NASA’s STEREO Mission

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The STEREO Mission

- Science and technology definition team report, 1997 December:
  - Understand the origin and consequences of coronal mass ejections (CMEs)
  - Two spacecraft in earth-leading and -lagging orbits near 1 AU (Solar Terrestrial Probe line)
  - “Beacon” mode for near-realtime warning of potentially geoeffective events
Level 1 Requirements

• Understand the causes and mechanisms of CME initiation
• Characterize the propagation of CMEs through the heliosphere
• Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium
• Develop a 3D, time-dependent model of the magnetic topology, temperature, density, and velocity structure of the ambient solar wind
Implementation

- Two nearly identical spacecraft launched by a single ELV
  - Bottom spacecraft in stack has adapter ring, some strengthening
  - Spacecraft built at Johns Hopkins University APL
  - Four science investigations
Scientific Instruments

- S/WAVES - broad frequency response RF detection of Type II, III bursts
- PLASTIC - solar wind plasma and suprathermal ion composition measurements
- IMPACT - energetic electrons and ions, magnetic field
- SECCHI - EUV, coronagraphs and heliospheric imagers (surface to 1.5 AU)
Instrument Hardware

- PLASTIC IMPACT boom
- SECCHI SCIP
- SECCHI HI
- S/WAVES
Orbit Design

• Science team selected a separation rate of 22° year\(^{-1}\) from the Sun-earth line
• Implemented by launching the spacecraft into slightly different phasing orbits with apogees beyond the moon’s orbit
• Use moon for gravity assist to achieve heliocentric orbits with desired separation rate
Launch and Transfer

- Spacecraft launched 2006 October 25 (26 UT)
- Delta II 7925-10L from CCAFS
- Ahead spacecraft transferred to heliocentric orbit 2006 December 22
- Behind in heliocentric orbit 2007 January 21
- To see where STEREO A and B are today, use:
  - http://stereo-ssc.nascom.nasa.gov/where.s.shtml
A unique view
(during early heliocentric ops)

- Lunar transit of the Sun, 2007 February 25

QuickTime™ and a MPEG-4 Video decompressor are needed to see this picture.
An Aside

• Question: What will happen on 2011 February 6 at 7:30 PM CST?
  • Super Bowl XLV
  • STEREO spacecraft will be in opposition
Space Weather
Information from STEREO (I)

- Beacon mode
  - Low rate (633 bps)
  - Informal antenna partners
    - Arranged in partnership with NOAA SWPC
    - Currently: Bochum and Kiel (radio amateurs in Germany), Toulouse, France (CNES), Koganei, Japan (NIISC)
    - Don’t quite span the globe: need more!
  - Large gap between 139°E and 7°E
  - Need site(s) in Pacific, mainland US
Beacon mode data availability

- Like all STEREO data, under the NASA Heliophysics Data Management Policy, the beacon mode data are publicly available as soon as they hit the ground and are reformatted (< 5 min.)
  - from the STEREO Science Center (SSC)
  - Images
    - [http://stereo-ssc.nascom.nasa.gov/browse/](http://stereo-ssc.nascom.nasa.gov/browse/)
  - *In situ* and radio
    - [http://stereo-ssc.nascom.nasa.gov/browse/insitu.shtml](http://stereo-ssc.nascom.nasa.gov/browse/insitu.shtml)
What do we get in beacon mode?

- SECCHI images reduced to 256 x 256 pixels and mercilessly compressed
- Subsampled solar wind and energetic particle data (PLASTIC, IMPACT)
- Subsampled RF data from S/WAVES
- Links to higher level beacon-mode products, such as “J-plots”
Beacon mode data

- Images, links to movies
- Solar wind plasma and magnetic field data
- Energetic particles
- RF data (2.5 kHz - 16 MHz)
How long can we keep this up?

Spacecraft will pass one another on the far side of the Sun in 2015

- Will need to rename them Abaft and Before, or something like that
How long can we keep this up?

<table>
<thead>
<tr>
<th>Telemetry rate (kbps)</th>
<th>Date (Behind)</th>
<th>Date (Ahead)</th>
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<tbody>
<tr>
<td>720</td>
<td>2007/01/22</td>
<td>2007/01/22</td>
</tr>
<tr>
<td>480</td>
<td>2008/09/15</td>
<td>2008/10/3</td>
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<tr>
<td>360</td>
<td>2009/09/08</td>
<td>2009/08/7</td>
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<tr>
<td>240</td>
<td>2009/12/07</td>
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<tr>
<td>120</td>
<td>2010/11/5</td>
<td>2011/04/1</td>
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<tr>
<td>96</td>
<td>2011/09/9</td>
<td>2011/09/6</td>
</tr>
<tr>
<td>96 (??)</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Beacon mode?

• Beacon mode will need to switch to a different encoding scheme to maintain data rate with increasing distance
  • Will create issues with some receiving sites
  • Will work with NOAA SWPC to resolve
• Some receiving sites may not have sufficient link margin to obtain data from ~ 2 AU
What have we learned?

- We can model CME propagation
  - in 2 dimensions, geometrically
  - in 3 dimensions, using a forward model
Geometric triangulation using J-maps

- Able to predict speed, arrival time of at least two features in a CME
Forward modeling


- Assume flux-rope geometry
- Works well for 17 events considered
- Implies that nearly all CMEs are flux ropes
- Can predict flux rope orientation → geoeffectiveness
Angular extent of energetic particle events


- STEREO A, B; ACE measurements show impulsive electron profile over > 80° in heliolongitude
- 2010/02/12 event was visible when
Complexity of Magnetic Cloud field (CIR interaction)

- 2007 November 19 - 21

- Interaction of a CIR and a magnetic cloud near the heliospheric current sheet

- Farrugia et al. 2010, submitted to JASTP (special CME/ICME issue)

- “Double-dip” event in Dst (peak of -100 nT)
Complexity of Magnetic Cloud field (CIR interaction)

• Reconstructions from three measurements (B, WIND, A) appear to show, from E to W, magnetic cloud:
  • after interaction with CIR
  • interacting with CIR, and
  • before interacting with CIR
And I’m leaving out....

- Dust impacts
- High-amplitude whistler waves in solar wind halo electrons
- and about 300 other refereed journal articles
A Unique Set of Viewpoints on Solar and Heliospheric Activity

Movie sequence from all four SECCHI telescopes on both STEREO spacecraft
2010 April 3 - 12
A Unique Set of Viewpoints on Solar and Heliospheric Activity
Full-resolution telemetry

• Acquired through Deep Space Network sites only
• Reformatted and available online in ~ 2 days
  • Longer for some higher level data products
• Available from the STEREO Science Center:
  • [http://stereo-ssc.nascom.nasa.gov/data.shtml](http://stereo-ssc.nascom.nasa.gov/data.shtml)
  • Includes “instrument resource pages” link
STEREO data

- Instrument resource pages
- Anonymous ftp access
- Data at PI institutions and elsewhere
- Access via virtual observatories
- Ancillary data
A sample “instrument resource” page (SECCHI)

- File contents description
- User’s guide
- Contact info