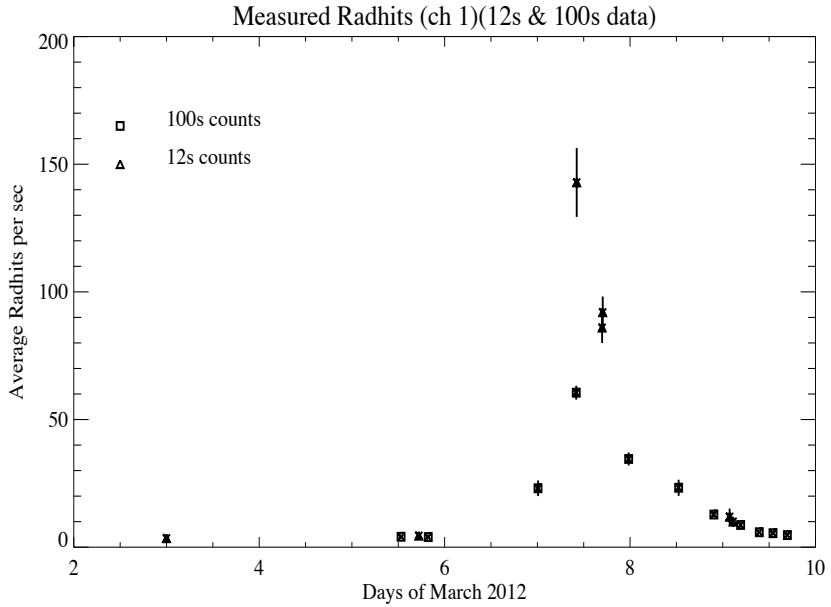


The accumulated and cumulative counts increased resetting the STA. This correlated with the May 2012 space weather event.

Spitzer's Space Weather Impacts

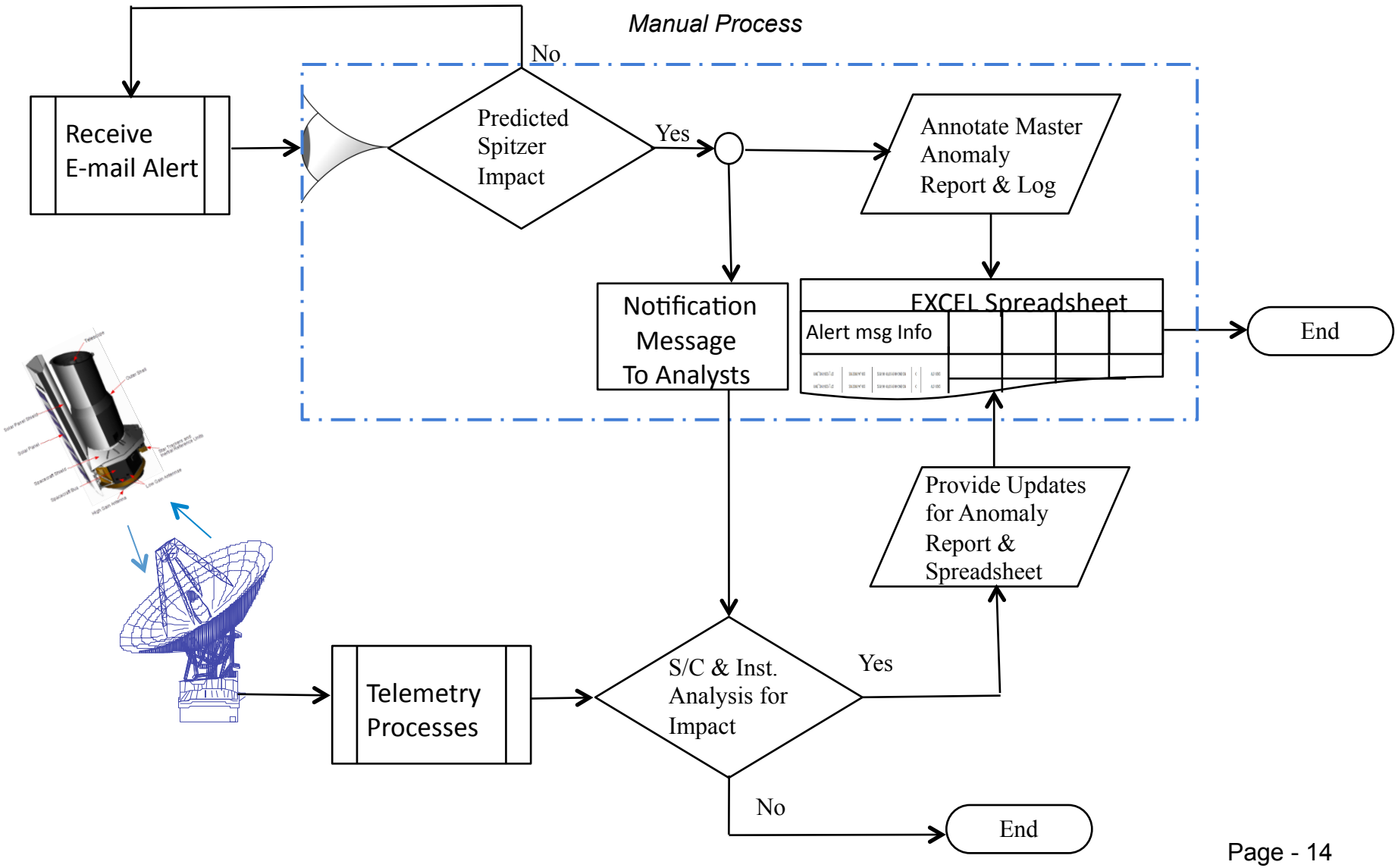
- **Infrared Array Camera (IRAC) Radhits**

  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).

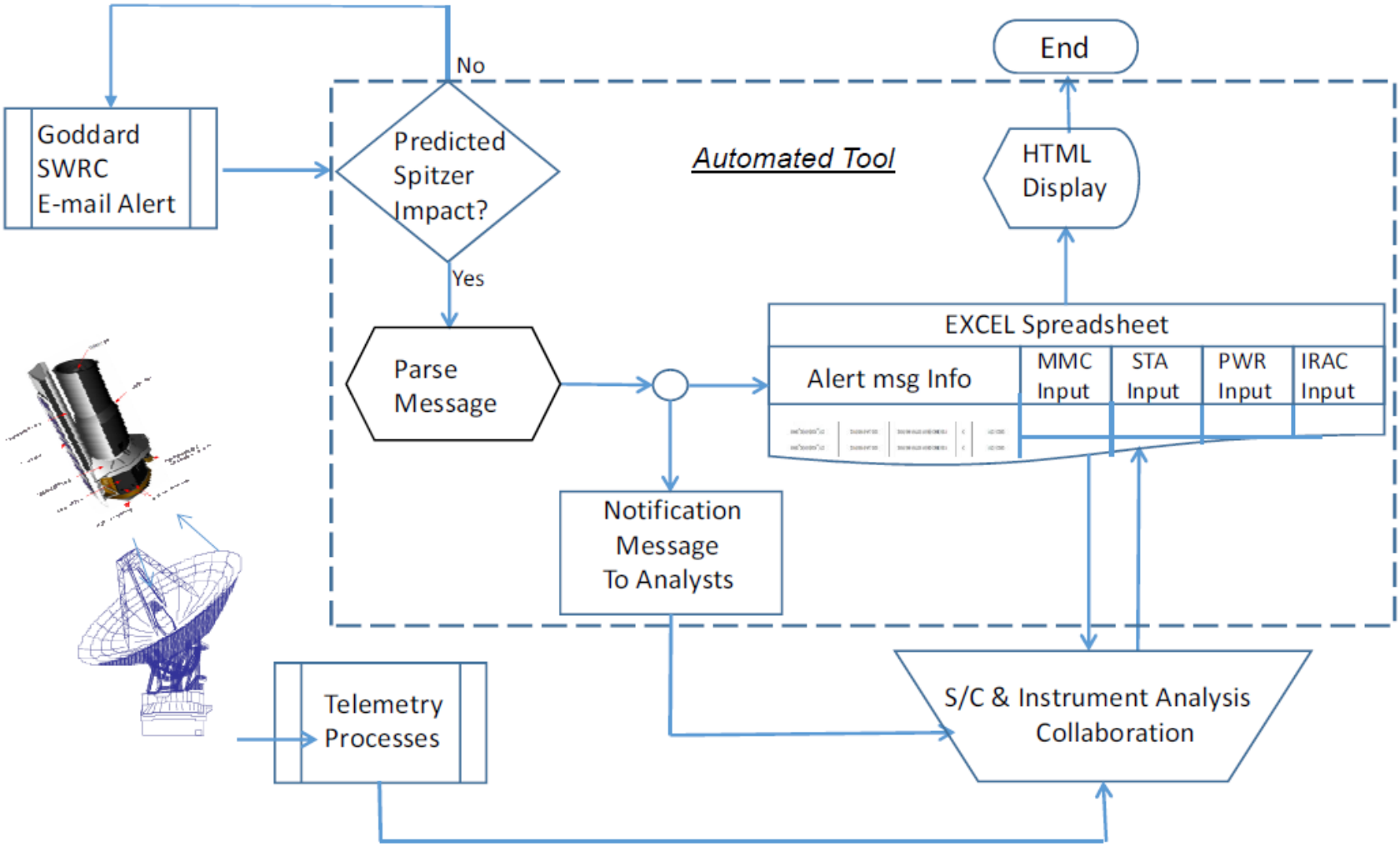
Spitzer Space Weather Process



Master Space Weather Summary

Event		Description Section Space Weather Alert Message				Spacecraft Analysis Section				Instrument
Item #	Title	Message ID	Activity ID	Class	Edge Time	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	20120307-AL-009	-----	O	069 / 0837	B1-DBE	Board 0 & 1	No	No	Plot (LS)
3	SWE_2012-0327_087	20120327-AL-003	-----	O	088 / 1726	Yes	Nominal	Printout	No	No
4	SWE_2012-0416_107	20120416-AL-001	2012-04-16T18:10:00-CME-001	O	109 / 1523	Yes	Nominal	No	S/A Plot	No
5	SWE_2012-0512_133	20120512-AL-002	2012-05-11T23:54:00-CME-001 2012-05-12T01:54:00-CME-001	O C	135 / 1428	No	Board 0	No	No	No
6	NSE_2012-0517_138	20120517-AL-004	2012-05-17T:01:48:00-CME-001	O	150 / 1140	Yes	Nominal	No	No	Plot
7	SWE_2012-0527_148	20120527-AL-003	2012-05-27T:06:24:00-CME-001	C	150 / 1140	Yes	Nominal	Timeline (FI)	No	No
8	SWE_2012-0614_166	20120614-AL-002	2012-06-14T14:09:00-CME-002	C	169 / 1704	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	20120712-AL-006	2012-07-12T16:54:00-CME-001	O	196 / 1356	No	Nominal	No	No	---
11	SWE_2012-0728_210	20120729-AL-001	2012-07-28T21:24:00-CME-001	C	213 / 1252	No	Nominal	No	No	---
12	SWE_2012-0831_244	20120831-AL-003	2012-08-31T20:36:00-CME-001	O	246 / 0054	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	20120924-AL-001	2012-09-23T15:12:00-CME-001	O	270 / 0008	No	Nominal	No	No	No
15	SWE_2012-0928_272	20120928-AL-001	2012-09-28T02:25:00-CME-001	O	275 / 0156	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	20121108-AL-003	2012-11-08T11:09:00-CME-001	O	316 / 0012	No				
18	SWE_2013-0123_023	20130123-AL-001	2013-01-23T14:55:00-CME-001	C	026 / 1126	No	Nominal	No	No	No
19	NSE_2013-0210_041	None	N/A	N/A	041 /0000	No	IDIO	drop Acq	No	Yes
20	SWE_2013-0305_064	20130305-AL-002	2013-03-05T04:24:00-CME-001	O	065 / 1126	No	Nominal	No	No	No
21	SWE_2013-0313_072	20130313-AL-001	2013-0313T00:36:00-CME-001	C	074 / 1806	No	Nominal	No	No	No

Space Weather Process - Automated



Collaborative HTML Page

Item	Title	Message	Activity ID	Class	Edge Time	Alarms	MMC Soft Scrub Errors	Star Tracker	Power	IRAC
1	SWE_2015-08-10_ 222	20150808-AL-001	2015-08-08T00:24:00-CME-001	C	222 / 1442	No				
2	SWE_2015_0623_174	20150621-AL-004	2015-06-21T02:48:00-CME-001	C	174 / 1120	No	Nominal	No	No	No
3	SWE_2015-0621_172	20150619-AL-002	2015-06-18T03:18:00-CME-001	C	172 / 0202	No	Nominal	No	No	No
4			2015-06-18T17:24:00-CME-001	O						
5	SWE_2015-0511_131	20150509-AL-001	2015-05-09T01:36:00-CME-001	C	131 / 2049	No	Nominal	No	No	No
6			2015-05-09T09:12:00-CME-001	C						
7	SWE_2015_0506_126	20150503-AL-001	2015-05-04T04:00:00-CME-001	C	126 / 2056	No	Nominal	No	No	No
8			2015-05-02T21:12:00-CME-001	S						
9			2015-05-03T01:25:00-CME-001	S						
10			2015-05-02T21:36:00-CME-001	S						
11	SWE_2015-0504_124	20150502-AL-001	2015-05-01T18:12:00-CME-001	C	124 / 1643	No	Nominal	No	No	No
12			2015-05-01T19:24:00-CME-001	C						
13	SWE_2015_0423_113	20150421-AL-001	2015-04-21T10:36:00-CME-001	O	113 / 0128	No	Nominal	No	No	No
14	SWE_2015_0401_091	20150330-AL-001	2015-03-29T18:36:00-CME-001	C	091 / 2135	No	Nominal	No	No	No
15	SWE_2015-0311_070	20150310-AL-005	2015-03-10T00:00:00-CME-001	O	070 / 2205	No	Nominal	No	No	No

Summary of Key Events to Date

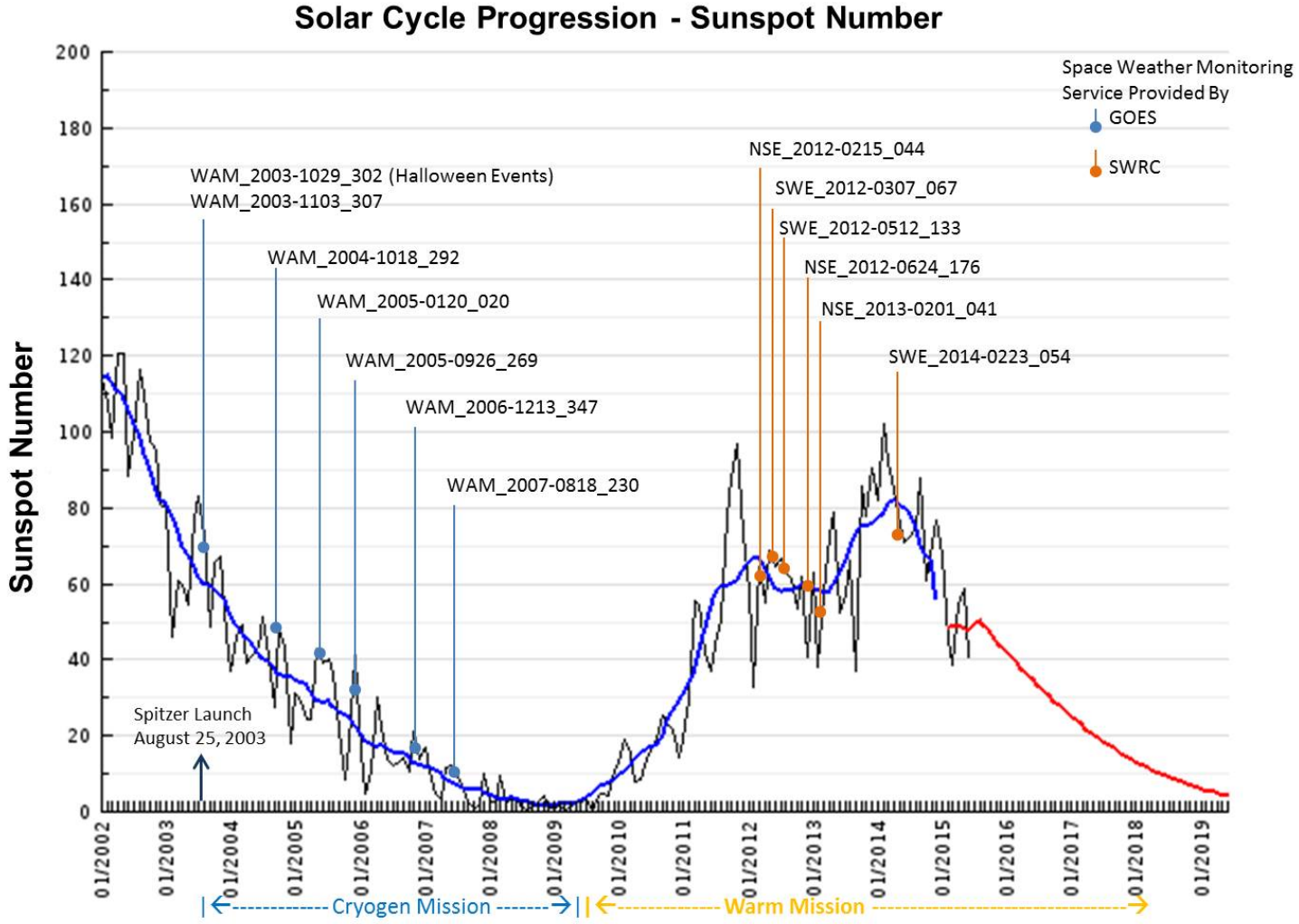


Table of Key Events

INPUT	IMPACT RESULTS			
Title	MMC	Star Tracker	Power	IRAC
WAM_2003-1029_302	Board 0 & 1 SSE	Noise + WASS Errs	SA pwr degraded	Increased Noise
WAM_2003-1103_307	Board 0 & 1 SSE	Noise + WASS Errs	SA pwr degraded	Commanded Off
WAM_2004-1018_292	Board 0 & 1 SSE	No	No	No
WAM_2005-1020_020	Board 0 & 1 SSE	No	No (CTA temp inc)	(IRS – Inc. Noise)
WAM_2005-0926_269	Board 0 & 1 SSE	No	No	No
WAM_2006-1213_347	Board 0 & 1 SSE	No	No (CTA temp inc)	Commanded Off
WAM_2007-0818_230	Board 1 SSE	No	No	No
NSE_2012-0215_044	Board 1 SSE	No	No	No
SWE_2012-0307_067	Board 0 & 1 SSE	No	No	Lost Science Data
SWE_2012-0512_133	Board 0 SSE	No	No	No
NSE_2012-0624_176	No	No	No	Increased Noise
NSE_2013-0201_041	Masked by IDIO	Dropped Acq	No	Increased Noise
SWE_2014-0223_054	Board 0 & 1 SSE	No	No	Increased Noise

Summary

- Can alert messages be tailored to threshold levels for customers

- Online helpdesk support template
  - Customer request feedback for particular event times based on orbit location

- Collaboration of user community for space weather events via “DONKI”
  - How do we manage NASA’s missions proprietary data

Acknowledgement

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

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