GSFC Space Science Mission Operations (SSMO) and Space Weather

Rick Harman
Space Science Mission Operations
## SSMO Spacecraft

<table>
<thead>
<tr>
<th>Mission</th>
<th>Launch Year</th>
<th>MOC Location</th>
<th>Mission Director</th>
<th>Science Type</th>
<th># s/c</th>
<th>Orbit Regime</th>
<th>Catalog #</th>
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* ARTEMIS is a bifurcation of the THEMIS extended mission.

*** SOHO is a cooperative program between ESA and NASA.
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# Future SSMO Mission

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SSMO Spacecraft

GEO: SDO

HEO: THEMIS, IBEX, Van Allen, MMS

LEO: AIM, Fermi, IRIS, RHESSI, Swift, TIMED

L1: ACE, SOHO, WIND

Heliocentric: Stereo Ahead

MAVEN

Heliocentric: Stereo Behind

Heliocentric: OReX
STEREO Solar Conjunction

• Background
  – Both AHEAD and BEHIND behind the Sun relative to the Earth and out of contact with the ground for a period of weeks in 2015

• Issue
  – Each Spacecraft has a Hardware Command Loss Timer (HCLT) that resets the spacecraft if commands are not received in 72 hours.
  – Conjunction Operations for Each Spacecraft lasted for weeks and resulted in multiple HCLT spacecraft resets with the instruments and the star tracker powered off each time.
FRB: Anomaly Cause/Sequence of Events

- On October 1, 2014, Spacecraft HCLT reset as expected during a pre-solar conjunction test.
- After reset, the Star Tracker did not output attitude solutions.
- As programmed, the Spacecraft used Inertial Measurement Unit (IMU) data for rate information.
- The IMU x-axis failed.
- Spacecraft likely spun up as a result of autonomous momentum dump in response to erroneous x-axis IMU rate measurements.
  - No telemetry exists beyond a single frame that shows the IMU x-axis failed w/ an erroneous x-axis rate
FRB Assessment

• Post-Anomaly State
  – The spacecraft is in a probable spin about Y-axis
    • Unknown rate
    • Unknown spin axis orientation
    • Likely in a cycle of power system collapse and partial recovery when SAs illuminated
  – Solar array illumination is
    • Governed by the final orientation of the spin axis
    • Seasonal as BEHIND moves about Sun

• Recovery efforts consist of commanding
  – Increased battery charge rate
  – Subsequently powering on the transmitter
  – If spin rate is too high, the spacecraft will be incapable of receiving commands until January 2020 as BEHIND-Earth range
    • Multiple commands need to be received to stabilize power system recovery
    • Jan 2020: the command rate increases due to decreased Earth range
Failure Review Board’s Recommendations

- DSN developed faster frequency segmented acquisition sequence
  - 18 one kHz segments
  - Send short critical commands multiple times each segment
  - Successfully tested on AHEAD on Sep 29, 2015
- Battery state of charge recovery
  - Increase battery SOC by removing loads
  - Procedure developed and tested on flatsat in April 2015
- Downlink carrier recovery
  - Power on TWTA, carrier only
  - Procedure developed and tested on flatsat in April 2015
  - Determine rotation rate and BLF
- Utilizing other antennas to detect downlink
  - Arecibo Observatory, Green Bank Radio Telescope, and Allen Telescope Array are being used when available
- Periodically perform recovery operations to maximize the chance of the Sun illuminating the arrays
  - From modeling, minimal solar array input when anomaly occurred (2014-274). Seasonal effect may increase solar array input.
STEREO Update

AHEAD

• Conjunction: 3/24-7/7/15
• Instrument Recommissioned: 12/31/15

BEHIND

• Contact lost 10/1/14 during Conjunction Operations Testing
• Contact regained on 8/21/16
• First Telemetry: 8/26/16
• Attempted Momentum Unload and Sun Pointing on 9/7/16
• Current State: Spinning with ~50 second period, Damaged Battery, Possibly Compromised Propulsion System, No Communication Since 9/20/16
• Plan Ahead:
  • Continue to characterize spin
  • Continue attempt to upload macro to protect battery
  • Telemetry if possible
STEREO BEHIND Orbit Timeline

Oct 2014 – Loss of Comm
Dec 2015 – Resume Recovery Ops
Oct 2016
Oct 2017
Oct 2018
Oct 2019
Oct 2020
Oct 2021
Oct 2022
July 13, 2023 – Closest Approach

STEREO AHEAD & BEHIND Motion in the Earth Fixed Frame

Courtesy of Dave Quinn