The World's Forum for Aerospace Leadership

Investigating Space Weather Events Impacting Spitzer Space Telescope

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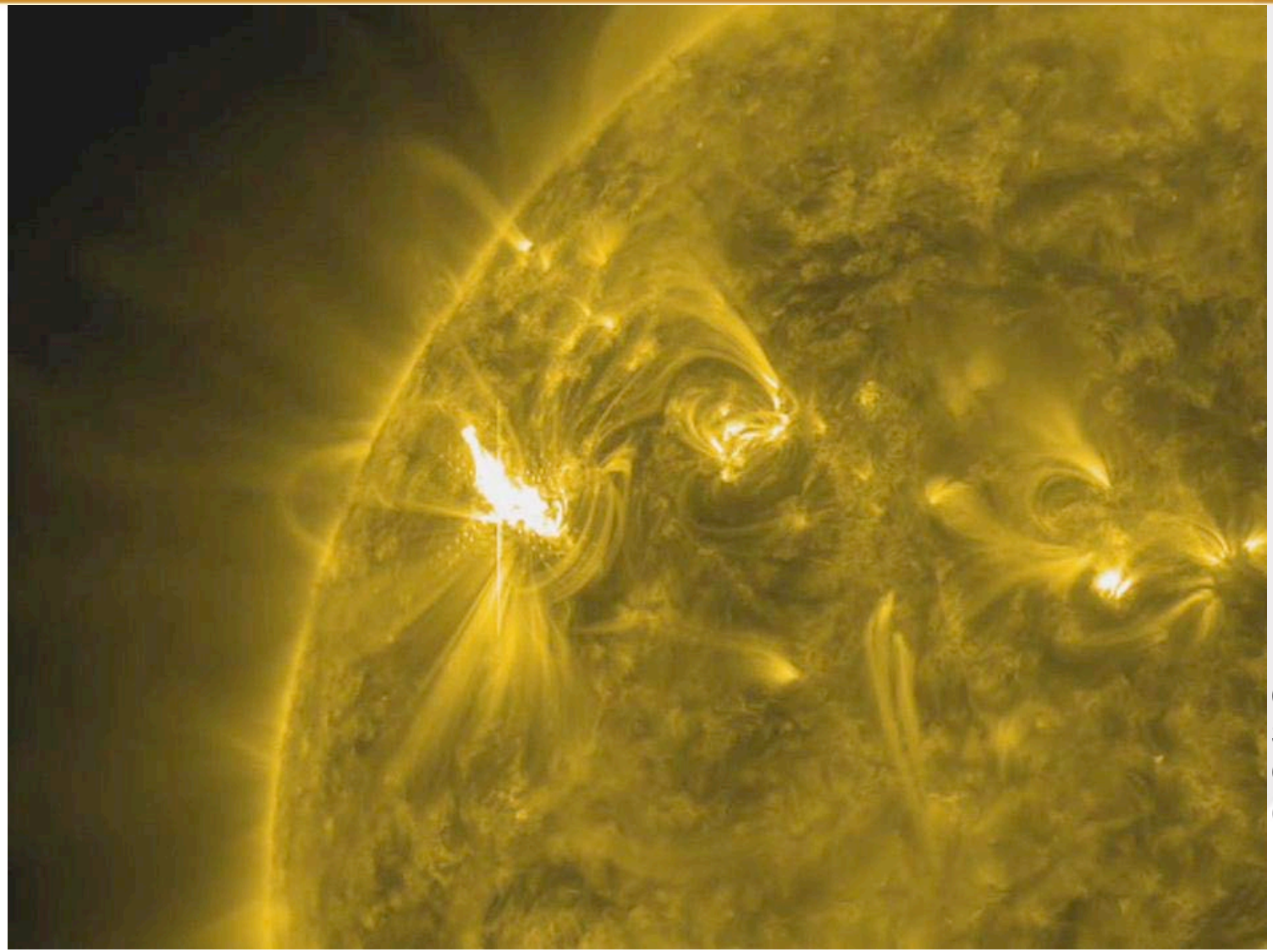
SpaceOps 2014, 5-9 May , Pasadena, CA

March 5, 2012 X1 Solar Flare Eruption



Credit: NASA's Solar Dynamics Observatory (SDO)

March 5, 2012 X1 Solar Flare Eruption

YouTube Video of March 5, 2012 Solar Flare

GSFC Space Weather Notification and Alert

- Spitzer has a collaborative relationship with Goddard Space Flight Center (GSFC) Space Weather Research Center (SWRC)

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Subject: Space Weather Alert - CME
From: GSFC-Space-Weather-Desk
Date: 03/05/2012 09:55 AM
To: GSFC-Space-Weather-Desk

## NASA Goddard Space Flight Center, Space Weather Laboratory ( SWL )
## Message Type: Space Weather Alert
##
## Message Issue Date: 2012-03-05T14:55:00Z
## Message ID: 20120305-AL-002

## Alert Summary:
Significant CME detected by STEREO-A COR2 / STEREO-B COR2 / SOHO LASCO C3.

Start time of the event: 2012-03-05 04:00Z.
Estimated speed: ~1363 km/s.
Estimated opening half-angle: 51 deg.
Direction (lon./lat.): -70/22 in Heliocentric Earth Ecliptic coordinates.

Based on preliminary heliospheric modeling carried out at SWL, it is
estimated that the CME may impact the Messenger, STEREO B, and Spitzer
spacecraft. Simulations indicate that the leading edge of the CME will
reach Messenger at about 2012-03-05T15:33Z (plus minus 7 hours), STEREO B
at about 2012-03-07T16:39Z (plus minus 7 hours), and Spitzer at about
2012-03-07T03:16Z (plus minus 7 hours).  This CME is associated with the
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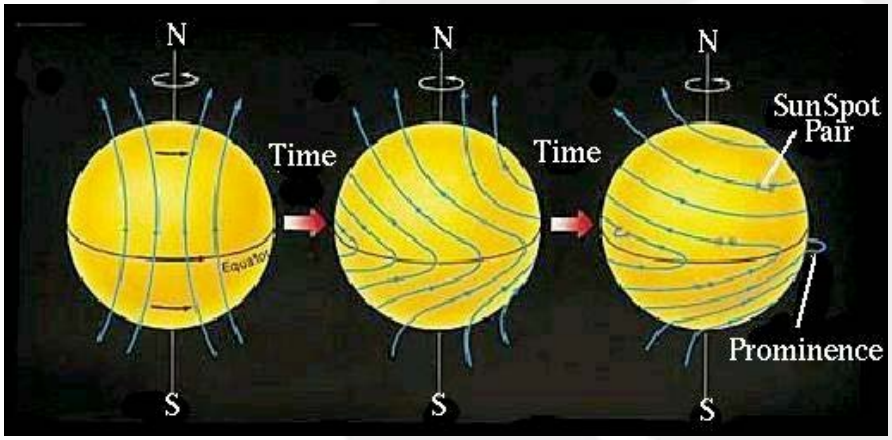
What is Space Weather?

- "Space Weather" is collective term
  - Any phenomena resulting from plasma, magnetic fields, particle flows or radiation that alter *or* impact space or earth based systems
  - Primary source => sun, but galactic cosmic rays count
- Highly inter-disciplinary
  - Scientifically studied in astrophysics and geophysics
  - Engineering – aerospace, electrical, mechanical

Quick Primer on Space Weather

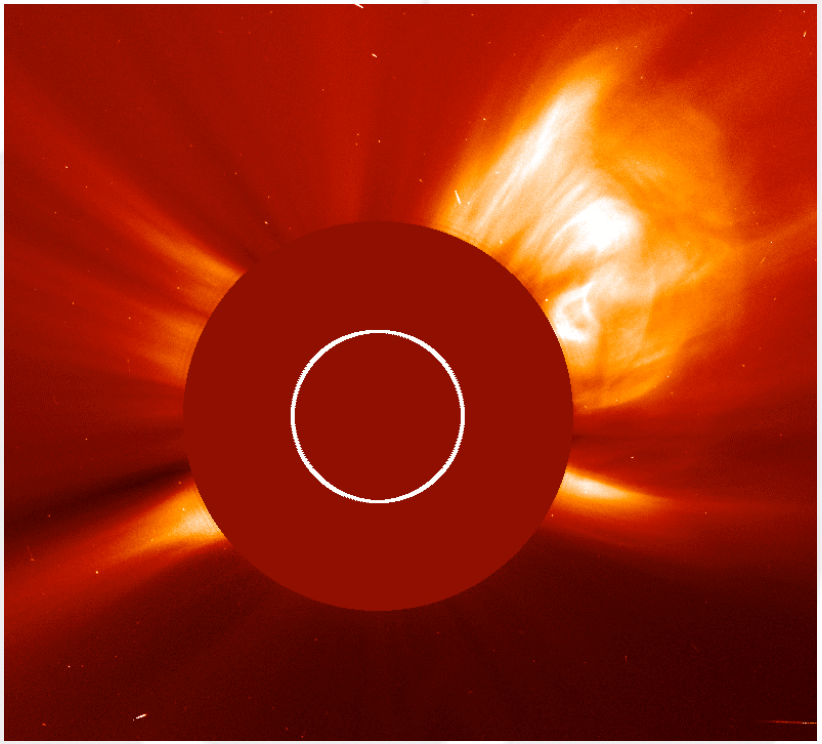
- Sun's ionized gas/plasma creates a magnetic field (dynamo)
  - Rotation plus convection "wind up magnetic field"
  - Creates "kinks" and warps in field lines, causing rapid energy release, or "flares"



  - Flips North/South field every 11 years
  - Peak activity called "solar maximum" and opposite is "solar minimum"

Solar Flares and CMEs

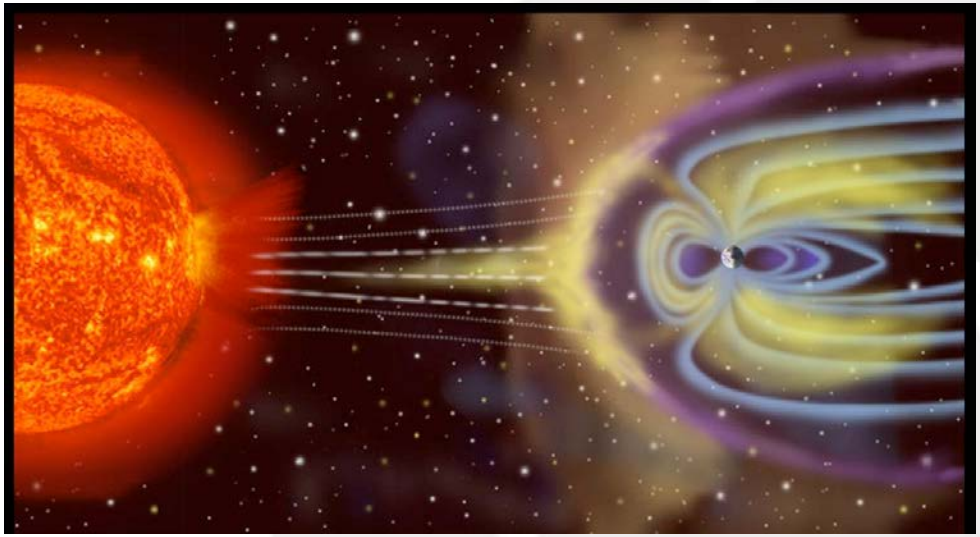
- Solar Flares emit energy across entire spectrum
  - Plasma/High energy particles are ejected
    - Called Coronal Mass Ejection (CME)
    - Relationship of flares and CMEs under study
    - Most agree they are a result of the magnetic energy released
  - “Solar flare” and “CME” interchangeable for this talk.



Credit: ESA/NASA SOHO

Space Weather and the Earth

- Earth's magnetic field protects us from most high energy particles

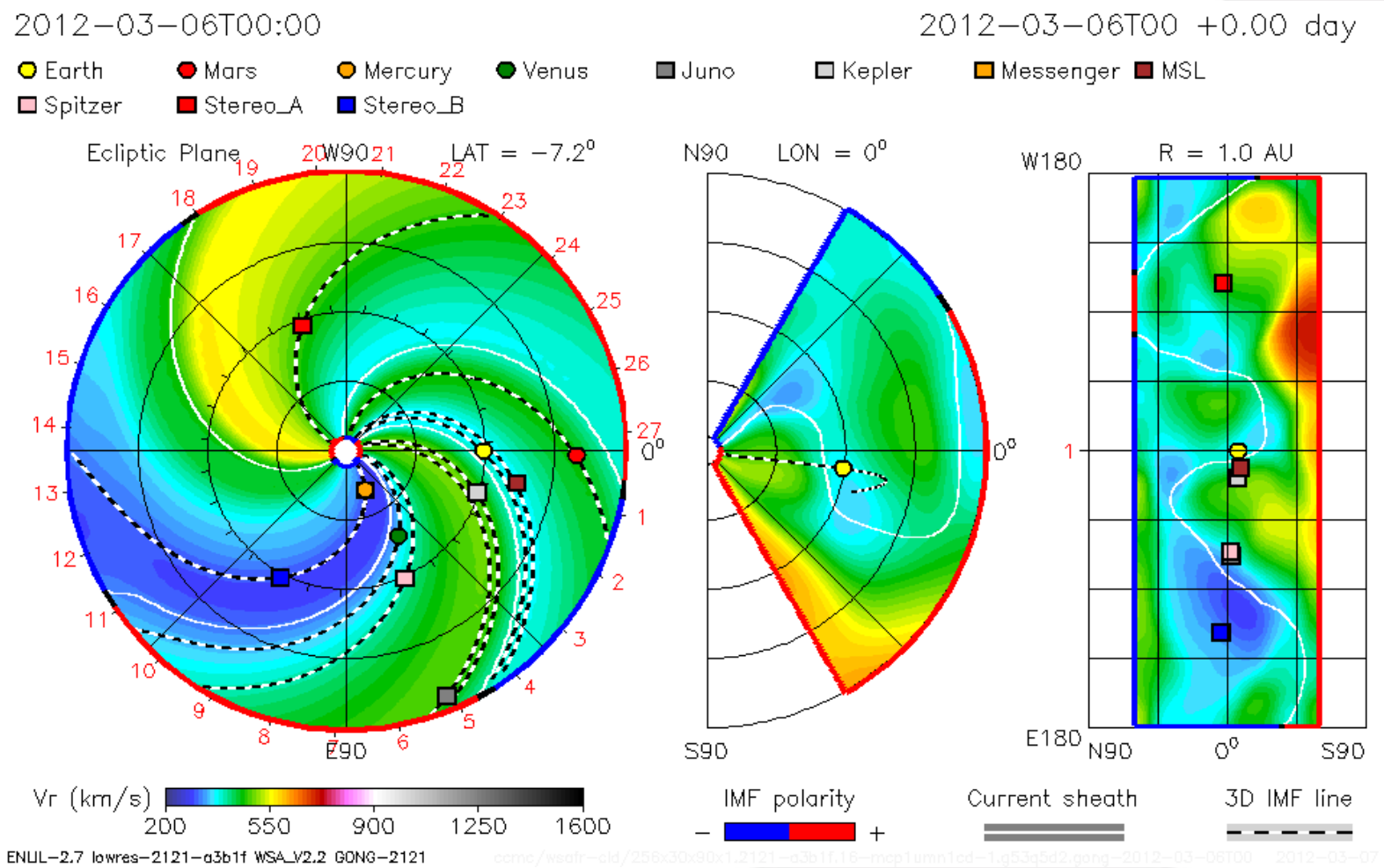


- Some do get through and effect:
  - Satellites, Radio transmissions, Electrical grids
- Need to monitor with space satellites
  - GOES, STEREO-A, STEREO-B, SOHO, SDO, ACE, Hinode, Yohkoh, and others

Don’t Forget the Solar Wind

- Constant plasma flow permeating interplanetary space
- The magnetic field imbedded in wind resembles a rotating sprinkler head
- Thought this wind “sweeps” out many galactic cosmic rays during solar max

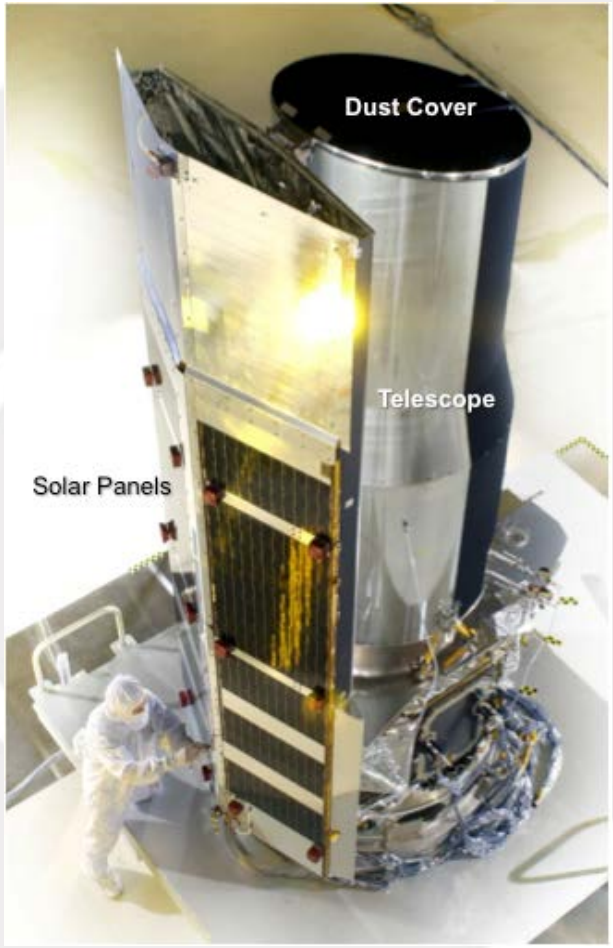
2012 0308 WSA-ENLIL-CONE CME Evolution Velocity Inner Planets Model



Source: http://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp

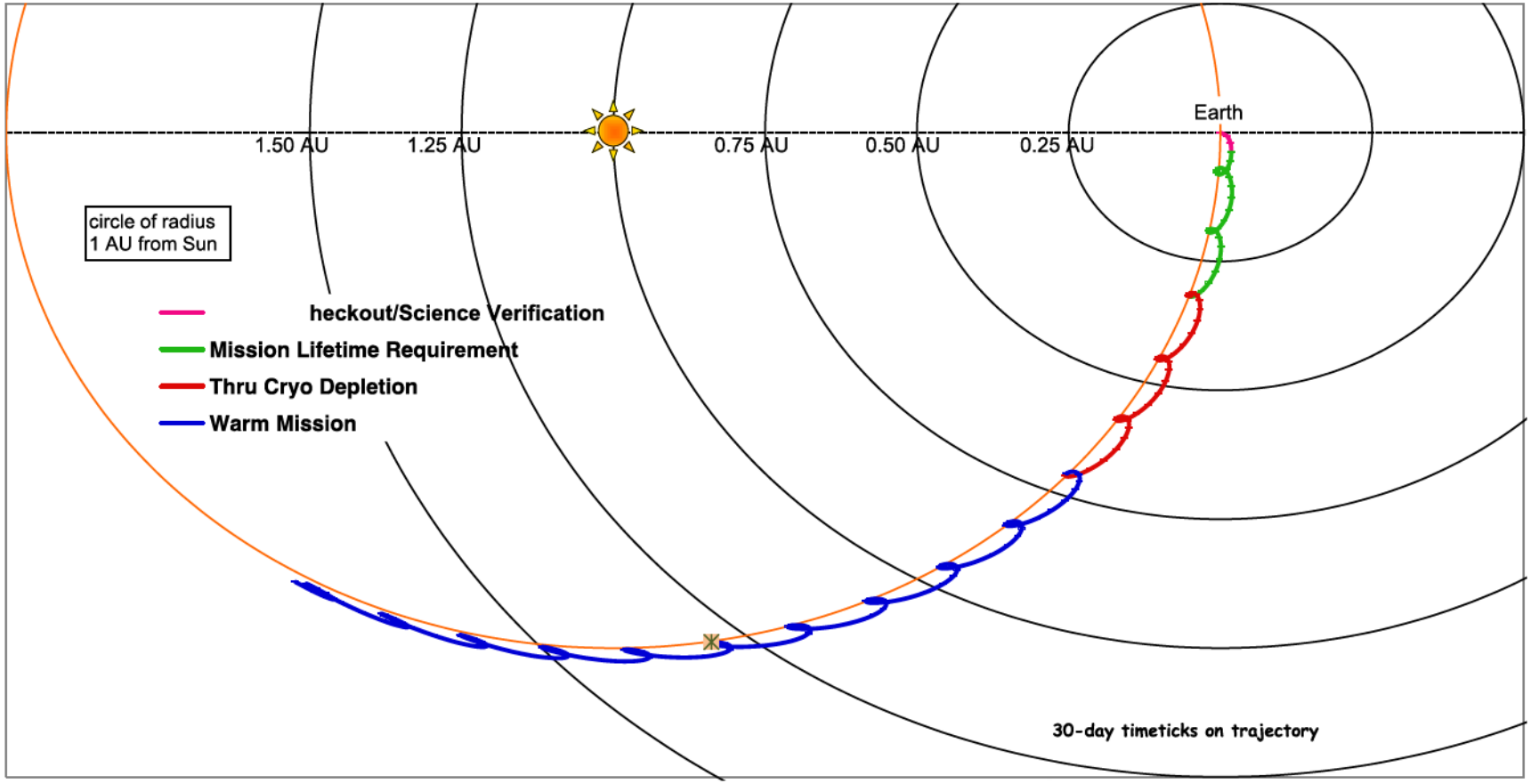
The Spitzer Space Telescope Mission

- Launched in August 2003
- Cryogenically cooled infrared telescope
- Payload: Three science instruments
  - Infrared Array Camera (IRAC)
  - Infrared Spectrograph (IRS)
  - Multi-band Imaging Photometer for Spitzer (MIPS)
- Cryogen depleted in May 2009
- Spitzer continues to operate with a single science instrument (IRAC)
- Extended mission known as “Warm Mission”



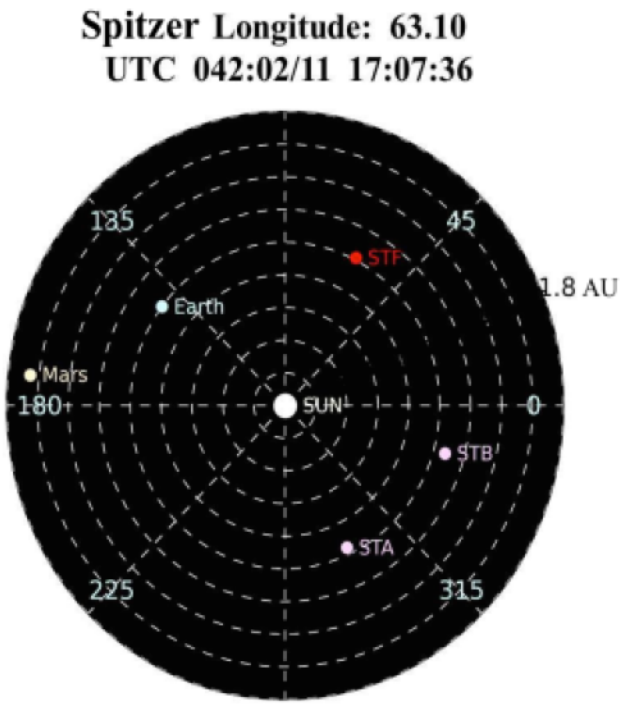
Spitzer's Orbit and Mission Phases

- Spitzer is in a heliocentric, Earth trailing orbit
- Drifts away at ~0.1 AU/year



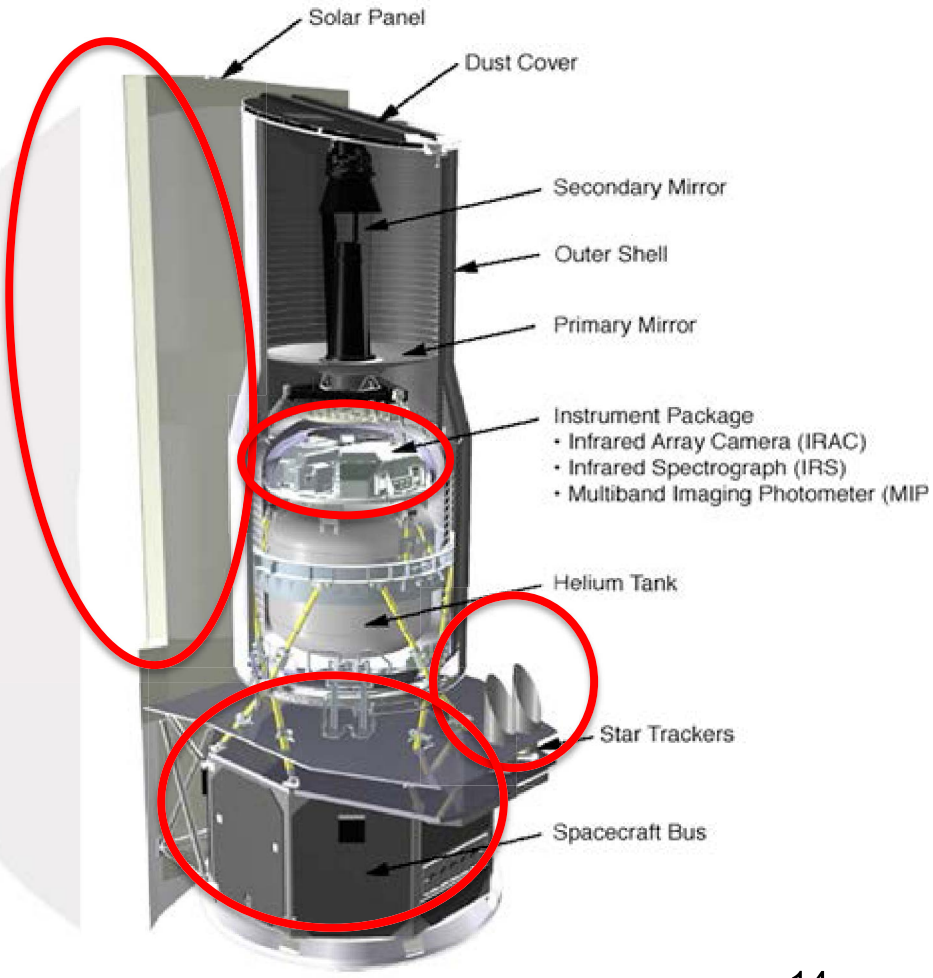
GOES and STEREO A & B Satellites and Spitzer

- During the Cryogenic (Prime) mission, Spitzer was close enough to the Earth for GOES Space Weather warnings
  - Today, GOES does not serve us as a predictive tool
- 2006: STEREO-A, STEREO-B launched
  - Gave improved capabilities
  - STEREO-B Right Ascension angle placed it close to Spitzer during Cryogenic mission
  - Now – not so useful for *direct predictions*



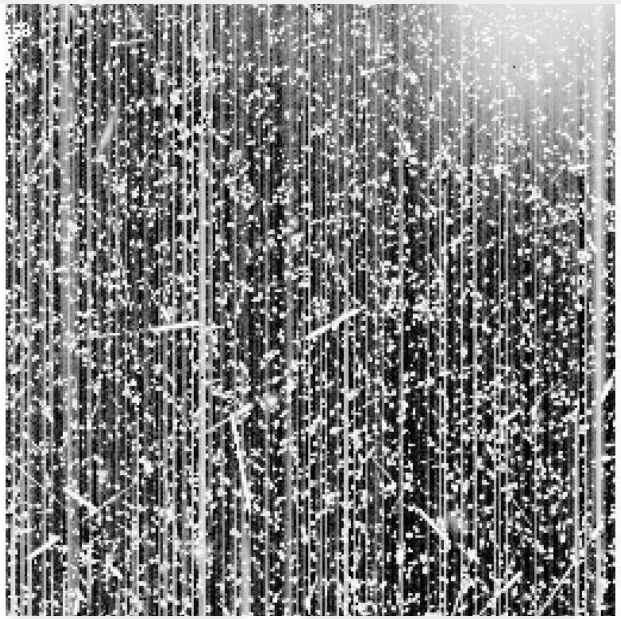
Isn't Spitzer Radiation Hardened?

- Yes, but some subsystems on-board are vulnerable
  - Star Tracker Assembly (STA)
  - Solar Panel Assembly
  - Mass Memory Card (MMC)
  - Common electronics for IRS, MIPS Instruments

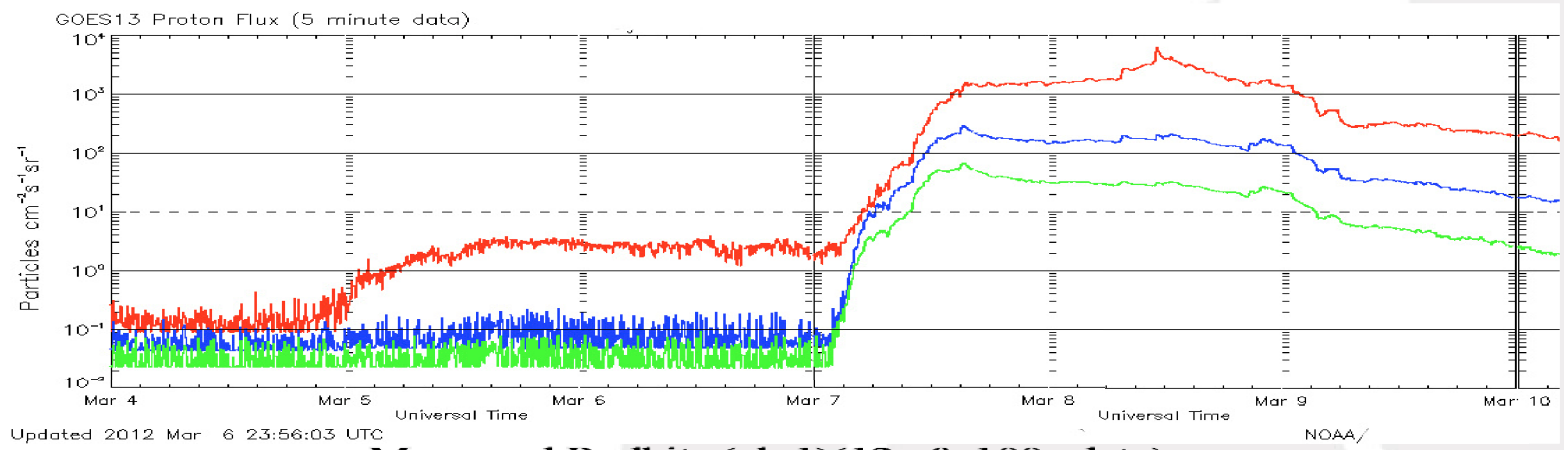


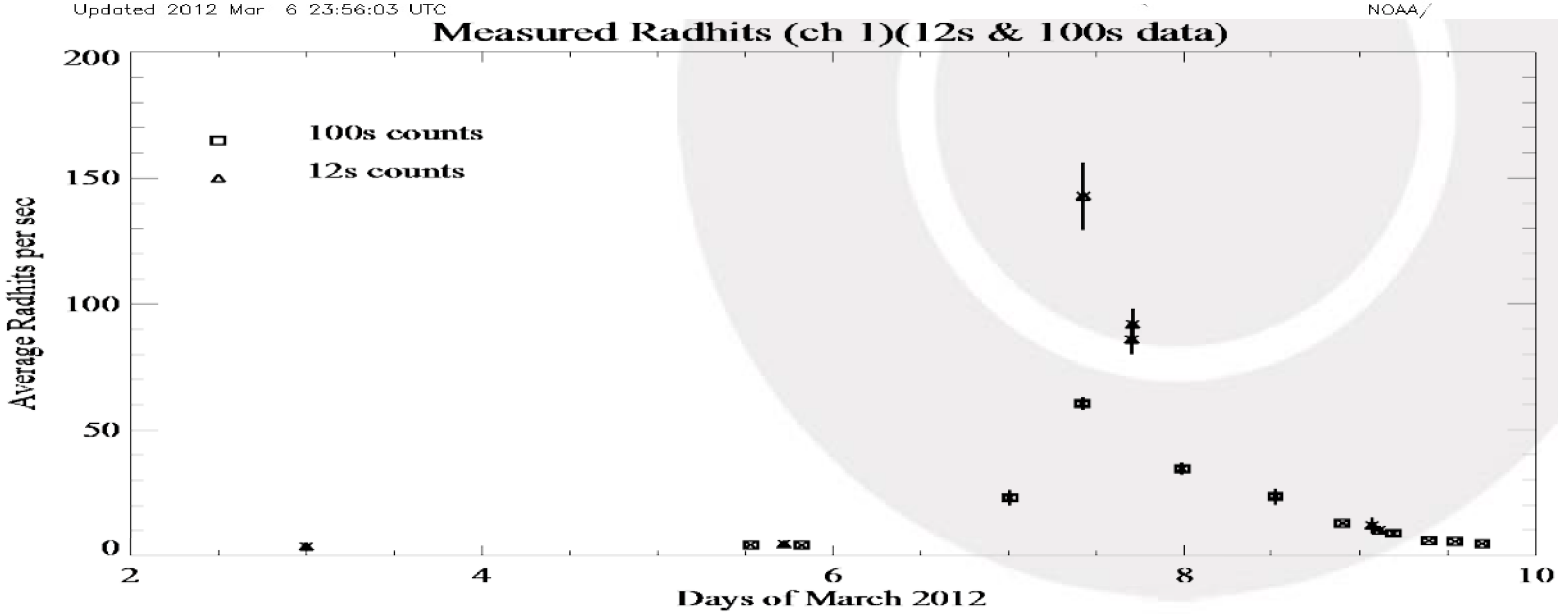
Effects on Infrared Astronomical Camera (IRAC)

- During a nominal observation
  - Approximately 4 pixels per second are “outliers”
    - Due to galactic cosmic rays or solar radiation
- When a flare occurs directed at Spitzer
  - Can get > 150 affected per second
  - Wipes out observation
  - Some hits cause column pulldown
- Not every flare will have similar strength or direction



March 2012 CME Event and IRAC Instrument

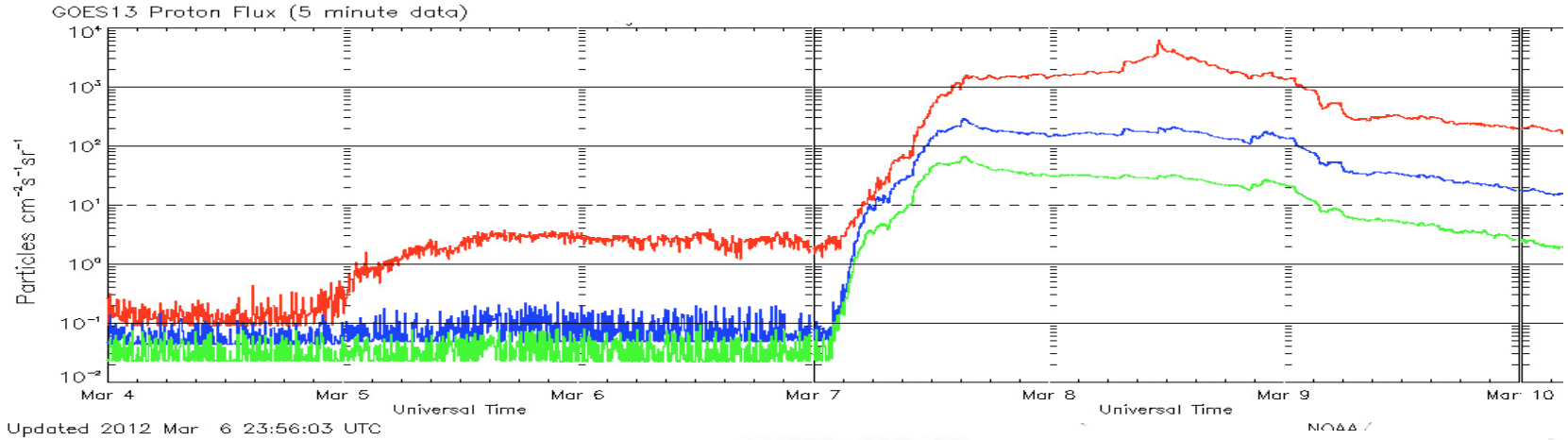




Effects on the Mass Memory Card (MMC)

- Soft Scrub Errors
  - A single-bit error that flight software encounters at any memory location
  - Upon detecting a soft error, the “scrub” process automatically corrects it.
- Multi-bit errors cannot be corrected autonomously
  - Multi-bit errors can either be corrected by being overwritten with new data or through ground intervention.
- Neither type of error disrupts the normal function of the MMC. However, science data may be degraded.

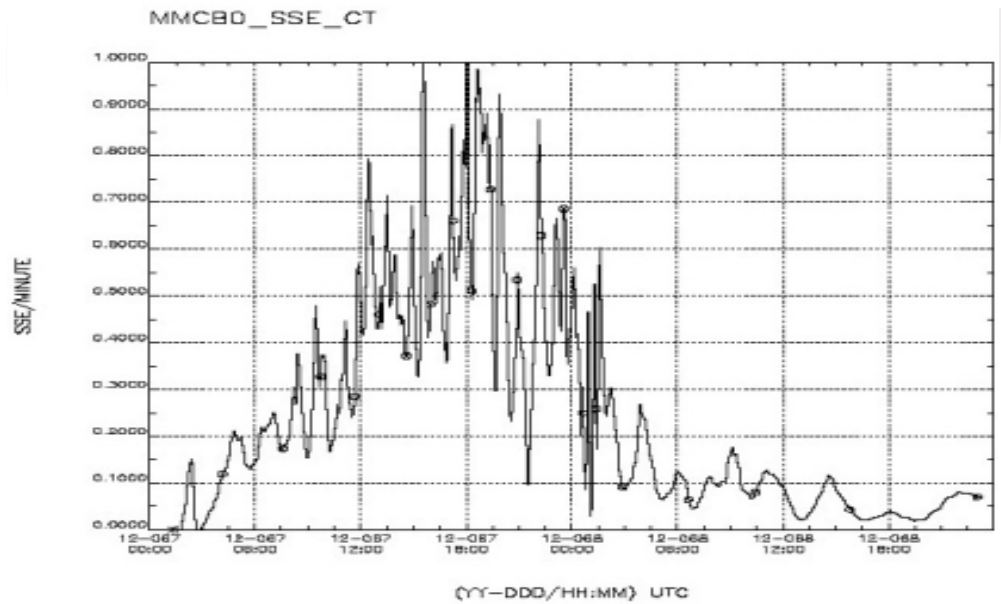
March 2012 CME Event and MMC



March 2012

Single Bit "Soft Scrub" Errors

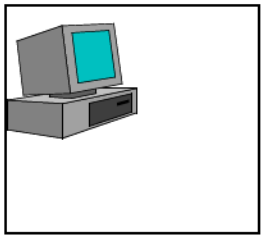
(MMC Board 0)



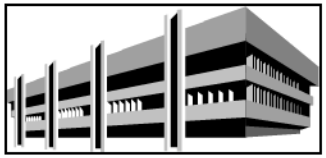
The Need for a Processes Beyond the Subsystem Level

- Before Feb. 2012, no formal process existed to correlate possible Space Weather effects on subsystems
- Unexpected subsystem behaviors were analyzed as part of “trend analysis” by each subsystem
- This poses a challenge for distributed operations missions such as Spitzer

Spitzer Distributed Operations



Observatory Engineering Team
(Lockheed Martin - Denver)



Spitzer Science Center
(Caltech - Pasadena, CA)

The Need for a System Level Approach

- We needed a “System Level Approach”
  - Determine the causes of anomalous data seen in subsystem trending analysis.
  - Correlate anomalous data with space weather alerts and forecasts
  - Gather data for events not associated with space weather alerts
- Spitzer Team developed “The Integrated Warm Mission Space Weather Spreadsheet”

The Integrated Warm Mission Space Weather Spreadsheet

Item #	Title	Message	Activity ID	Edge Time	Class	Alarms	MMC Soft Scrub Errors	Star Tracker	Power	Instrument 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					

SWE: Event associated with GSFC Notification

NSE: Event not associated any Notification

Innovation in Space Operations

- Spitzer has also contributed to knowledge of space weather activity in some unique situations
  - In 2012 Spitzer's orbital location allowed us to provide an analysis of solar energetic particles for the Mars Science Laboratory (MSL) Mission.
  - During the critical Entry Descent and Landing (EDL) phase.
- While designed without dedicated space weather radiation detectors, we are able to support other missions
- Essence of innovation in space operations

Acknowledgments

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  - Ron Beck (Spitzer Science Center)
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