STEREO:

Two Eyes on the Rise of Cycle 24

A PROPOSAL TO THE SENIOR REVIEW OF HELIOPHYSICS OPERATING MISSIONS, 2010 MARCH.

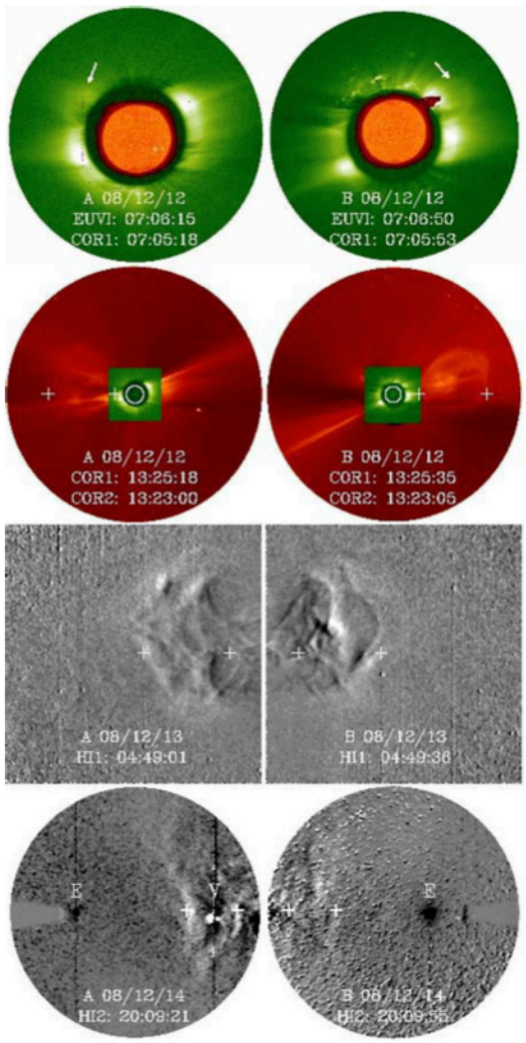

Figure 2. CME evolution observed by STEREO A (left) and B (right) near simultaneously. From top to bottom, the panels display the composite images of EUVI at 304 Å and COR1 showing the nascent CME (indicated by the arrow), combined COR1 and COR2 images of the fully developed CME, and running difference images from HI1 and HI2 when the CME is far away from the Sun. The crosses mark the locations of the two features obtained from Figure 3. The positions of the Earth and Venus are labeled as E and V.

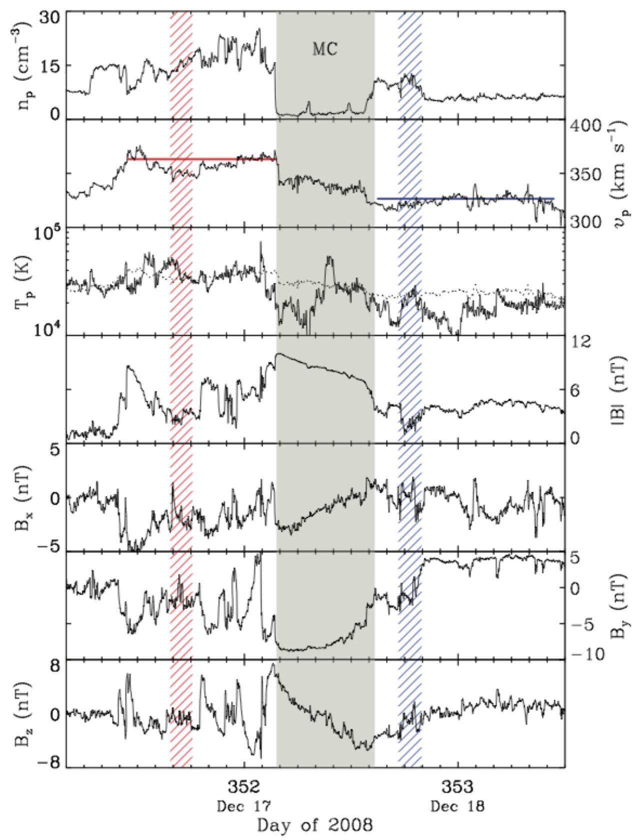

Figure 5. Solar wind plasma and magnetic field parameters across the MC observed at WIND. From top to bottom, the panels show the proton density, bulk speed, proton temperature, and magnetic field strength and components, respectively. The shaded region indicates the MC interval, and the hatched area shows the predicted arrival times (with uncertainties) of features 1 (red) and 2 (blue). The horizontal lines mark the corresponding predicted velocities at 1 AU. The dotted line denotes the expected proton temperature from the observed speed.

Remote sensing (left) of a coronal mass ejection in 2008 December in the STEREO SECCHI Ahead (left column) and Behind (right column) COR1, COR2, HI1, and HI2 images (top to bottom), and the in-situ measurements of solar wind density, proton bulk velocity, proton temperature, and magnetic field in the corresponding ICME from WIND at 1 AU. The horizontal red and blue lines in the bulk velocity represent the predicted speeds, and the hatched, colored areas, the predicted arrival times, of two features marked by + signs in the images, from an analysis by Liu et al. (2010, ApJ, 710, L82).

Table of Contents

Appendices

Solar TErrestrial RElations Observatory (STEREO)

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I. Executive Summary

The STEREO mission completed its prime phase in 2009 January, after nearly two years of heliocentric operations. STEREO is a significant component of the Heliophysics System Observatory, and there has been significant uptake of STEREO measurements by the solar and heliospheric communities, as well as groups working in related fields. Data from the mission are being freely served by the STEREO Science Center and instrument team Websites, and as of this writing, over 200 STEREO publications have appeared in the refereed literature, over 170 of those in 2008 and 2009.

Section II describes the accessibility of STEREO data from a multiplicity of online resources. As can be seen in Section III, a number of exciting scientific insights have been achieved during the deep solar minimum conditions STEREO has encountered in the last two years. Whether in measurements of energetic particles from corotating interaction regions, matching *in situ* and remote sensing observations of solar wind events and waves, novel diagnostics for CIR development, narrowing down the candidate mechanisms for the production of energetic neutral atoms from space weather events, the origin of Type III bursts, the nature of the transition from fast to slow streams in the solar wind, the forward modeling of coronal mass ejections, or the projection of surface magnetic fields, the unique, binocular views afforded by STEREO, in combination with other Heliophysics System Observatory spacecraft have provided novel insights into solar and heliospheric structure and dynamics.

As solar activity begins to pick up, we hope to extend those discoveries to more activity-related phenomena. In Section IV, we note a few of the scientific objectives we intend to address during the next four years, in light of the changing telemetry rates over that period. Section V provides a brief overview of budget and management issues.

Mandatory appendices address education and public outreach (A) and the legacy mission archive plan (B). Additional appendices cover publications (C), and spacecraft and instrument status (D), and provide lists of Heliophysics Roadmap research focus areas (E) and acronyms (F).

The following individuals were among those involved in the writing of this proposal on behalf of the STEREO Science Working Group: A. Galvin, J. Luhmann, R. MacDowall, A. Vourlidas, M. Aschwanden, C. Cohen, C. Farrugia, R. Gomez-Herrero, J. Gosling, L.K. Jian, T. Kucera, B. Lavraud, R. Mewaldt, C.T. Russell, W. Thompson, and J.B. Gurman. We would also like to thank the S&H Guest Investigators who provided material for this proposal: M. Desai, B. Jackson, Y. Li.

II. Data Accessibility

A Note on Hyperlinks: Rather than spelling out URL's, which tends to introduce awkward line breaks in the text, we provide a hyperlink (in blue and underlined) for each Internet-accessible resource mentioned in this proposal. The hyperlinks should be clickable in the PDF version of this document.

Research and space weather uptake. Data from STEREO have been incorporated into many scientific investigations, and some of the same services currently using observations from older assets of the Heliophysics System Observatory (HSO). Since the launch of STEREO in 2006 October, over 200 refereed publications have made use of STEREO data (see Appendix C). There have been twenty Science Working Group meetings, and a combined workshop with the *SOHO* mission was held in Bournemouth, UK in 2009 May. 23 refereed papers from that meeting appeared in a special issue of *Annales Geophysicae*, as well as a total of 51 other STEREO papers in two special, double issues of *Solar Physics* in 2009 (volumes 256 and 259). Examples of services using STEREO data include the Space Weather Browser from the Royal Observatory of Belgium, the SolarSoft Latest Events service maintained by the Lockheed-Martin Solar and Astrophysics Laboratory, and the Integrated Space Weather Analysis System from NASA Goddard Space Flight Center. The NOAA National Space Weather Prediction Center uses STEREO Beacon data on a regular basis, and serves them *via* a Website similar to that used for serving ACE realtime solar wind data. In China, University of Science and Technology's DREAMS Website includes a SECCHI EUVI 304 Å eruptive event database as well as a mirror of the SSC movie site. Also, the asteroid and comet-hunting community and more recently the variable star community have become avid users of the STEREO data.

Accessibility. All STEREO science data are accessible on the Web through the STEREO Science Center (SSC) archive and PI sites. The data in the SSC archive are identical to those on the PI sites, and are maintained by regular mirror processes running several times per day. Over 23 terabytes of data have been served over the Web by the SSC in 2009.

Adherence to standards has allowed STEREO data to be easily incorporated into a number of online browse tools. Interactive plots of *in-situ* and radio data, together with the data themselves, are available through the CDAWeb. The Virtual Space Physics Observatory maintains an extensive list of STEREO-related services. STEREO image data are incorporated into the tools listed above, under "uptake."

Although tools for accessibility are already in existence, a number of browse tools that enhance accessibility have been developed by the instrument teams. A daily browse tool based on the SECCHI images and beacon in-situ data is maintained on the SSC website. Customized browse pages are also available from the SECCHI, IMPACT, PLASTIC, and S/WAVES instrument sites. For example, daily Javascript movies from the SECCHI telescopes can be viewed at various resolutions at a SECCHI movies Webpage. Additional S/WAVES data are available from the Centre de Données de la Physique des Plasmas in France. The NOAA Space Weather Prediction Center provides a browser of the beacon data patterned after their ACE browser . The SECCHI/COR1, SECCHI/HI, and S/WAVES teams are providing higher-level data products (e.g. event catalogs) to direct researchers to the most interesting data sets. An additional event list combines IMPACT and PLASTIC data on shocks, ICMEs, stream interactions, and SEP events. The STEREO Space Weather website at NRL, accessible through the SSC website, contains links to ancillary data for major events observed by many of the STEREO instruments.

Research access. The Virtual Solar Observatory (VSO; Hill *et al*., 2009) acts as the primary access point for all STEREO data, with the SSC as the data provider. This maximizes the use of existing resources without duplication, and enables collaborative data analysis with other solar observatories. Efforts are also underway to incorporate the STEREO data into the Virtual Heliospheric Observatory. Magnetometer data from IMPACT are already available through the VHO, and efforts are underway to incorporate SWEA, SEPT and SIT data in the near term.

Data are available from the individual PI and Co-I institutions, and in the case of some of the in-situ and radio data at the CDAWeb website at the NSSDC. A list of all access sites is maintained on the STEREO Science Center Website.

A number of additional data products have been made available since the last Senior Review. PLASTIC Level 2 data are now available in both CDF and ASCII formats, and are archived in the SSC. The SSC also archives and makes available the combined IMPACT/PLASTIC Level 3 event lists. Additional work is needing on completing the IMPACT Level 2 data sets, but Level 2 ASCII files are available for LET, and HET data, and ASCII MAG Level 2 data are available combined with solar wind parameters from PLASTIC.

Space weather. In addition to the normal science data provided by the instrument teams, STEREO also provides instantaneous beacon data to the space weather community. These data are used extensively by the NOAA Space Weather Prediction Center. The Solar Influences Data Analysis Center at the Royal Observatory of Belgium uses STEREO coronagraph beacon images to automatically detect coronal mass ejections through their CACTUS (Computer Aided CME Tracking) project. The Community Coordinated Modeling Center (CCMC) is modeling both the ambient solar wind and selected eruptive events in support of STEREO data interpretation. The Global Oscillation Network Group (GONG) is providing daily updated magnetograms, synoptic maps and potential field source surface models that can be used in analyzing prevailing coronal magnetic field geometry and solar wind sources on a near real-time basis.

Publications. The SSC maintains a database of published journal articles and proceedings on the SSC Website. Many pre-publication works are made available by the authors through the Solar Physics E-Print Archive.

II. Scientific Insights from STEREO, 2008 - 2009

In Appendix E, we reproduce the first page of Chapter 1 of the current Heliophysics Roadmap, which lists the research focus areas (RFAs) in each of three general goal areas: Frontier (F), Home in Space (H), and Journey of Exploration (J). Each insight described below is identified by goal letter and RFA number within the goal.

The primary scientific goals of the STEREO mission are: 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; and develop a 3D, time-independent model of the magnetic field topology, temperature, density, and the velocity structure of the solar wind. Perhaps the most interesting developments have come in studies involving combinations of imaging and *in situ* measurements from the STEREO spacecraft, as well as those combining insights from STEREO and other Heliospheric System Observatory (HSO) spacecraft as well. Below we present recent insights into these areas achieved with STEREO and other elements of the HSO.

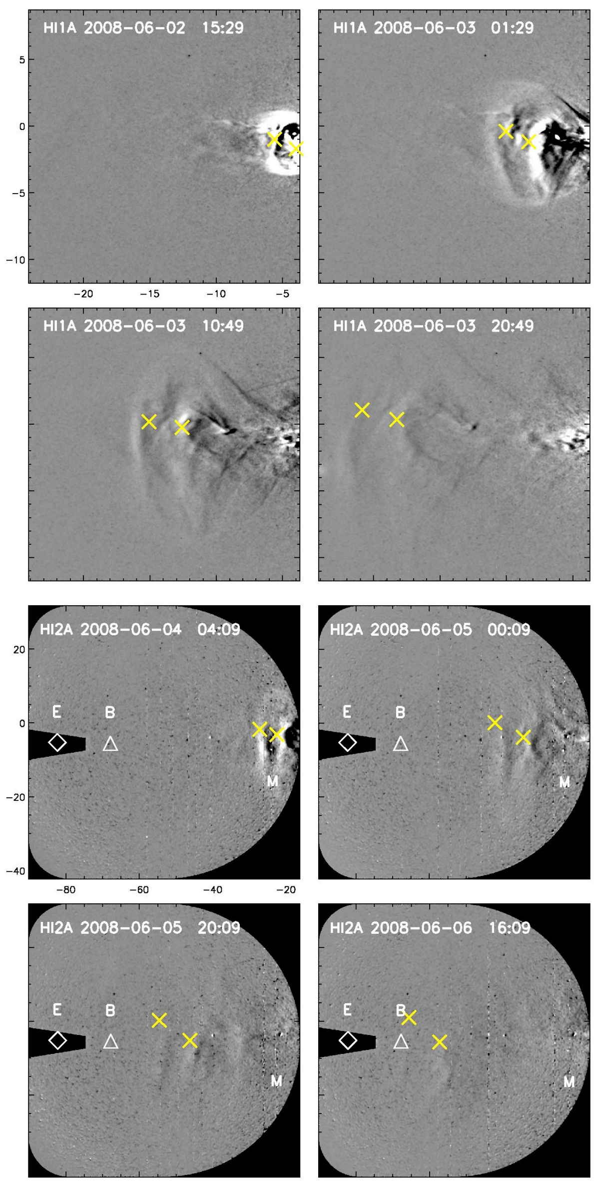


Figure 1. Successive images from STEREO-A HI1/2 for the 2008 June 1 – 6 CME. Earth (E) and STEREO-B (B) are indicated. The tracked features of the CME leading edge and core are given by yellow crosses.

Remote Imaging and 1 AU, in situ signatures of a Coronal Mass Ejection (H1, J3). One of the main goals of the STEREO mission is to follow coronal mass ejections all the way from the Sun to 1 AU. Using in situ PLASTIC and IMPACT measurements and SECCHI HI imaging of an especially clean event (2008 June 6-7), Möstl et al. (2009a) examined whether those in situ properties can be anticipated from remote observations obtained a few days earlier. STEREO-B encountered typical signatures of a magnetic flux rope, which they modeled using the Grad-Shafranov technique. The flux-rope axis was inclined at 45° to the solar equatorial plane, and appears to be related to an arc-like morphology of the CME in the STEREO-A HI images, as well as an asymmetric disappearance of the CME intensity with respect to the solar equatorial plane. Möstl et al. applied various CME direction-finding techniques to check for mutual agreement and consistency with the flux rope model. This exercise yielded similar results to within 15°. The classic three-part-structure of CMEs (leading edge, void, core) was essentially conserved up to 1 AU, with density peaks bracketing the low-density magnetic flux rope. This CME originated over a quiet solar region (Robbrecht et al., 2009) without the typical, on-disk eruption signatures. It would not have been possible to use typical indicators such as filament- or neutral-line orientation to roughly estimate the flux rope orientation. Instead, the flux rope's axial and poloidal magnetic fields reflect the large-scale magnetic field of the Sun and its launch from the southern hemisphere.

CIRs as a source of counter-streaming suprathermal electron beams (F2). Counter-streaming suprathermal electrons (CSEs) observed by STEREO IMPACT SWEA, *i.e.*, with "beams" both parallel and anti-parallel to the local magnetic field, are shedding more light on the heliospheric magnetic field topology. This type of anisotropy is often interpreted as a signature of closed field lines with both ends attached to the Sun, especially in the flux rope-like CME related magnetic clouds. CSEs are also frequently observed outside of CME-related disturbances. Lavraud *et al*. (2010) used STEREO IMPACT data to study the statistical properties of CSEs in the vicinity of corotating interaction regions (CIRs) during the period 2007 March – December. CSEs at this time near solar minimum primarily stem from suprathermal electron leakage from the CIRs into the upstream regions. Superposed epoch analysis further demonstrates that CSEs are preferentially observed both before and after the passage of the stream interface (with peak occurrence rate > 35% in the trailing high speed stream), as well as both inside and outside CIRs. The results confirm that CSEs are common in the solar wind during solar minimum. In particular Lavraud et al. (2010) conclude that the formation of shocks commonly contributes to the occurrence of enhanced counter-streaming sunward-directed fluxes as suggested in earlier studies by Gosling et al., (1993) and Steinberg et al. (2005). The presence of small-scale transients with closed-field topologies also contributes to the occurrence of counter-streaming patterns, but only in the slow solar wind prior to CIRs (*e.g.* STEREO results by Kilpua *et al*. [2009b] and Rouillard *et al.* [2010])

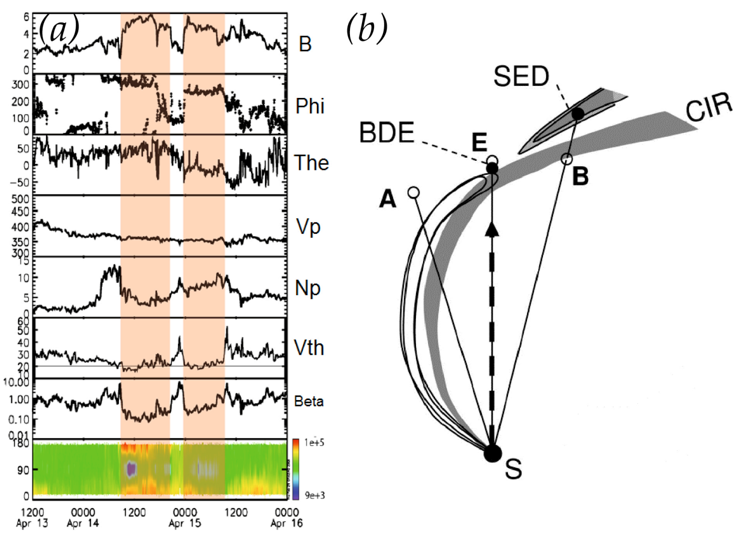


Figure 2. (a) STEREO-B in situ measurements of slow solar wind transients (shaded areas) (from Kilpua et al., 2009b). (b) Illustration of the magnetic topology of slow solar wind transients propagating in the inner heliosphere, as deduced from both imaging and multi-spacecraft in situ measurements (from Rouillard et al., 2010).

Tracking of solar wind transients from the Sun to 1 AU (H1, J1, J3). STEREO SECCHI imagers have recently presented evidence for intense, intermittent, transient outflows originating near the cusps and/or boundaries of coronal helmet streamers (*e.g*. Rouillard et al., 2009a). Such recurrent structures have been identified at 1 AU by Kilpua et al. (2009b) and Rouillard et al. (2010), using STEREO IMPACT and PLASTIC data. The transients were consistently found to be restricted to slow solar wind regions that are expected to originate near the boundaries between the helmet streamers and the open fields of coronal holes. Rouillard et al. (2010) connect *in-situ* observations from the STEREO and ACE spacecraft to SECCHI heliospheric image features. Several transient events were predicted to impact either the ACE or STEREO spacecraft. In one case, ACE confirmed the presence of a transient signature, including helical magnetic fields and counter-streaming, suprathermal electrons. On the same day a strahl electron dropout was observed at STEREO-B, correlated with the passage of a structure with high plasma β. This set of data from STEREO-A, -B and ACE, showing very different slow solar wind properties, was interpreted as the result of the release of transients with the formation of both closed and fully disconnected loops, as sketched in Figure 2(b). These studies demonstrate the value of the STEREO capability for combining both remote sensing and in situ observations to track the propagation of transients (even small scale ones) all the way from the Sun to 1 AU. These observations also have the potential to allow us to evaluate the contribution of such transients to the slow solar wind as the solar cycle evolves.

Further evidence for magnetic reconnection in the solar wind (F1, H1, J3). In near-Earth space and the solar wind it is possible to observe magnetic reconnection in its collisionless form using *in situ* observations. At Earth magnetic reconnection is often observed as an intermittent phenomenon, leading the community to wonder whether this is an intrinsic property of the process. Observations from STEREO (Gosling et al., 2007) helped to demonstrate that magnetic reconnection can occur in a surprisingly steady fashion (5.3 hours) and over very large scales (X-line of 0.0284 AU). Recent STEREO observations have provided further evidence for the occurrence of magnetic reconnection in the solar wind. In particular, electron observations from IMPACT SWEA have confirmed the existence of reconnection separatrix layers in the solar wind (Lavraud et al., 2009). Figure 3 shows that the strahl, observed on each side of the reconnecting Heliospheric Current Sheet (HCS), was field aligned prior to the HCS and anti-parallel after the HCS, but clearly mixed inside the reconnection exhaust (vertical dashed lines). Such a spatial structure, which results from time-of-flight effects, provides further evidence for the identified events' being the consequence of magnetic reconnection at an X-line. This reconnection exhaust was moreover observed at spacecraft separated by 1800 R_E, indicating the very large scales sometimes associated with magnetic reconnection in the solar wind (also see recent results of separated measurements of reconnection-related flows from Eriksson et al., 2009).

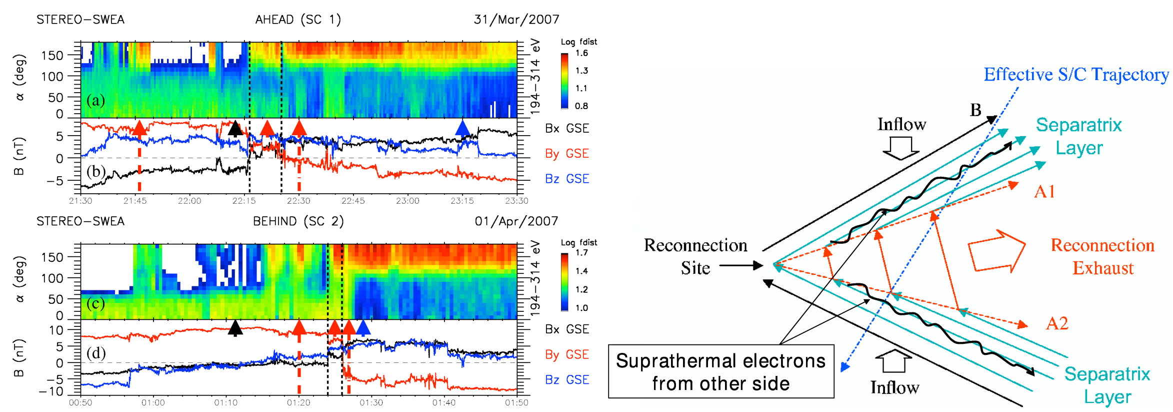


Figure 3. (a) STEREO/SWEA suprathermal electron (250 eV) pitch angle spectrograms and magnetic field data for a reconnection exhaust observed at the HCS at both spacecraft. The reconnection exhaust is marked with vertical dashed lines (from Lavraud et al., 2009). (b) Schematic of the magnetic field topology around a reconnection exhaust, with illustration of suprathermal electron leakage into separatrix layers outside the exhaust itself [adapted from Gosling et al., 2009).

Multipoint Studies of Co-rotating Interaction Regions (F2). *In-situ* data from IMPACT and PLASTIC on both STEREO spacecraft, together with ACE, Wind, and Ulysses observations, have enabled multipoint studies of CIRs over a wide range of separations. Jian *et al.* (2009a) investigated the multipoint observations of three representative CIRs, in May, August, and November of 2007, respectively, when the spacecraft had quite different spatial separations. The May and November events demonstrate that solar wind parameters can vary greatly across a CIR, whether examined at separations of 7° or 42° in longitude. CIR properties thus appear to be inherently variable on rather short time scales. Another conclusion is that shocks driven by CIRs at 1 AU are still forming, and are somewhat weak and transient structures. A shock driven by the same stream interaction can vary significantly with location, in terms of the direction of the shock normal to the magnetic field, associated wave structure, and other features. To successfully predict the space weather associated with CIRs, the inherent variability of streams and their interactions need to be considered. Even though CIRs are defined by their recurrence on successive solar rotations, STEREO in-situ observations show the stream properties are constantly changing.

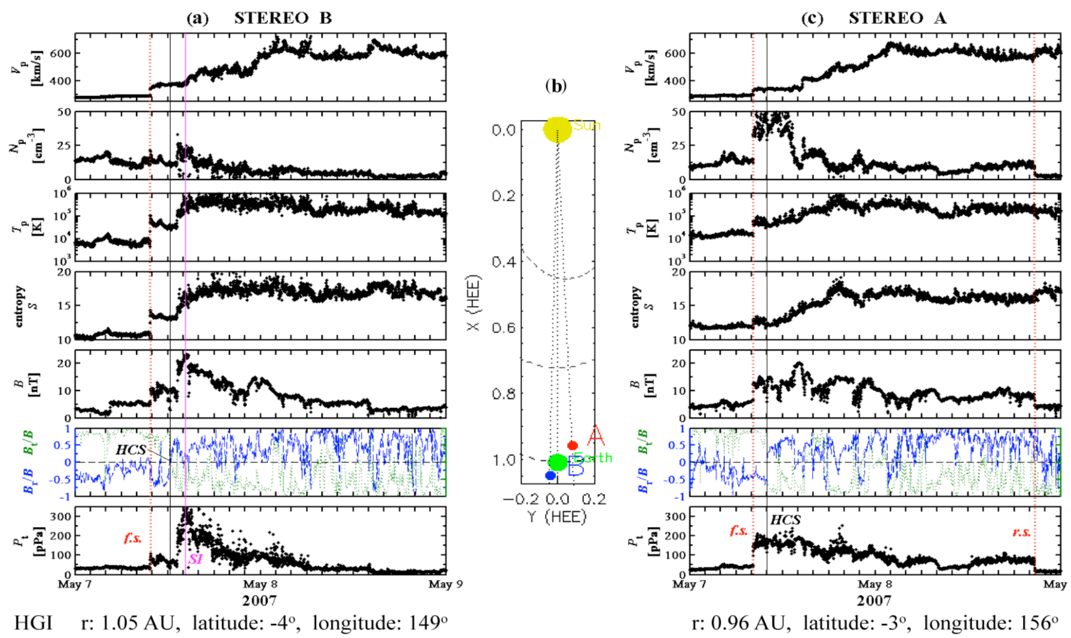


Figure 4. The in situ observations of an SIR by both STEREO spacecraft during 2007 May 7 – 8 (Jian et al, 2009a). The locations of the spacecraft in the heliographic inertial (HGI) coordinate are indicated at the bottom. From top to bottom: solar wind speed, proton number density, proton temperature, entropy defined as $ln(T_p^{3/2}/N_p)$, magnetic field intensity, the ratios of B_r (blue dashed line) and B_t (green dotted line) to B, total perpendicular pressure in the unit of pico-Pascal. The black solid vertical line indicates the heliospheric current sheet (HCS) crossing, and the magenta solid line marks the stream interface (SI) defined by the pressure peak. The red dotted lines mark the forward (f.s.) and reverse (r.s.) shocks. The panel in column (b) sketches the spatial separation of the B and A spacecraft in heliocentric Earth ecliptic (HEE) coordinates.

New Diagnostics of Solar Wind Conditions using Three-Dimensional Velocity Distributions of Iron Ions (H4, J3). STEREO/PLASTIC provides a unique opportunity for investigating the kinetic properties of iron ions in the solar wind. The sensor provides maps of three-dimensional velocity distributions with a cadence of 5 minutes. Typically, 300 counts are registered in such time intervals. Using a bi-Maxwellian, axisymmetric model of ion flows, it has been able to derive the ten parameters necessary to describe such distributions by means of a maximum likelihood technique. The ten parameters are the density, the flow vector, and the six components of the axisymmetric pressure tensor. The results show excellent reproducibility in succeeding intervals during periods of quiet solar wind. Rapid changes, *e.g.* under shock conditions, are also readily identified. A summary histogram of kinetic temperature components is shown in the Figure 5 (Bochsler *et al.* 2010a), where β_p denotes the proton plasma beta (ratio of thermal pressure over the magnetic pressure). Our measurements, covering the entire month of May 2007, cluster in the region of stability bound by the dashed lines, which delineate the ion-cyclotron and the firehose instabilities. Similar results have earlier been found for protons and electrons in the solar wind, but this is the first time such distributions have been determined for a minor ion species. Bochsler *et al.* (2010b) have also been able to derive the slope of the interface between fast and slow regimes at the source surface of the solar wind using iron as a diagnostic for corotating interaction regions (CIR's). This parameter is perhaps the most important physical property that determines the further development of a CIR in the interplanetary space .

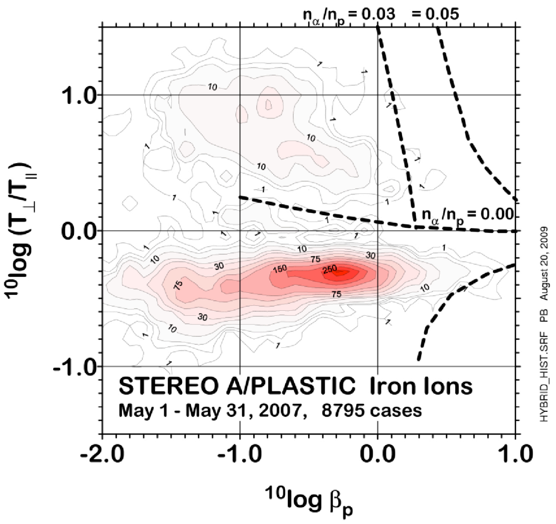


Figure 5. Logarithmically spaced contour plot of frequencies of iron kinetic temperature ratios measured by STEREO PLASTIC. The dashed lines indicate the limit against the ion-cyclotron instability. For $T_\perp/T_{ll}$ >1, the different abundances of helium have a strong influence on the onset of the instability. This is not the case for $T_\perp/T_{ll}$ <1.

Ion cyclotron waves in the solar wind (F2). Although ion cyclotron waves (ICWs) have been observed in a variety of space environments, they have not been detected in the solar wind away from planets and comets. In analyzing the STEREO IMPACT MAG data, Jian et al. [2009b] discovered that narrow-band ICWs are ubiquitous in the solar wind. Because the STEREO spacecraft are far from any planet during the period of investigation, a planetary source can be excluded. The IMPACT magnetometer's sensitivity and high data rates were instrumental in this observation. Jian *et al.* (2009b) find the ICWs often appear when the interplanetary magnetic field is more radial than the nominal Parker spiral. They propagate nearly parallel to the magnetic field and are below the local proton gyrofrequency in the solar wind frame. Because the wave frequency in the spacecraft frame is higher than the local proton gyrofrequency, the waves cannot be locally generated by ion pickup. The observations are consistent with wave generation closer to the Sun and outward transport by the super-Alfvénic solar wind. Jian *et al.* (2009b) also find that the median transverse power of these ICWs is about 0.016 nT^2 at 1 AU. If the waves are distributed uniformly over 4π steradians, then they can provide a power of about 1.4×10^{14} W. This indicates the potential solar wind heating energy for the region further out beyond STEREO. In addition, because the waves detected at 1 AU are most likely only a small fraction of the waves originally generated close to the Sun and because even the part of the power spectrum observed has been attenuated significantly, the original power should be much greater than measured at 1 AU. Work is ongoing to further investigate the implications of these results.

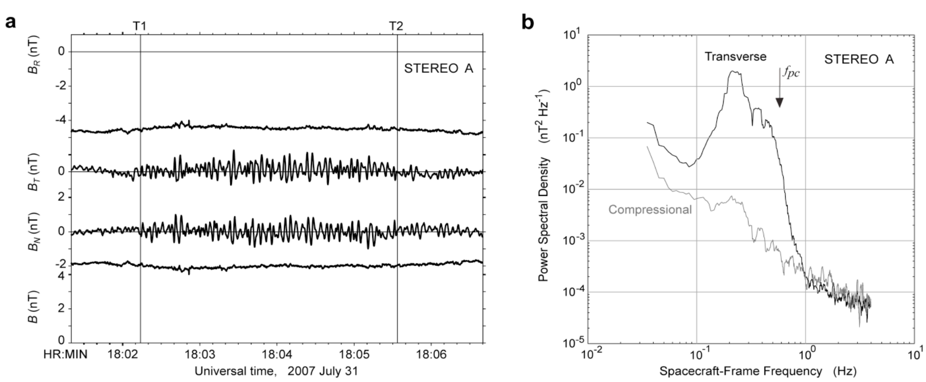


Figure 6. Example of the ion cyclotron waves in the solar wind: (a) 8-Hz magnetic field vector from STEREO A spacecraft in the RTN coordinates. (b) Power spectrum of the wave during the interval T1-T2 averaged using 13 frequency bands. The transverse power is significant and dominates the compressional power (Jian et al. 2009b).

Nearly Monoenergetic Ion Beams (F2). The IMPACT Solar Electron and Proton Telescopes (SEPT) onboard the STEREO spacecraft detect electrons in the energy range 30-400 keV and ions from 60 to 7000 keV (Müller-Mellin et al., 2008) with one minute temporal resolution and an energy resolution of ~10% in the range <1200 keV. This resolution permits a detailed study of the fine-structure of the sub-MeV ion spectra during particle increases of different origin. Recently, Klassen *et al*. (2009) reported observations of several Almost Monoenergetic Ion (AMI) events in the energy range of 100-1200 keV detected by SEPT. Most of these events were streaming from the Earth's magnetosphere, and show similar characteristics to the AMIs observed by Interball-1 near the bow-shock. These events were explained as ions accelerated in a bursty, strong electrostatic field (Lutsenko and Kudela, 1999). In addition to the AMI events streaming from the magnetosphere, STEREO observed a few events showing similar almost-monochromatic spectra but associated with interplanetary shock passages (Klassen et al., 2009). Similar spectra with a maximum were reported also by Simnett et al. (2005). Figure 7 presents STEREO-A observations of one such event associated with the passage of a CIR-related forward shock on August 25, 2007. Ions were accelerated at the shock and were not associated with magnetospheric activity. The expected increase of solar activity during the coming years, together with the rising phase of solar cycle 24, will provide the opportunity to investigate similar features of the energy spectra originating at interplanetary shocks driven by Interplanetary Coronal Mass Ejections (ICMEs).

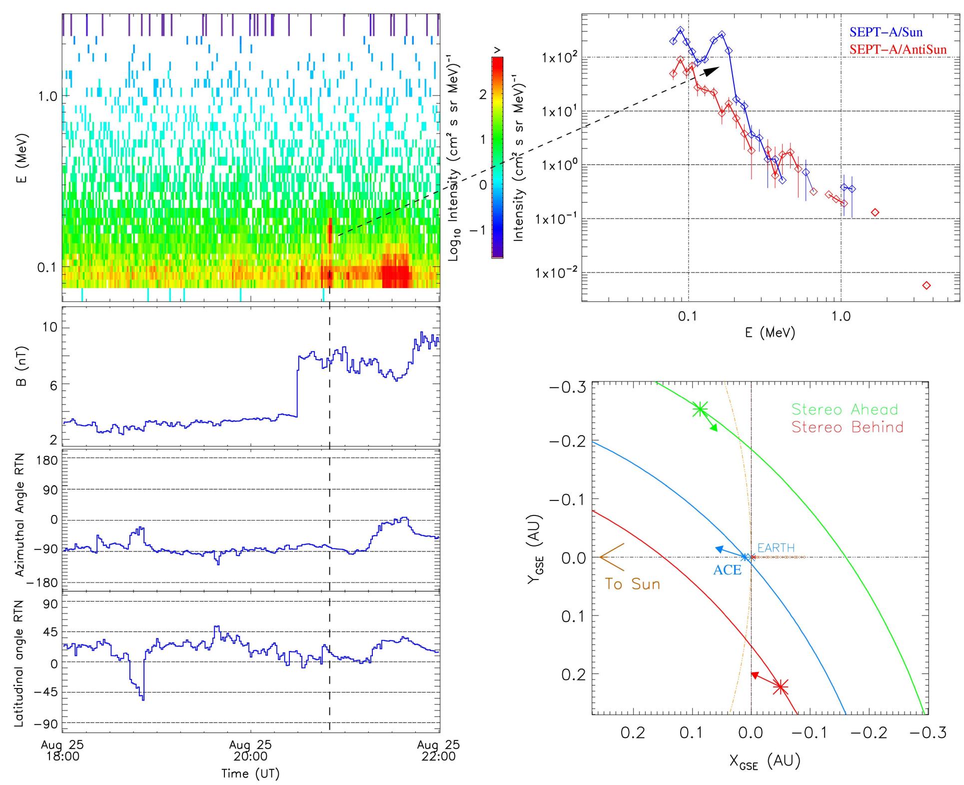


Figure 7. Almost Monoenergetic Ion (AMI) beam event observed by STEREO-A on 2007 August 25. The event occurs 20 minutes after the IP shock passage. Left: dynamic energy spectrum and magnetic field components. Top right: spectra observed by the SEPT ion telescopes pointing in solar (blue) and antisolar (Earthward) directions. Note the almost monochromatic peak centered at 165 keV observed by the Sun looking telescope. Bottom right: position of STEREO-A (green) and arrows showing the projection of the interplanetary magnetic field vector on the ecliptic plane during the event.

The Angular Distribution of Impulsive SEP events (F2). In impulsive solar energetic particle (ISEP) events, the release of accelerated ions and electrons into the interplanetary medium is thought to be very localized in space and time. Since cross field diffusion in the interplanetary medium should not play a major role, it is commonly thought that the point-like injection at the Sun should be reflected in a relatively limited spread in heliolongitude when particles are detected at 1 AU. Earlier, single spacecraft studies (Reames 1995; Nitta *et al*. 2006) found particles were most likely released with an rms spread of ~20°. Using STEREO together with near-Earth spacecraft such as ACE and Wind, it is now possible to obtain multipoint measurements of individual ISEP events and thereby improve the understanding of the longitude spread of these events.

Seven periods with ^{3}He enhancements detected by the LET instrument on one or both of the STEREOs occurred over the period 2007 January through 2009 November. During this interval the STEREOs had moved from 0° to ~64° from Earth. Searching the ACE ULEIS and SIS data sets for ^{3}He enhancements associated with these events resulted in clear associations for 6 of the 7 periods, including those near the widest separation. Thus it appears that ISEPs can frequently have access to a wider range of longitudes in the interplanetary medium than previously thought. The apparent inconsistency with the earlier, single spacecraft investigations might be attributable to instrument sensitivity limitations, since event intensity does appear to vary with separation from the observer's connected field line. As solar activity increases and the STEREO spacecraft continue to separate, it will be possible to further probe the heliolongitude distribution in ISEP events, to look for possible differences between electron and ion distributions, and to determine whether the distributions vary over the solar cycle.

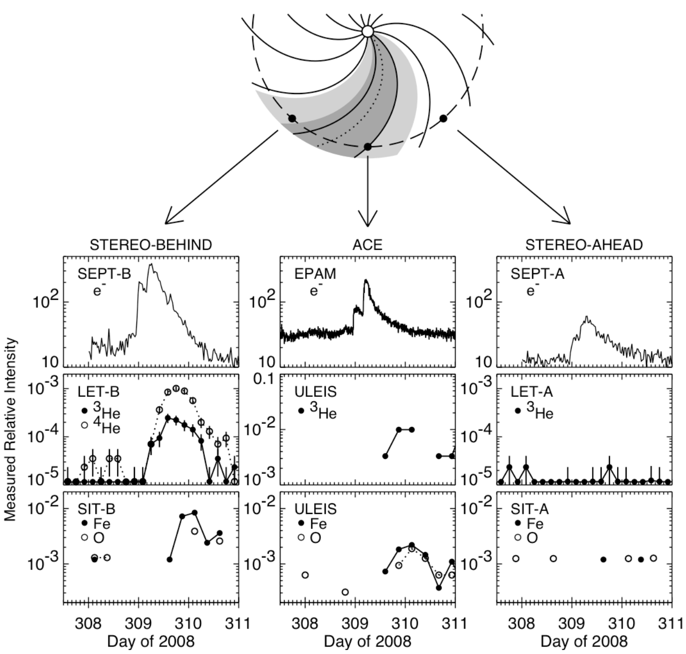


Figure 8. Measurements of energetic particle intensity versus time in the ISEP event of 2008 November 3-4. Cartoon shows locations of STEREO-A, STEREO-B, and ACE at the time of the event. The dotted line shows nominally best connected field line to the flare site, with the dark (light) shaded region indicating a ±20° (±40°) spread about this field line. Electrons from the event were detected at all three spacecraft, and heavy ions with enhanced ^{3}He and Fe/O were detected at STEREO-B and ACE.

Figure 8 (Wiedenbeck et al. 2010) shows measurements of the ISEP event of 2008 November 3-4 from the STEREO SEPT, LET, and SIT instruments together with EPAM and ULEIS on ACE. At the time of this event the two STEREO spacecraft were located ±41° from ACE in heliolongitude, and the flare event occurred at ~40W, as seen from Earth, as illustrated in the cartoon. The electron event was observed at all three spacecraft, implying a longitude spread of >80° at 1 AU. Flare ^{3}He and heavy ions were detected at STEREO-B and ACE, both of which were ~20° from the nominal Parker spiral field line connecting the flare longitude to 1 AU.

Energetic Neutral Atoms from the Sun (F2). During the X9 solar flare and associated CME event of 2006 December 6, the IMPACT Low Energy Telescopes (LETs) on STEREO A and B observed a burst of 1.6 to 15 MeV neutral hydrogen atoms (ENAs) that arrived from a longitude within ±10° of the Sun more than two hours before the main SEP event (Mewaldt *et al.* 2009). This unexpected observation revealed a new capability of the LET, as well as a new signature of particle acceleration at the Sun. Assuming isotropic emission, an estimated 2 x 10^{28} ENAs escaped the Sun from this east-limb event. When the arrival times of the burst particles were traced back to the Sun using their measured velocity, the derived emission profile was similar to that of the x-ray flare. RHESSI γ-ray observations from this flare indicated that more than 1.3 x 10^{31} protons with energy > 30 MeV interacted with the solar atmosphere, ~1000 times more than enough to explain the ENA emission, but only if most of the observed ENAs were produced at heliocentric radii >~2 R_S (at lower altitudes not enough ENAs would escape without being ionized). Thus the observed ENAs could have been produced by flare particles if a significant fraction made it to the high corona.

It is also possible, however, that the ENAs were produced by protons accelerated by a CME-driven shock (the ENA emission was consistent with the onset of type-II and type-III radio bursts indicating the formation of a coronal shock and electrons escaping from the corona). Although there are no CME observations of this event, it is estimated that charge-changing interactions of accelerated protons from a CME typical of large SEP events could explain the ENA fluence and time profile, as also shown in the Figure 9 (Mewaldt et al. 2010).

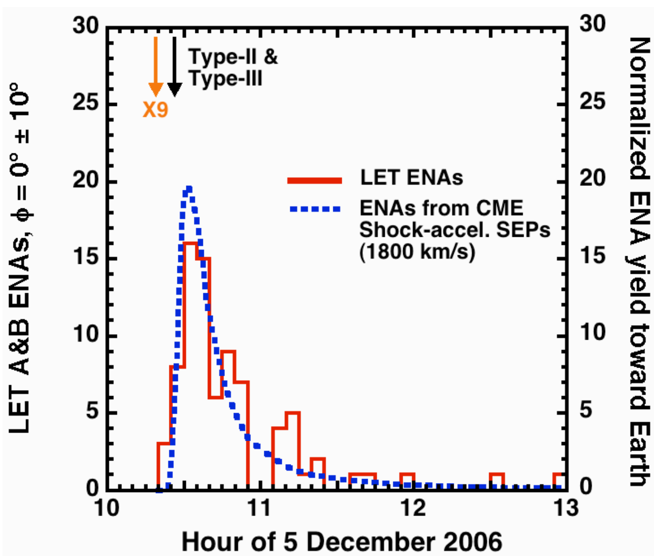


Figure 9. The estimated ENA emission profile due to energetic protons accelerated by an 1800 km/s CME (dotted curve) is compared with the ENA emission profile observed by the STEREO LETs (red histogram). The onset time of the X9 flare and solar radio bursts are indicated.

Now that the STEREO spacecraft are separated, they can add a new dimension to ENA observations of solar events. Since the escaping ENA emission observed from a given direction depends strongly on the thickness of the overlying solar atmosphere, the two STEREO spacecraft should not see the same emission profile, and it should be possible to discern flare and CME origins for the emission. In the approaching solar maximum STEREO ENA and SEP observations from multiple points of view, aided by STEREO imaging and by modeling, can provide a new window into solar particle acceleration and transport on the Sun by revealing in greater detail when, where, and how the relatively poorly known spectra of low-energy (<10 MeV) solar protons are accelerated, interact with solar matter, and escape from the Sun.

Solar Radio Burst Triangulation (F2,J3). Type III solar radio bursts result from suprathermal electrons as individual bursts from flares or Type III storms. Such storms correspond to the quasi-continuous, bursty emission from electron beams propagating on open field lines above active regions. Type III bursts with sufficient intensity on both STEREO spacecraft for useful analysis have provided triangulation results like those shown in Figure 10 (Reiner *et al.* 2009). Results obtained for the burst shown in the figure indicate a wide beaming pattern with maximum directed along the tangent to the Parker spiral at the source location. With the expected increase in solar activity, many similar type III bursts will be studied from different spatial perspectives. The statistical analysis of the type III dataset will provide significant new results on the physics of the type III emission process and the best opportunity to date to assess and understand radio propagation delays and scattering at these low frequencies.

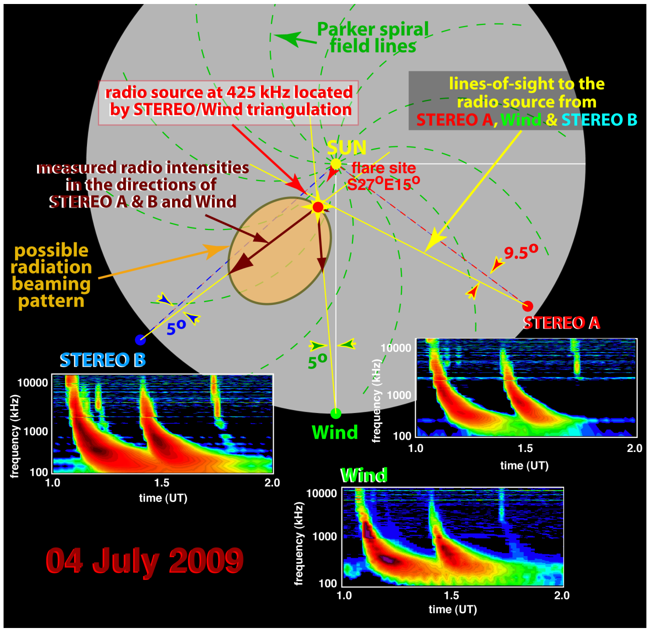


Figure 10. Dynamic spectra showing type III radio bursts simultaneously observed by STEREO A & B and by Wind on 2009 July 4. Analysis of the signals on the 3 orthogonal antennas are used to derive the line-of-sight direction to the radio source at a given frequency. The triangulation for 425 kHz is indicated. Triangulation results at all observed frequencies trace the exciter electron beam through the inner heliosphere.

Solar type III storms (F2,J3). In spite of low solar activity, the sun has produced several type III storms over the course of the STEREO mission thus far. The mechanisms by which a storm can persist in some cases for more than a solar rotation while exhibiting considerable radio activity are poorly understood. Furthermore, type III storms have also been observed as precursors to coronal mass ejections (Reiner *et al.* 2001), and so a better understanding of their properties may help to elucidate the dynamics of active regions prior to eruptive events. In a study by Eastwood *et al.* (2010) of a storm lasting several days in 2009 November, the waiting-time distribution (the distribution of times between individual type III bursts within the storm) is shown to obey piece-wises Poisson statistics, *i.e.*, constant rates governed by Poisson statistics over intervals of hours, followed by an abrupt change in the rate, as seen in Figure 11. This indicates that the individual type III bursts occur independently of one another and suggests that in the active region under consideration, magnetic energy and flux, slowly injected from below and being driven *e.g.* by twisting due to footpoint motion, are being released in a series of independent events which result in the emission from electron beams propagating on open field lines. In particular, the long lifetime of type III storms indicates that the active region can remain in such a dynamically balanced state for a prolonged period of time even as the burst rate changes. This stability was not disturbed by the ~21 GOES flares in this time interval from AR 10923, including five C-class events before 2006 November 14 (Eastwood *et al.* 2010).

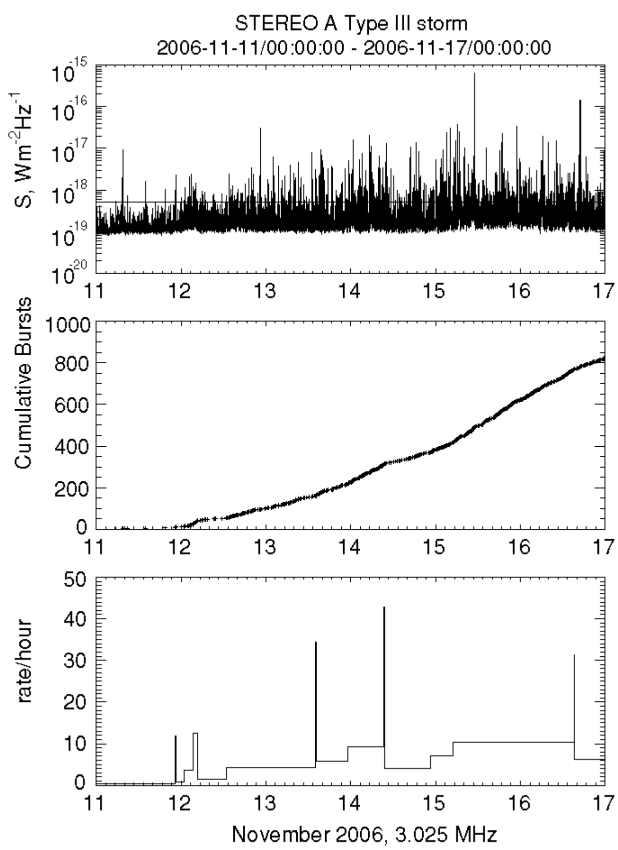


Figure 11. Top: time series at 3.025 MHz; middle panel: cumulative number of bursts; and bottom panel: results of the Bayesian blocks decomposition showing constant rates over many hours, abrupt changes, and occasional, large, short-duration increases in the rate.

Plasma wave studies (J3). The S/WAVES Time Domain Sampler (TDS) is capable of sampling at variable speeds up to 250 kilo-samples per second, however, it is most often operated at half that rate. Events with the highest peak voltage values are selected via an on-board algorithm and telemetered to Earth in blocks of 130 milliseconds (Bougeret et al., 2008). The TDS, with its 16 -bit data capture, permits new analyses of various wave modes - Langmuir, ion-acoustic, etc. - in the solar wind that have been extensively studied, but are still incompletely understood. Using the TDS, Malaspina and Ergun (2008) find clear evidence of Langmuir waves of 1, 2, and 3-dimensions (Figure 12). Nearly three quarters of ~ 1900 Langmuir waves considered were linear and oriented close to the B-field direction. Waves with significant transverse components to B were both less common and clustered in time. On the basis of this observation, Langmuir waves with 2D and 3D structure either represent a unique population or their transverse nature must be triggered, perhaps by a property of the local plasma environment – studies which are ongoing. Also using the TDS, Henri *et al.* (2009) reported direct evidence for electrostatic (three-wave) Langmuir decay during a type III burst. This is a process by which radio waves at twice the plasma frequency might be generated. Bicoherence analysis showed phase locking between the three waves on the different waveforms, characteristic of quadratic resonant interactions. Wavelet

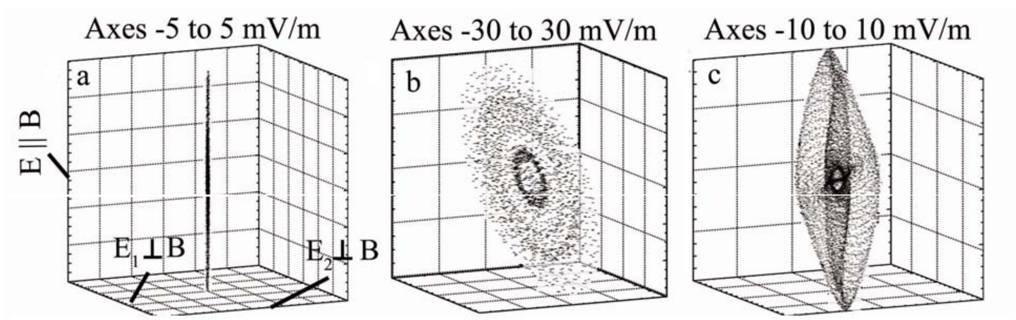


Figure 12. Hodograms of Langmuir wave with (a) 1D, (b) 2D, and (c) 3D structure. E_1 is perpendicular to B and the solar wind velocity direction. E_2 is the direction of the solar wind velocity vector component perpendicular to B. Three hundred plasma oscillations are plotted in each case for visual clarity, but the hodogram trends persist for > 500 oscillations.

analysis permitted resolution of the spatial scale of the coupling regions for the first time, estimated to be 18 ± 5 km. Numerical simulations were used to compute new instability thresholds, confirming the range of energies where the Langmuir decay occurred (Henri *et al.* 2010).

Dust (F2). An unexpected result from S/WAVES was the frequent detection of numerous short-duration voltage spikes by the Low Frequency Receiver and the TDS. These bursts were often atypically intense, saturating the TDS, whereas natural signals such as Langmuir waves have much lower peak voltages. Some of these spikes are associated with "debris" detections by the SECCHI suite of instruments (St. Cyr *et al.,* 2009). The most likely scenario is that interplanetary dust strikes the fragile indium-tin-oxide (ITO) coated thermal blanketing on the Sun-facing side of the spacecraft; the resulting short-lived plasma cloud is detected as an event by the TDS; pieces of the ITO or the blanketing are ejected from the spacecraft and detected by the SECCHI instruments. The coincidence of such SWAVES events with SECCHI HI1 debris during otherwise-quiet periods is 48 of 51 events (94%), strongly supporting the dust scenario.

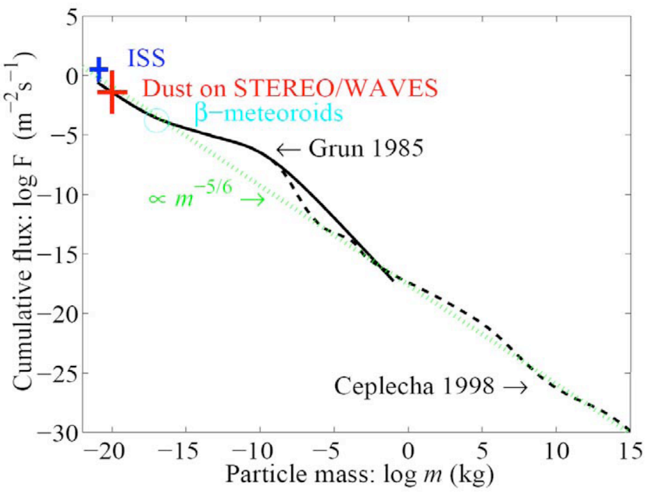


Figure 13. Flux of particles of mass greater than m. The S/WAVES result, the ISS detection, and the β meteoroids detected by Ulysses are superposed on the interplanetary dust flux model (solid line, Grün et al., 1985) and the model derived from meteor and small solar system object observations (dashed, Ceplecha et al., 1998).

In addition to S/WAVES voltage spikes during SECCHI debris events, there are many other intervals when S/WAVES detects a similar phenomenon. These signals are believed to be produced by impact ionization of nanoparticles striking the spacecraft at a velocity of the order of magnitude of the solar wind speed. Nanoparticles, which are half-way between micron-sized dust and atomic ions, have such a large charge-to-mass ratio that the electric field induced by the solar wind magnetic field accelerates them very efficiently. Since the voltage produced by dust impacts increases very fast with speed, such nanoparticles produce signals as high as do much larger grains at smaller speeds. The flux of 10-nm radius grains inferred in this way is compatible with interplanetary dust flux models (Figure 13). The present results may represent the first reported detection of fast nanoparticles in interplanetary space near Earth orbit (Meyer-Vernet *et al.*, 2009).

Identifying Solar Wind Stream Interfaces Near 1 AU (F2, H1, J3). The transition from fast to slow solar wind has not received as much attention as the inverse transition, *i.e.,* from slow to fast streams. This region is of interest however, because the solar wind speed profile is not distorted as it is by the acceleration and deceleration processes that occur in the compression region (an important factor in mapping the solar wind boundaries back to solar source regions). Burton *et al.* (1999) found the fast-to-slow stream interface could be identified by an abrupt change in specific entropy, with coincident but more gradual changes in solar wind minor ion composition. These Ulysses results were obtained at distances > 4.5 AU. Using solar wind plasma data from STEREO, the PLASTIC team further investigated both slow-to-fast and the fast-to-slow solar wind interfaces. An example of the variation of charge states in streams and their identified (by entropy) interfaces is shown in Figure 14 (Galvin *et al.* 2009). Simunac *et al.* (2009a) gave particular emphasis on possible correlations between changes in the proton specific entropy argument and the solar wind's in-ecliptic flow direction for the fast-to-slow transition. The expectation was to find a discontinuous drop in entropy associated with the change in flow angle that was used to identify the transition from fast to slow solar wind. In many cases, however, the change in flow angle took place while there was a plateau in the proton specific entropy argument. These results suggest that the sharp entropy drops observed by Ulysses (Burton *et al.* 1999) may sometimes develop outside 1 AU. In all twenty STEREO cases examined by Simunac *et al.* (2009a), the flow angle transition clearly takes more than 1 hour, supporting a gradual transition from fast to slow solar wind near 1 AU. The average timescale based on the change in flow angle is about one day, but with significant variation from case to case.

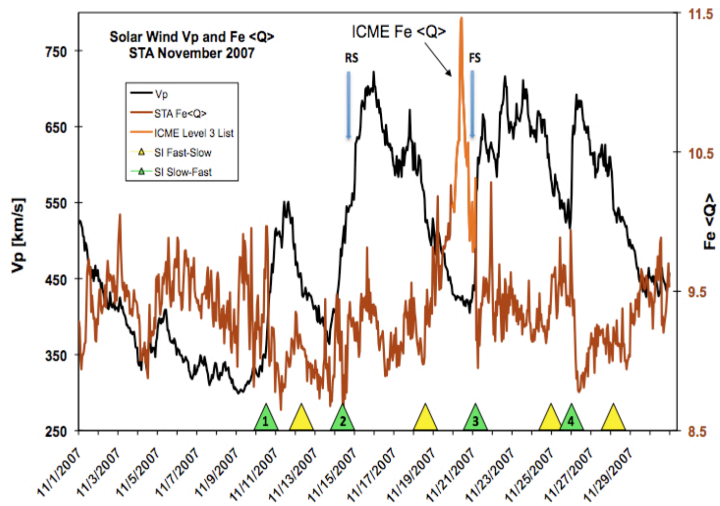


Figure 14. Coronal hole-associated high speed streams, slow solar wind, and an interplanetary coronal mass ejection observed in November 2007 by STEREO A (Galvin et al., 2009). ICMEs and shocks are identified by IMPACT/PLASTIC level 3 data sets. Stream interfaces are based on entropy changes (Simunac, 2009). Data shown are one-hour averages.

Evolution of Solar Wind Stream Interfaces (H1, J3). The heliocentric orbits of the two STEREO spacecraft are similar in heliocentric distance and ecliptic latitude, with the separation in longitude increasing by about 45 degrees per year. This arrangement provides a unique opportunity to study the evolution of stream interfaces near 1 AU over time scales ranging from hours to a few days, much less than the period of a Carrington rotation. Assuming non-evolving solar wind sources that corotate with the Sun, Simunac *et al.* (2009a) calculated the expected time and longitude-of-arrival of stream interfaces at the AHEAD observatory based on the earlier *in situ* solar wind speeds measured at the BEHIND observatory. They find agreement to within 5 degrees between the expected and actual arrival longitude until the spacecraft are separated by more than 20 degrees in heliocentric inertial longitude. This corresponds to about one day between the measurement times. Much larger deviations, up to 25 degrees in longitude, are observed when the 20 degrees satellite angular separation is exceeded. Some of the deviations can be explained by a latitude difference between the spacecraft, but other deviations most likely result from evolution of the source region. Both remote and i*n situ* measurements show that changes at the source boundary can occur on a time scale much shorter than one solar rotation. In 32 of 41 cases, the interface was observed earlier than expected at STEREO/AHEAD.

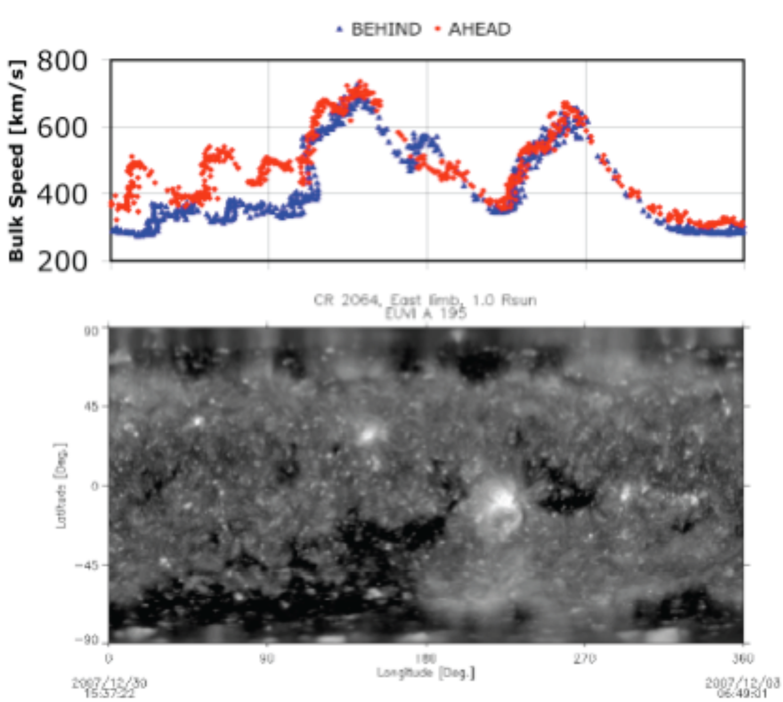
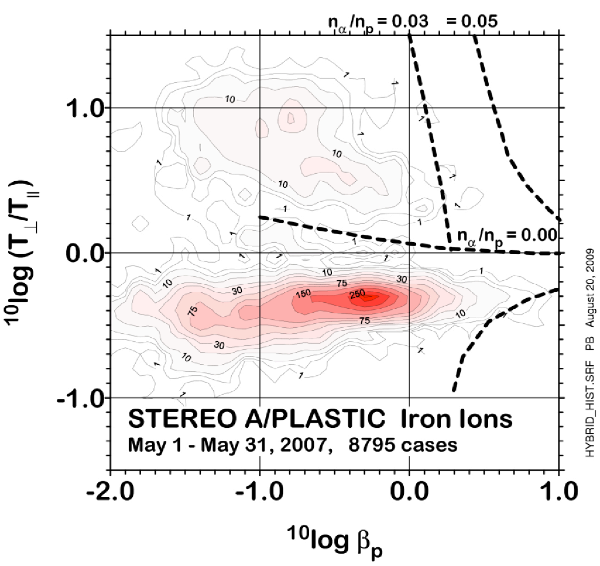


Figure 15. (Top) Bulk solar wind speed measured at STEREO/PLASTIC and mapped back to its source longitude. Bottom panel: STEREO-A/SECCHI 195 Å synoptic map. Note that the high-speed streams observed by PLASTIC correspond to the dark coronal hole regions in the SECCHI map (Bottom).

Reconstruction of a Magnetic Cloud using STEREO-WIND observations (F1, F2, H1). Using observations of a magnetic cloud (MC) event observed by Wind and STEREO-A, on 2007 May 23. Möstl *et al.* (2009b) tested the validity of the ideal, 2-D MHD Grad-Shafranov (GS) reconstruction method for the cloud's magnetic structure. Having ascertained that the method was applicable, they used the results to improve the GS method. They applied the GS reconstruction to the STEREO-A plasma and magnetic field data from IMPACT and PLASTIC, respectively, and then optimized the resulting field map with the aid of observations by Wind. The latter observations were made at the very outer boundary of the magnetic cloud, at a spacecraft angular separation of 6°. For the correct choice of reconstruction parameters, such as axis orientation, interval and grid size, Möstl *et al.* found both a very good match between the predicted magnetic field at the position of Wind and the actual measurements, as well as a correct arrival time. The resulting shape of the magnetic cloud cross-section consisted of a distorted ellipse, slightly flattened in the direction of motion. The internal field geometry, however, was inconsistent with a classic force-free model for MCs (Burlaga 1988). The part of the MC closer to the Sun is non-force-free and is interacting with the trailing high speed stream. Based on the optimized reconstruction Möstl *et al.* suggest guidelines for the improved use of single-spacecraft Grad–Shafranov reconstruction. The magnetic cloud orientation was also consistent with the CME direction shown by Mierla et al. (2008) so that the apex of the CME has passed below the ecliptic and the spacecraft encountered rather a "leg" of the CME.



. Reconstructed magnetic field map of a magnetic cloud from -A measurements, optimized using Wind observations. Black represent transverse magnetic field lines in the paper plane, -coded is the Bz component pointing out of the paper. The s at the white dot. Upper (lower) yellow (red, black) arrows REO-A (Wind) observations of transverse magnetic field ts, green arrows are residual velocities in the deHoffmann – me at STEREO-A. The solid white contour is the MC

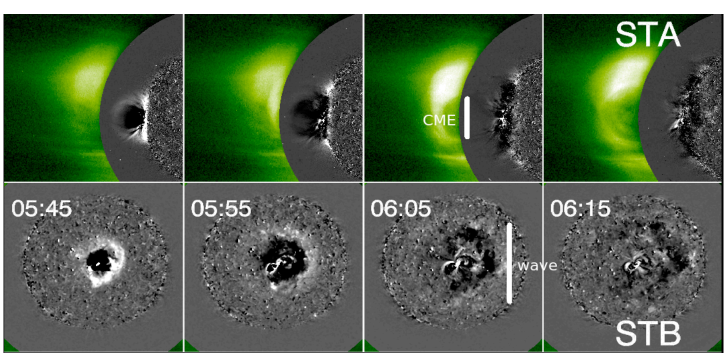


Figure 17. Quadrature EUVI Fe XII 195 Å difference and COR1 images of the CME and EUV wave of 2009 February 13. The two viewpoints make it easy to disambiguate the CME material from the wave, due to their different sizes.

Confirming the nature of EUV Waves (F1, F2, H1). Thompson et al. (1998) first reported propagating wavefronts in the extreme ultraviolet (EUV) low in the corona that originated in the same regions as CMEs. The waves appeared consistent with propagating, fast-mode disturbances, but at least some authors (e.g. Delannée and Aulanier 1999) interpreted the observations as evidence of reconnection at the footpoints of large loop structures, possibly those bounding the CME itself. It was realized at the time that EUV observations from the STEREO spacecraft, when sufficiently separated, could distinguish between the two interpretations. When the STEREO spacecraft were essentially at quadrature (2009 February 13), Finally, the quadrature observations of a CME-wave event on February 13, 2009 allowed Patsourakos and Vourlidas (2009) to separate the CME material from the material displaced (not ejected) by the wave (Figure 17). They were thus able to conclude unambiguously that a true, low coronal, propagating wave was being observed. This result was further verified by 3D reconstructions where it was found that a separate wave structure was necessary to replicate the observations from the two viewpoints. (A NASA press release made this work accessible to the public.)

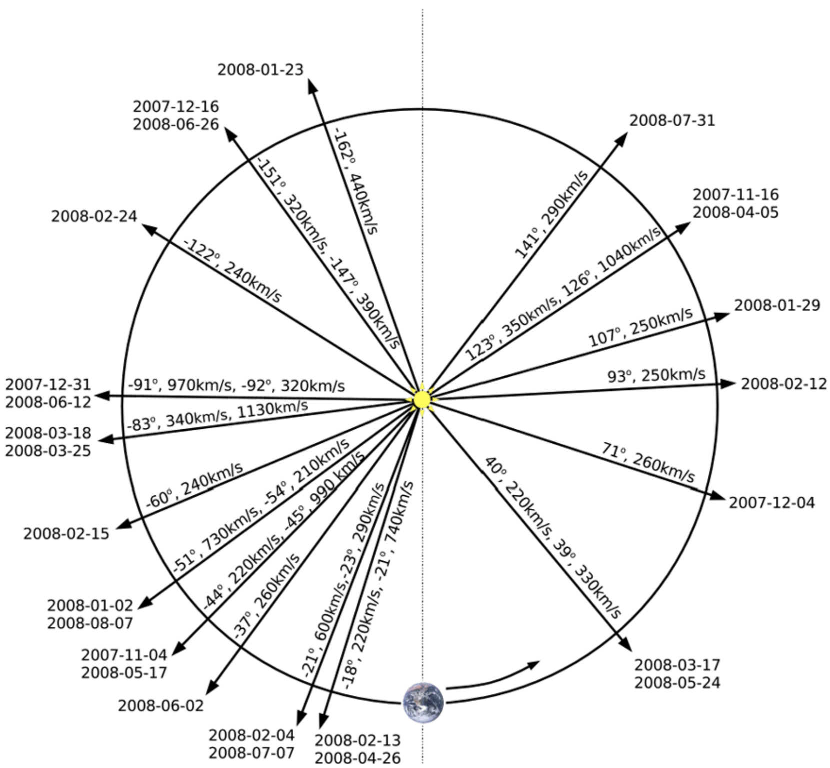


Figure 18. True velocities and directions of CMEs (From Thernisien et al 2009).

3D CME Reconstruction Reveals the Fluxrope Nature of CMEs (H1,F1,F2). Despite the prolonged minimum, the SECCHI coronagraphs have already observed more than 400 CMEs. Since 2007 November, CME reconstruction has become possible, and progressively easier, as the increased separation of the spacecraft results in very different projections of the same event in each coronagraph. Thernisien *et al*. (2009) have shown that it is possible routinely to reconstruct almost every CME and determine its true speed and direction with an accuracy of <10° (Figure 18 shows an example for 17 events. A geometric model with the outline of a magnetic flux rope has successfully fit *all* of the events analyzed so far. This indicates that most, if not all, CMEs are flux ropes, and the SECCHI reconstructions can provide the orientation of the flux rope axis. This is one of the important parameters for determining the geoeffectiveness of a CME; the others are the direction and strength of the magnetic field in the fluxrope. This research was the subject of a NASA Science Update on 2009 April 14. Moran *et al.*(2010) have shown that it is also possible to reconstruct CME location and propagation direction from the polarized brightness (pB) measurements obtained by SECCHI COR-1 coronagraphs.

Improved coronal magnetic field extrapolation (F1, F4, H1). The 3D topology of the corona above an active region was derived from stereoscopically triangulated loops in EUVI images by Aschwanden *et al.* (2009). The results were compared to force-free extrapolations of photospheric magnetographic measurements of the same active region (DeRosa *et al.* 2009). A significant misalignment of 20-40° was found between the coronal magnetic fields computed from the techniques, depending on the complexity of the active region (Sandman *et al.* 2009). This study proves that the magnetic field in the photosphere is not force-free and fundamentally cannot reproduce the coronal magnetic field. Forward modeling of 3D coronal loop geometries is required to improve modeling of the coronal field. Preliminary results also show misalignments, but typically of only 10-20°.

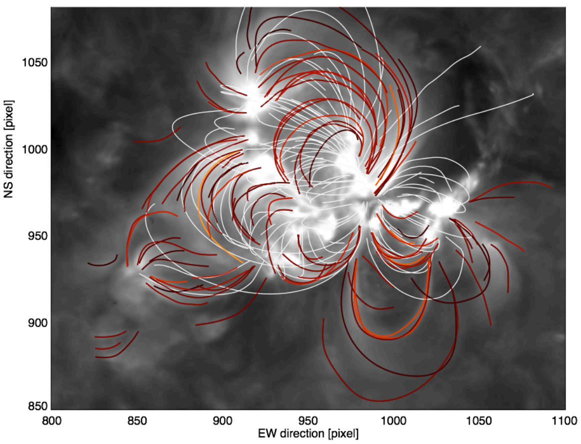


Figure 19. STEREO SECCHI EUVI loop image, with unstretched potential field extrapolation (white lines) superposed and hand-identified loops (red lines).

A Test for Space Weather Monitors at L5 (F2, H1, J3). Corotating interaction regions, or CIRs, are a well-known cause of recurrent geomagnetic storms. Trailing the Earth by 60º in heliographic longitude, the L5 Lagrange point is a logical location for a solar wind monitor. Nearly all CIRs could be observed at L5 several days prior to their arrival at Earth. Because the Sun's heliographic equator is tilted about 7º with respect to the ecliptic plane, the separation in heliographic latitude between L5 and Earth can exceed 5º. In July 2008 the two STEREO observatories were separated by about 60º in longitude and more than 4 degrees in heliographic latitude. This period thus provided a timely test for the practical application of a solar wind monitor at L5. Despite the heliographic latitude separation, the solar wind speed profiles observed by STEREO-B/PLASTIC and STEREO-A/PLASTIC were similar during this period of very low solar activity. Under the assumptions of ideal corotation and minimal source evolution, the arrival times at STEREO-A of two high-speed solar wind streams, first observed at STEREO-B, were predicted to within 10% of the total corotation time between the two observations. Ongoing work will determine if solar wind-magnetosphere energy/momentum coupling functions in common use are retained in going from L5 to Earth.

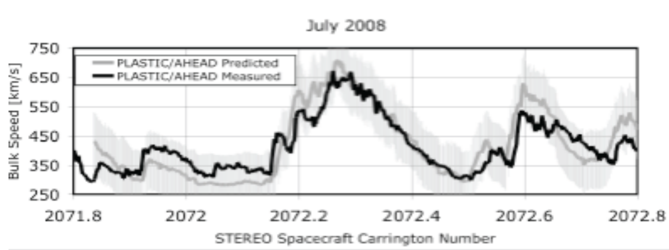


Figure 20. Predicted and observed solar wind speed at PLASTIC/AHEAD during July 2008. An uncertainty of ± 100 km/s on the predicted speed is shown with grey shading, while the observed values are given by the solid black curve.

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IV. Proposed Science, 2011 – 2014

During the period FY1 1- FY14, the maximum of solar activity cycle 24 should occur, the STEREO spacecraft will reach 180º separation (on 2011 February 6), and heliophysicists should be able to combine STEREO observations with the knowledge from the SDO and RBSP LWS missions. Simply put, STEREO will observe space weather disturbances both remotely and *in situ* through the rise to solar maximum.

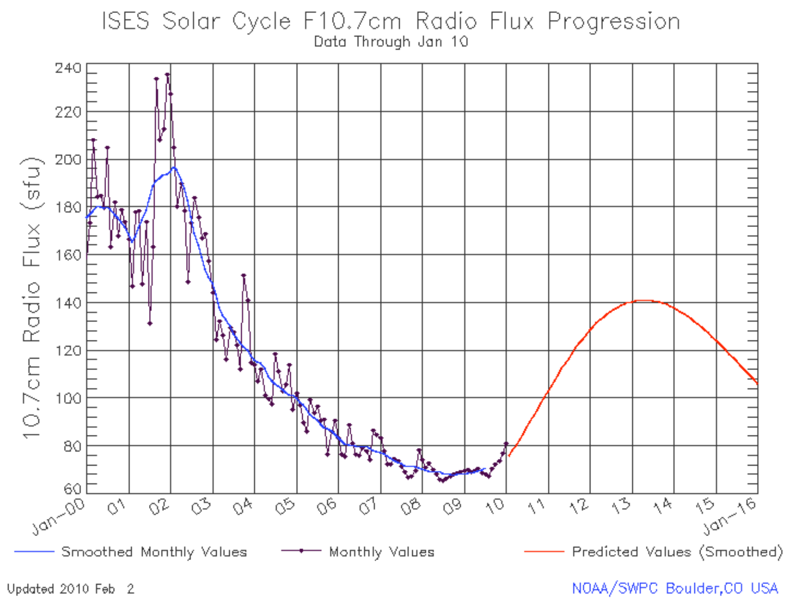

Figure. Solar activity cycle 24 follows a prolonged and deep solar minimum. Current predictions are for the lowest activity maximum (shown here: solar $F_{10.7}$ flux) in the last 9 - 10 activity cycles.

As the STEREO spacecraft reach mutual opposition, they will image the entire range of solar longitudes. An animated projection onto a sphere of 195 Å images from both SECCHI EUVI telescopes on the STEREO homepage, and a Mercator projection of the same images on the SSC latest images page illustrate the shrinking area of no coverage. STEREO imagers should thus be able to view as limb- or near-limb events all activity of interest on the earthward hemisphere for much of the four years under consideration.

Rate (kbps)	Ahead	Behind	Daily Telemetry Volume (Gbit)	Pass duration (hr)
720	2007/01	2007/01	5	4
480	2008/10	2008/09	5	5
360	2009/05	2009/06	5	6
240	2010/04	2009/12	4	7
160	2010/09	2010/09	2.7	8
120	2011/04	2010/11	2.1	8
96	2011/09	2011/09	1.7	8
60	2012/08	2012/08	TBD	TBD

Rate (kbps)	Ahead	Behind	Daily Telemetry Volume (Gbit)	Pass duration (hr)
30	TBD	TBD	0.6	10

Table IV-1. STEREO telemetry rates and start dates. Projected dates in grey. The 720 kbps rate was the rate at heliocentric orbit insertion. Pass duration increases as rates decrease. Daily telemetry volume indicates a requirement; mission ops has surpassed these figures consistently during the mission to date. The 60 kbps rate is under consideration.

As the distance between earth and each of the STEREO spacecraft continues to increase, the telemetry rate must necessarily drop until the two spacecraft are at 2 AU from the earth in 2015 March. Through the period covered by this proposal, Table IV-1 gives the expected rates and total daily telemetry for each spacecraft. The reduction in telemetry rates forces tradeoffs for each instrument, which must reduce temporal and or spatial sampling rates, or increase data compression. The current version of the STEREO Science Operations Plan describes each instrument team's observing plans for the decreased data rates. It should be stressed that none of these plans limit the ability of the STEREO mission to continue its pursuit of its primary scientific goals, or of those listed below.

STEREO and the Heliophysics System Observatory. Most of the STEREO scientific results in the 2009 special issues of *Solar Physics* and *Annales Geophysicae* involved the interpretation not only of two or more STEREO instruments' data, but of data from other Heliophysics missions as well. In the three years since the STEREO spacecrafts' insertion into heliocentric orbits, they have become major assets in addressing the scientific goals of NASA's Heliophysics effort. We describe below a sample of ways in which these efforts will continue in the epoch of SDO and RBSP.

Specific Scientific Objectives, FY11 - FY14

Observing the rise of a new solar cycle from novel viewpoints (H1, H4, J3). For the first time, STEREO has made it possible to observe the behavior of the full Sun. Many of the objectives listed below will be possible because of the locations of the STEREO spacecraft relative to each other, and to other Heliophysics assets in the inner heliosphere.

CME RF triangulation (F2, J3). Although the mutual opposition separation of the STEREO spacecraft in 2011 will not be the ideal configuration for radio triangulation, structures moving Earthward (or anti-Earthward) from the Sun and beyond several tenths of an AU from the Sun will be appropriately located for triangulation. Thus interval from late 2010 to mid-2011 is a period when S/WAVES remote observations and *in situ* solar wind and magnetic field measurements by a near-Earth asset such as Wind would be complementary. The focus will be on Earth-oriented CMEs and their potential space weather effects.

Type II bursts (F2, J1, J3). Beyond mid-2011, as STEREO A and B converge behind the Sun as viewed from Earth, a maximum in solar activity will present numerous type II bursts, produced by CME shocks, for statistical analysis. The combination of remote observations from SECCHI and S/WAVES, in conjunction with *in situ* particle and field data from IMPACT and S/WAVES, will provide the necessary datasets to study the fastest CMEs and shocks of the solar cycle.

Multipoint Studies of Large SEP Events (F1, F2, H1 J3, J4). Measurements of a modest SEP event on 2009 December 22 observed by ACE and both STEREO spacecraft indicates that fairly narrow CME's can result in energetic particles distributed over more than 130° of heliographic latitude. As larger events occur during the coming solar maximum they can provide direct measurements of the longitudinal evolution of CME shocks and SEPs and can be used to test model predictions of the dependence of SEP composition and spectra on shock geometry (Tylka et al. 2005, Li et al. 2009). Using SEP/CME/EUV/radio timing and comparisons of spectra and composition at different longitudes allows us to separate CME-driven from flare-driven contributions to SEP events. Realtime, multi-spacecraft studies with widely-separated spacecraft (STEREOs/ACE) will explore the use of SEP intensities from a well-connected spacecraft to forecast SEP intensities once the shock arrives at poorly connected spacecraft.

Multi-Point Imaging and In Situ Studies of Particle Acceleration and Transport (F2,H1). There have recently been examples of small impulsive SEP events observed by both STEREO spacecraft at separations up to >130°, indicating that these events have access to a wider range of longitudes than previously thought. Multi-spacecraft imaging, radio-burst, and *in situ* studies should constrain possible acceleration and release mechanisms for these impulsive SEP events that are associated with coronal jets.

Probing the interplanetary medium before and after a CME (F1,H1,J1,J3). Type III bursts, which are produced by radio emission from flare-accelerated electrons escaping beyond the corona on open field lines, provide a means of tracing the open field lines. As the electrons spiral along the magnetic field, the plasma and radio waves that are excited will enable S/WAVES to track the field lines, as indicated in Figure 9. In addition, the densities at the radio source locations can be derived from the emission frequency, and major changes in field orientation or density along the field lines will affect the observed type III bursts.

Thermal noise as a probe of filament material in magnetic clouds (J1, J2, J3). The S/WAVES antennas are sensitive to both electromagnetic waves from distant sources and electric fields generated locally. Thermal electrons in the solar wind induce measurable electric field "noise" in the antennas, and the resulting spectrum can be fitted in the frequency range of the electron plasma frequency to derive the density and electron temperature *in situ*. The technique would work well in the relatively dense, cold material from a filament eruption; therefore, magnetic cloud intervals will be examined for any intervals when such material passes either of the spacecraft.

Solar System space weather studies (F2, H1, J3). With spacecraft carrying plasma and field instrumentation spread throughout the inner solar system, particularly Messenger at Mercury, Venus Express at Venus and Mars Express and MAVEN (arrival 2014) at Mars, STEREO measurements can be used to track disturbances even when not earthward directed, and observe their consequences at other planets. In particular, the MAVEN mission has as its mandate a goal of determining the effect of solar and interplanetary activity on Mars atmosphere escape. Similarly, Messenger will make measurements of the interplanetary particles and fields at 0.3 AU of importance to Mercury's magnetosphere and exosphere, and with possible relevance to Solar Probe planning. Wide availability of the STEREO data sets and tools to put them in context with other observations, such as provided by the developing VSO and VHO, will allow exploitation of the STEREO information for understanding space weather at these other terrestrial planet and inner heliosphere locations.

Ion cyclotron waves and reconnection in the solar wind at active solar times (F2, J1, J3, F1, H1, H4, J2). As the solar wind evolves with the progression of the activity cycle, we will have the opportunity to determine how its characteristics change, and thus the relative contributions of different processes to its generation. For example, ion cyclotron wave heating is one of the primary contenders for fast solar wind acceleration, while transient reconnections at the open/closed field boundaries of coronal holes is expected to contribute a significant portion of the slow solar wind. The discovery of periods of ion cyclotron waves in the solar minimum solar wind with STEREO (Jian *et al.*, 2009b) has contributed to the continuing debate on fast solar wind acceleration mechanisms. As the solar evolves with solar activity it will be important to track the change in occurrence and strength of these waves. Likewise, it will be important to monitor the solar wind for signatures of either remote or local reconnection, by looking for the Gosling et al. (2007) type of local signatures, or the Rouillard et al. (2009) and Kilpua et al. (2009a) type of near-Sun reconnection debris signatures. STEREO's unique capabilities such as high time resolution *in situ* field measurements and HI imaging, combined with multispacecraft *in situ* plasma and field measurements are key to such observations.

Energetic neutral atoms (F2). Studies of solar ENAs from separated points of view should distinguish possible accelerated-particle populations and sites responsible for their production, and reveal how accelerated particles escape the corona.

Solar cycle modulation of anomalous cosmic rays (H1). The recent STEREO/ACE/Ulysses study of anomalous cosmic-ray spatial intensity gradients (Cummings *et al*. 2009) is an example of how the heliosphere modulates the propagation of incoming cosmic rays on large spatial scales. We should be able to determine if those spatial gradients vary with the onset of solar maximum.

The first full coverage of the lower solar corona (H1, H3, F4, J2). Starting in 2011, the SECCHI EUVI imagers will be able to view the full, 360^o solar corona. As they drift behind the Sun, they will stop observing parts of the Earth-facing disk. That gap, however, will be fully covered by the AIA telescopes on the recently launched SDO. The result will be continuous, full coverage of the EUV corona for as long as STEREO remains operational. This is likely our only opportunity to understand the evolution of the large-scale structure of the solar corona (active regions, filaments, streamers) without observing interruptions and for a significant part of a solar cycle. It will also provide a "calibration" of the far-side imaging from the helioseismology observations leading to a better understanding of the magnetic flux emergence and the evolution of the solar dynamo.

Multipoint observations during the rise to solar maximum (F1, H1, F2, J3, J4). The continuing availability of the LASCO coronagraphs in combination with the SECCHI coronagraphs and heliospheric imagers will allow measurements of CMEs throughout the inner heliosphere from multiple perspectives, thus enabling us to determine their three-dimensional extent as well as the extent of their driven shocks, and allowing us to separate CME-driven from flare-driven SEP events.

Coordinated Observations of the Interstellar Helium Cone with Pickup He^+(F2, H1, H4). An interstellar wind of neutral atoms flows through the inner heliosphere due to the Sun's motion relative to its neighborhood. Ionization by solar UV, solar wind ions, and solar wind electrons transforms some neutrals into pickup ions**,** most prominently He^+ at 1 AU. There is a factor of two difference observed between production and loss rate. An adiabatic relationship has been assumed, but not verified. Pickup ion distributions vary strongly, even on time scales of days, most likely due to strong transport effects under varying solar wind conditions. These variations are still poorly understood and prevent more accurate determinations of the interstellar gas parameters. Recent observations with STEREO/PLASTIC point to the importance of solar wind stream interaction regions, which are prevalent during solar minimum conditions, in shaping the pickup ion fluxes across the focusing cone (Figure 21).

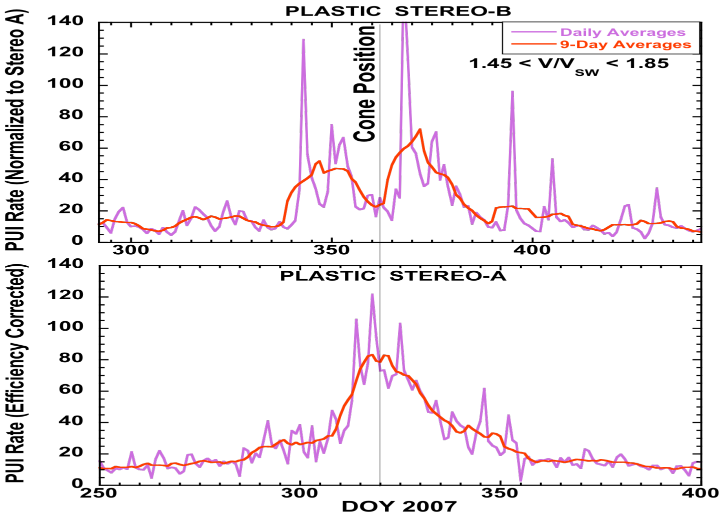

Figure 21. He^+ pickup ion rate with STEREO A and B averaged over 1 day and 9 days for the focusing cone traversals in 2007. The cone structure as observed in pickup ions is strongly modulated in a starkly different way at the two spacecraft by the passage of high-speed solar wind streams concurrent with the pickup ion flux increases that do not coincide necessarily with cone center.

Combining pickup He^+ measurements (from STEREO A & B, ACE, MESSENGER, and CASSINI) with direct observations of the neutral He gas flow distribution (from IBEX at 1 AU) will provide multi-point observations from different latitudes and longitudes at increasing separation, as well as radial distances. The upcoming observation period will likely fall into rising solar activity with starkly changing ionization and solar wind patterns. This will allow us to: determine the magnitude and spatial/temporal variations in the He ionization rate on all time scales, and thus improve the accuracy of interstellar gas parameters; investigate the mostly unknown causes for the medium and small-scale variability of the He+ fluxes; study the mobility and transport processes of pickup He+ ions in the solar wind using successive measurements of the pickup He+ cone profile; observe the radial evolution of pickup ion distributions from MESSENGER via ACE and STEREO to Cassini; and examine ionization parameters using both PLASTIC instruments and TIMED/MAGIC.

Relating remote images of interplanetary coronal mass ejections and magnetic clouds to their in situ signatures at 1 AU (F2, F1, H1). Möstl *et al.* (2009a) and Liu *et al.* (2009) were able to link remote imaging of a coronal mass ejection (CME) to its in situ signatures at 1 AU. This technique is predicated on the availability of data from two distant observing points. They were able to determine for the first time the detailed relationship between features in the images of a CME in the inner heliosphere (taken by the STEREO-A HI) and *in situ* data of its interplanetary manifestation at 1 AU (observed by STEREO-B). In particular, the direction of propagation of the ICME was calculated by various techniques, which were found to be consistent with one another to within a few degrees. With the expected rise of the solar activity we anticipate having many opportunities to apply these powerful techniques to ICMEs and magnetic clouds passing one spacecraft (STEREO A or Wind, for example) while their passage through the inner heliosphere is imaged from the other remote STEREO spacecraft. The data analysis tools (such as the Grad-Shafranov reconstruction techniques for modeling the *in situ* data) are now well developed from our earlier STEREO studies (Möstl *et al.* 2009b, 2009c, Liu *et al.* 2009) and we are prepared to track the inner-heliospheric propagation of ICMEs, one of the major goals of the STEREO mission.

Spatial and Temporal Evolutions of Intensity as a Probe for Acceleration Efficiency (F2). Observing energetic He^+ at CIRs and/or CMEs at multiple locations simultaneously, but distributed over longitude, will shed more light on the acceleration efficiency of large-scale structures. For instance, when observing the same CIR, CME, or compression region at different locations we can study dependence of the acceleration efficiency on the local shock normal angle and the turbulence associated with these plasma structures.

Spectra, and Composition of Suprathermal Particles as Probes for Energetic Ion Source Populations (F2, H4). During the recent, deep solar minimum the strength of the tails was extremely low. Increases in solar activity usually start with some isolated disturbances that travel through interplanetary space. Furthermore, with higher solar activity the seed populations of ions (for instance He^{+}) will increase and/or change, which in turn may lead to mediation of particle acceleration efficiency at interplanetary structures. Data from ACE/SEPICA are available for the energetic He^{+}/He^{++} ratio for the declining phase of the former solar cycle. With STEREO A & B we will measure this ratio during the rise phase of the new solar cycle. These two solar cycle phases are significantly different. In the increasing phase we start with a quiet interplanetary space (almost no interplanetary disturbances and therefore fewer seed particles for ion acceleration) whereas in the declining phase the interplanetary space is full of seed particles and disturbances. By comparing the spatial and temporal evolution of the intensity, composition, and spectral properties of the tails with that of the local turbulence level and the occurrence of solar wind disturbances, source regions and mechanisms can be identified.

References: See References after Section IV

V. Technical and Management

The STEREO End of Prime Mission review was held in 2009 November, and the mission was found to have achieved all of its Level-1 scientific goals. Although mission operations staffing is unchanged, *science operations and data analysis stepped down to ~ 50% of the level during the prime mission at the beginning of 2010 February*. Since the science operations (planning, pipeline data processing, &c.) staffing is difficult to reduce safely, the net effect of this, regrettably, is to reduce the amount of science the PI teams can carry out, in keeping with the Heliophysics mission extension paradigm.

Cost Area	FY10	FY11	FY12	FY13	FY14
IMPACT	989	1,198	1,211	1,215	1,278
PLASTIC	333	556	555	545	574
SECCHI	2,536	2,373	2,367	2,345	2,428
S/WAVES	585	549	522	507	510
Guest Investigators	790	0	0	0	0
Civil service Co-I's	544	398	374	325	342
STEREO Science Center	504	559	521	521	538
GSFC Directorate taxes	297	206	194	184	190
APL (mission ops)	3,675	3,781	3,911	4,026	4,026
SSMO (mission ops)	192	199	206	213	213
JPL (SECCHI Co-I)	254	180	140	120	140
Total**	10,700	10,000	10,000	10,000	10,240

Table V-1. Actual breakdown of STEREO mission funding by year. NOTES: (1) The APL mission operations effort is funded directly by NASA HQ. (2) Part of the FY10 level of effort was funded in FY09; as a result, the actual FY10 guideline is lower than the total displayed for this year. (3) The GSFC labor and travel lines covers civil service science operations labor and travel, and includes institutional taxes charged on them. (4) The parts of the IMPACT, SECCHI, and S/WAVES activities carried out by GSFC contractors also includes those institutional taxes. (5) All education and public outreach activities are carried out by the PI teams, with coordination by the Deputy Project Scientists.

The budget breakdown in Table V-1 may be more helpful than the standard spreadsheet submitted with this proposal; it at least represents the project scientist's way of thinking about the budget.

The STEREO Science Center line includes funds in FY11 for STEREO's share of the replacement of storage hardware used by *Hinode*, TRACE, and *SOHO* as well as STEREO.

Appendix A. Education and Public Outreach

Since the spacecraft were launched in late 2006, the many and varied STEREO E/PO efforts have touched upon people in just about every state and in many foreign countries as well. From classroom activities to products they have received to planetarium shows, the story of the first 3D solar mission has captured interest and engaged the public in the field of solar science. The *STEREO* project is involved in a diverse array of educational activities in the areas of formal and informal education. This is partly because each of the four instrument teams and the *STEREO* Science Center (SSC) has its own E/PO effort, and each PI team and the SSC have an E/PO lead, with Deputy Project Scientist T. Kucera as overall lead. It is also because we see ourselves as having a key role in providing mission related content and excitement to programs that are run by other groups. The different *STEREO* teams and partners communicate regularly by telecon and email, and support each other according to their specialties. Below we describe highlights of the work of the *STEREO* E/PO teams.

IMPACT

Over the past two years, STEREO/IMPACT and Wind Education and Public Outreach efforts have pooled resources toward common goals to: 1) engage the public in solar wind science using Wind and STEREO/IMPACT data and sounds made from this data; 2) increase the public's awareness of the solar wind, coronal mass ejections, and the effect of the solar wind and CMEs on Earth's systems; and 3) to increase the use of our magnetism activities in classrooms around the country. In an attempt at meeting our first two goals, we have given talks on the solar wind in the context of sounds and science (for instance through the UCLA sounds and science public conference webcast talks, the San Francisco Exploratorium's podcasts, and the Astronomical Society of the Pacific Amateur Astronomy Network for the International Year of Astronomy). There are more talks planned for this coming FY10 year. The sonification software turns solar wind data into sounds offering a new way for students and the public to perceive heliophysical data. The software was field-tested a public event at the Exploratorium, and we are currently working to debug and improve the software based on that test. Starting from the IMPACT E/PO website and working with the WIND and ACE E/PO teams, we created a new solar wind Website highlighting STEREO, Wind, and ACE missions and science.

To increase public awareness of STEREO science, we have presented the solar wind magnetism activities at the California Science Teachers Association conferences, taught the lesson to 150 middle school students in Piedmont, CA, and partnered with the Lawrence Hall of Science FOSS team to educate Oakland, CA elementary teachers about electricity and magnetism and physical science, using both hands-on activities and the 'story' of solar storms and their affect on Earth. A description of the IMPACT pre-launch programs is found in the more general STEREO E/PO paper (Peticolas *et al*., 2007). We are in the process of evaluating our most current sonification software product as a formative evaluation in order to update the product.

SECCHI

SolarMuse. The SECCHI team continues to work with SolarMuse, a part of the Museum Alliance effort dedicated towards heliophysics imagery. The Museum Alliance server provides access to STEREO mission products for 250 member museums and planetariums. They have been producing High Definition (HD) daily movies of STEREO data with automated captions formatted to be suitable for left eye/right eye viewing, and have been investigating other possible formats for exhibiting the images.

TOPS! (Top Teachers Of Physical Science!). TOPS is focused on instructing and inspiring K-8 students by assuring availability of motivated science-capable, space-oriented teachers, well-grounded in elementary physics, astronomy and space science and exploration. To this end, we have developed a university-level course designed specifically for pre-service, undergraduate Education majors. The course is team-taught at the Catholic University of America in Washington, DC in collaboration with the Departments of Physics and Education. It is an offering of the Department of Physics matched to the needs of students in the Education Department, where it is a requirement for all students with concentrations in Early Childhood and Elementary Education (K-8). The one semester course has completed six years of field-testing and development and a course text and CD are in preparation. Content in this non-mathematical course is focused on the concept of force fields and covers electromagnetic and gravitational fields. Each topic is introduced and illustrated by its manifestations in the Sun. Every attempt is made to engage the students and introduce them to the excitement of real, ongoing research, including the use of data from STEREO and other Heliophysics space missions. In addition to actual subject mastery, the TOPS objectives include an emphasis on attitudes toward science and development of the future teacher's self-confidence in his/her ability to learn and teach it. Approximately one hundred students have successfully completed the course, most of whom are now teaching in the primary schools of DC and suburban Maryland and Virginia.

PLASTIC

Christa McAuliffe Planetarium Partnership. The primary outreach activities of *STEREO*/PLASTIC to the general public (servicing all age groups) are developed and provided by PLASTIC E/PO partner, the Christa McAuliffe Planetarium (CMP), in Concord, NH. Recently, *STEREO* funds were used for an interactive exhibit centering on the electro-magnetic spectrum at the new McAuliffe-Shepard Discovery Center. The exhibit utilizes a variety of sensory approaches to understanding the different parts of the EMS, allowing al people, including those with disabilities to explore the EMS and access scientific information in an engaging manner, PLASTIC also funded CMP's participation in ViewSpace and an exhibit commemorating NASA's 50th anniversary.

PLASTIC sponsored activities at CMP include the Super Stellar Friday teen night, a monthly program initiated by *STEREO* funds in which young people ages 13-19 participated in engaging hands-on science and engineering workshops, led by scientists, engineers, and science educators, and the annual Spacetacular Saturday aerospace festival. PLASTIC has also funded CMP's participation in ViewSpace. and PLASTIC scientists from the University of New Hampshire (UNH) participate in CMP public events. CMP is currently developing a formal evaluation plan for Super Stellar Fridays.

PLASTIC helps sponsor teacher workshops in astronomy, space and earth science, and aviation, focused on making teachers comfortable teaching these topics in the classroom. In the summer of 2010 this will include a weeklong teacher professional development symposium, the STEREO Summer Solar Science Symposium, on the Sun for 28 K-12 that is expected to draw teachers from all over New England. Sessions will focus on solar science basics and in- and out-of-class activities. Scientists from UNH and Dartmouth College will participate in person as well as scientists and engineers from Goddard and other remote sites, who will participate via videoconferencing.

Undergraduate Interns. The PLASTIC team has long employed undergraduate interns, providing them with hands on experience on a NASA space mission, and many of them are pursuing careers in the aerospace related fields.

S/WAVES

Radio Classroom Activities. E/PO activity of the S/WAVES team focused on development of a set of educational activities with a lesson plan developed by a teacher from the Baltimore County, Maryland, school system. These activities, located on the GSFC S/WAVES web site (http://swaves.gsfc.nasa.gov), include instructions for building a model of the STEREO spacecraft with an AM radio inside for demonstrating basic aspects of radio waves, a history of radio astronomy, cross-word puzzle relating to S/WAVES in English and Spanish, vocabulary, etc. The lesson plan incorporates these items and other STEREO materials available on the web.

STEREO Science Center (SSC)

The SSC is dedicated to a number of outreach programs, many of them continuation of projects initiated by the *SOHO* mission. The activities have two main goals – 1) To spread *STEREO* and solar related materials informally through science centers, the internet, and public events and 2) To extend the excitement of *STEREO* related science to the classroom by using it to augment standards-based educational efforts.

STEREO Content for Museums and Science Centers. As part of the *SOHO*/STEREO Pick of the Week feature, *STEREO* images and movies are sent out two to four times a month to over 140 museums and science centers through ViewSpace kiosks and the American Museum of Natural History's AstroBulletins. These movies are also made available in the *STEREO* and *SOHO* web sites, and related video and stills have been featured on the Astronomy Picture of the Day and Spaceweather.com sites.

Hard Copy Materials for Outreach Events and Education. A number of STEREO products were developed and purchased in substantial quantities to support a range of educators and outreach efforts, including a 3D poster, 3D litho, 3D glasses, 3D lenticular card, a STEREO CD, the Sun & Space Weather CD (which featured contained a section on 3D and one on STEREO), a STEREO refrigerator magnet, and an elementary level poster about the Sun. The 3D poster and glasses, for instance, were sent to 15,000 educators via the Sun-Earth Day packet. These products were also made available to visitors and the public at numerous events and conferences. A box of assorted EPO materials has been sent out to each of over 200 astronomy clubs, NASA ambassadors, teacher workshops, STEREO instrument team EPO staff, professors, schools, and science centers to support events they have held.

Pennsylvania Schools Partnerships. STEREO has been actively involved in two programs with Pennsylvania schools. Endeavor is a year-long program operated in partnership with 18 school systems in Pennsylvania Northeastern Educational Intermediate Unit (NEIU) 19 and the Goddard Education Office. Teams of students focus on a solar mission (STEREO or SOHO or TRACE) and develop an outreach product or approach for that mission. They present their idea via the Distance Learning Network (DLN) at the end of the year. In the other program, supported by a Pennsylvania state education grant, teachers and classes from several school districts in the Philadelphia area learn about solar missions via DLN and teacher workshops. They solve various challenges and develop teaching strategies in solar science.

The Sun in 3D. SSC staff worked closely with the privately produced "3D Sun" planetarium show that has been showing at numerous planetariums around the U.S. We recently purchased 10,000 copies of the program (in 2D) to make them available to educators and the public. The SSC also provided material for Journey to the Stars, a planetarium developed by the AMNH. STEREO video clips have been adapted for both the Science on a Sphere and the Magic Planet to reach audiences in the informal education world. Inquiries continue to come in from educational institution in the US and world wide for STEREO 3D imagery.

Internet Outreach. The STEREO Website has developed into a centerpiece for STEREO EPO. Content has been regularly added, including the selection of highlights for The Best of STEREO Gallery, space weather section, overview video clips, links, new activities, graphics, online posters, incremental additions to the Newsroom and What's New sections, and a rotating spherical map of the Sun also featured on an iPhone app. Visitors can access all of the images in the archive and even see movies on the spot for any period they select. The data is accessed by other web sites for educational purposes, for instance STEREO-B images are now featured on the Space Weather Viewer

Evaluation. Because the activities by STEREO are so diverse our evaluation process is diverse as well. Many of the individual programs in which we participate perform individual evaluations. In addition, all STEREO produced products (posters, CDs, student activities) are submitted to the NASA Space Science Education Review process.

Partnerships. Our partnerships with both educational and science outreach organizations are extensive. In fact, many of the programs to which STEREO contributes are actually programs run by other organizations. As described above, we partner with formal educational institutions, such as Catholic University and school systems in Pennsylvania, science centers, such as CMP and AMNH, and larger NASA related programs such as the Museum Alliance. The Goddard Education Office partners with STEREO in the Endeavor project.

We see such partnerships as being an important part of our E/PO and a key part of these programs – as a NASA mission STEREO is optimally placed to bring the excitement of the latest NASA data to various outreach settings. Such programs are highly leveraged as we are contributing content and sometimes financing to programs also supported by other NASA missions, NASA Space Grant Funds, and local educational institutions. We judge the need for our efforts by the needs expressed by our partners in informal and formal educational institutions.

Future Plans

Although activities will be ramping down as funding declines, the STEREO E/PO team plans to continue with many of the activities described above, including Endeavor, TOPS, PLASTIC/CMP outreach activities, and support of an undergraduate intern to work on PLASTIC, and the Sun-Earth Viewer. Planned future developments include:

IMPACT-Wind. The main plans for the solar wind component (IMPACT-Wind E/PO) of the STEREO E/PO program are to 1) keep current the solar wind website, sonification products, and magnetism lessons and 2) disseminate these products and the science discoveries as widely as possible given the financial constraints by a) working with the overall STEREO E/PO team to make the best use of resources and events, b) leveraging other NASA-funded E/PO programs, and c) presenting at teacher workshops already being organized by other organizations (such as the California Science Teachers Association conference and Sacramento Municipal Utility District.) The IMPACT E/PO Lead will continue to attend local science team meetings to ensure that the Wind and IMPACT teams share press releases and science discoveries in appropriate language on the website and as talks to teachers during professional development workshops or through amateur astronomy networks, such as the Night Sky Network of the ASP. The IMPACT team will maintain the solar wind website, keeping it up-to-date and also connecting it with other sun-related websites such as those on Wikipedia and NASA websites, such as the ACE E/PO website, Cosmicopia.umbra.nascom.nasa.gov

In the next two years the IMPACT –Wind E/PO team will update the solar wind lesson to better meet the needs of middle school teachers and their students based on previous teacher feedback on this lesson and will work with ROSES EPOESS programs, Navajo Sky and Surfin' the solar wind, to help modify existing IMPACT-Wind resources for these NASA-funded programs that have components related to the Sun.

SolarMuse. In the next four years the SECCHI SolarMuse team plans to produce special high resolution special products for museums and planetarium domes, including full dome movies, and for movie theaters using industry standard formats including Digital Cinema, IMAX, and Ultra High Definition. They will produce products compatible with SkySkan planetarium equipment and with Google Sky. They will also distribute lower resolution STEREO imaging products suitable for Web and software such as PowerPoint.

SunStruck. The SSC will be collaborating with the Detroit Science Center over the next two years as they work to develop a solar centered planetarium show called "SunStruck." We will provide scientific and editorial support. The show will feature many new animations and use NASA solar content. It will be made in HD and become a digital show, available for other planetariums with that capability. Once the show is developed, it will also be formatted for and shared with other planetariums with lower level capabilities for very little cost.

The SSC also plans to work closely with Science on a Sphere, Magic Planet, and the San Francisco Exploratorium's podcasts to get our content included in presentations with these devices. Part of the success of this venture will depend on helping to establish a context for the video clips.

Leveraging others' efforts. The Sun-Earth Day program will enhance the presence of RHESSI and its relation to STEREO through the development of a series of dedicated podcasts focused on the latest RHESSI and STEREO science and education information.

Appendix B. Legacy Mission Archive Plan

Mission-wide Data and Software

The STEREO Science Center (SSC), located at NASA Goddard, serves as the main archive for all STEREO data. The primary source of ancillary data products for the STEREO mission is the STEREO Data Server (SDS) maintained as part of the Mission Operations Center at the Johns Hopkins University Applied Physics Laboratory. These data, which include all operational and engineering data and reports shared between the operations and instrument teams, are mirrored over to the SSC several times per day for archiving. All the ancillary data products are made available online except for the telemetry dictionaries which are archived separately for security reasons, and the DSN Schedule Change reports which are not made public because they include email addresses. The DSN Schedule Change reports are not archived because the information in them is included in the subsequent DSN schedule files. Event lists maintained by the PI teams and others are available at the SSC Website.

Telemetry, Ephemerides, and Attitude History. Final level-0 telemetry files are archived by the SSC for each of the instruments and spacecraft subsystems. All STEREO ephemerides and attitude history files are provided as SPICE kernels. SPICE is a standard ephemeris package provided by the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF), and used by many interplanetary and heliospheric missions. Information about SPICE and the SPICE software package can be obtained from the NAIF Website. The SPICE kernels archived by the SSC are in ASCII transfer format, which can then be compiled into machine-readable form for any supported platform.

SolarSoft. Data analysis software is distributed as part of the Solar Software Library, also known as SolarSoft. This multi-mission software library is used extensively within the solar physics community, and enables cross-mission data analysis. The primary emphasis is on Interactive Data Language (IDL) software, but source code for other languages is also distributed using the SolarSoft mechanism. Together with the large generic library supplied with SolarSoft, each instrument team provides software for analyzing their own data. Also provided are the most current ephemeris and attitude history files for the entire mission, and software to manipulate them in a large variety of standard coordinate systems.

Instrument resources. Resource pages are available for each of the STEREO instruments, using a standardized format first developed for the *SOHO* mission, and are accessible from the SSC Website.

Mission Documentation. A special issue (Volume 136) of Space Science Reviews (SSR) is devoted to the STEREO mission. In that issue are extensive descriptions of the spacecraft, instruments, and ground systems.

Data Distribution. The SSC resides within the Solar Data Analysis Center (SDAC) at the Goddard Space Flight Center. The SDAC is a multi-mission Resident Archive with extensive experience distributing data for a number of missions, including SOHO, TRACE, RHESSI, Hinode, and others, as well as archiving data for older missions such as the Solar Maximum Mission. The SDAC will act as the active Resident Archive for the lifetime of the mission and beyond. Ultimately, the data will be delivered to the Permanent Archive designated by NASA Heliophysics MO&DA management.

The Virtual Solar Observatory (VSO) acts as the primary access point for all STEREO data, with the SSC as the data provider. This maximizes the use of existing resources without duplication, and enables collaborative data analysis with other solar observatories. IMPACT magnetometer data are also available through the Virtual Heliospheric Observatory (VHO), and efforts are underway to serve other STEREO data through the VHO. An extensive list of all access sites, including those at the individual PI and Co-I institutions, is maintained on the SSC Website.

IMPACT

Scientific Data Products. The IMPACT investigation provides several levels of science data products. The primary, "Level 1" science products, include all science data at highest time resolution and in scientific coordinates. These products are produced at UC-Berkeley upon transfer of the Level 0 telemetry files from the SSC and validated by the IMPACT Co-Investigators within one month of generation. Once validated, these files are made publicly available (see below). Level 1 data files are in ISTP-compliant CDF format and intended to be self-documenting. The full complement of ISTP-required metadata are included within these files. All IMPACT Level 1 files are archived within the SSC. Appropriate metadata have been developed, or are being developed, for each Level 1 data product, and incorporated into the VHO.

Level 2 data are a merged data set, including data from the IMPACT and PLASTIC investigations, and averaged to ensure identical time cadences (1-minute, 1-hour and 1-day). These data are intended for quick browsing and are integrated with an online plotting and ASCII listing service hosted at UCLA. The IMPACT teams also intends to include data from S/WAVES in its Level 2 data set. Level 3 data are list-type data such as event lists compiled by the IMPACT team. They are in human-readable ASCII format. Appropriate metadata are being incorporated into the VHO to enable searching on the data.

Currently, the IMPACT investigation provides Level 1 data for all instruments except HET. Level 2 data including MAG and PLASTIC moments are being served at UCLA, while HET and LET Level 2 data are available from CalTech, and SEPT Level 2 browse plots are served by the University of Kiel. Development is ongoing to complete the Level 2 set. Level 3 event lists are served by UCLA, and archived within the SSC.

Documentation. The SSR special issue includes complete information regarding the IMPACT instruments and data products. In addition, documentation is served online through the IMPACT instrument resource page. Information about calibrations and software versions used in the production of Level 1 data products are listed on this website and included in the internal documentation of the CDF files themselves.

Analysis Tools. The IMPACT investigation provides data products in ISTP-compliant CDF and ASCII formats to ensure easy integration with users' native analysis environments. In addition, the IMPACT team provides custom software through the instrument resource page based on the UC-Berkeley TPLOT library. This is an IDL-based set of analysis routines designed specifically for in situ measurements.

Online browsers and plotters hosted by UCLA, UC-Berkeley, the University of Kiel, and the Centre d'Etude Spatiale des Rayonnements (CESR) provide tools on the web. At UC-Berkeley, a traditional browse-type, static plot tool is available. This tool links IMPACT and ACE plots and data with images and models.

Data Distribution. The IMPACT data sets are available through the main IMPACT UC-Berkeley instrument resource web site listed above. In addition, all data are mirrored by the SSC and available there. Data are also mirrored and available through CDAWeb. IMPACT data are being included in the VHO interface. Space Physics Archive Search and Extract (SPASE) descriptions of MAG, SWEA, and LET Level 1 data products have been written, and descriptions of the other products will be completed in 2010.

Together with the above, Caltech hosts a site specific to the Solar Energetic Particle (SEP) suite. This site provides SEP and some ancillary data (notably, orbit and attitude information) in ASCII format. A site hosted by the CESR includes additional data products and analysis tools for the SWEA instrument.

PLASTIC

Scientific Data Products. Level 1 data are the highest-resolution, complete data set. They have the epoch time and instrument section decommutated, counts decompressed, and entries separated into meaningful products (solar wind proton moment array, reduced proton and alpha distributions, heavy ion species count rate arrays, pulse height data, housekeeping, etc.), but are not fully converted into physical units (such as flux) that require the incorporation of detection efficiencies which may change over the life of the mission (due to gain changes in the detectors). Level 1 data products are produced at UNH within 24 hours of receipt of Level 0 telemetry files. Software and calibration/efficiency files to convert the data into physical units, along with appropriate documentation, are delivered electronically to the SSC archive. Level 1 data products are in ISTP-compliant CDF files.

Level 2 data products include the most frequently used quantities from PLASTIC in physical units. These data products are accessible on the PLASTIC Website (menu link to "Resources") and include both browse quality (typically available within 1 day of Level 1) and validated (updated monthly) products. Validated Level 2 products currently available on the UNH site as ASCII files include solar wind protons, alphas, selected minor ions, and helium pickup ions. Selected key parameters (such as solar wind bulk parameters, ion charge state distributions, and He^{+} intensities) are also provided on the UNH-hosted PLASTIC online browser as daily and/or monthly time series plots. Verified and validated products undergo both automatic and science personnel quality checks. These archival quality data are added to ISTP-compliant Level 2 CDFs and mirrored at the SSC. The validated PLASTIC proton moments are also included as a merged plasma plus magnetic field product courtesy of the IMPACT/MAG site at UCLA.

Level 2 products are continuing to be created and deployed, with associated data processing software and calibration files under development. Continuing Level 2 software development will allow the future inclusion of additional species and higher time resolution products. Updates to calibration files will be ongoing through the length of the mission.

Level 3 data products typically result from directed scientific analysis, and include specific intervals (such as identified ICMEs) and other value-added products. A list of suprathermal event periods and their parameters is under compilation and will be delivered in Spring 2010.

Documentation. Full descriptions of the PLASTIC instruments and the Level 1 data products can be accessed through the Instrument Resource webpage at the UNH website. Metadata relevant to particular data products are also available within the CDF files. ASCII products either have the product information contained within the file header, or else a "Readme" file is provided. The instrument and data products are fully described in the PLASTIC instrument paper in the SSR special issue. This paper is available online, free-of-charge to the public, and is linked through the PLASTIC Resource page.

Analysis Tools. PLASTIC data are available in ISTP-compliant CDFs such that they can be easily integrated into existing analysis and search tools, such as the VHO and SolarSoft. In addition, the PLASTIC team has extended the UC-Berkeley TPLOT library, (see IMPACT section, above), into the IDL-based SPLAT (**S**tereo **PL**astic **A**nalysis **T**ool) that further enables integration of data sets. SPLAT and other IDL programs, including those that support composition analysis and those that create specialized ASCII files from the CDF files, are distributed through the SolarSoft library.

Data Distribution. PLASTIC Levels 1 and validated Level 2 data are available both via the UNH-hosted Website and at the mirrored SSC instrument data site. PLASTIC archival data is also available at the CDAWeb, the VSO, and the Virtual Space Physics Observatory (VSPO), and will also be included in the VHO.

SECCHI

Scientific data products. All SECCHI image telemetry data are converted to FITS files upon receipt of version 02 of the Level-0 telemetry files, about 2 days from the date of observation. This processing is done at the SECCHI Payload Operations Center (POC), located at NRL. The FITS headers contain all instrument parameter and spacecraft pointing information. The images have been oriented to put the spacecraft north, which usually corresponds to ecliptic north, at the top of the image, but no interpolations are done at this Level0.5 stage. The images may be converted to Level-1 by the user using a SolarSoft IDL procedure, SECCHI_PREP, which performs all of the calibration functions using the latest calibrations. Image header metadata are available in a database, accessible from the SECCHI Website, which can be also used to download specific FITS files. In addition to the FITS data, browse images and movies are available in PNG, JPEG, and/or MPEG formats. A subset of EUVI data is available as PNG anaglyphs and stereo pairs.

Calibration activities for the SECCHI telescopes are almost complete. Pointing and flat-fielding (including vignetting) calibrations have been established for all telescopes. Geometric distortion corrections have been implemented for all applicable telescopes (COR2, HI1, and HI2), as have the shutterless readout corrections for HI1 and HI2. Photometric calibrations have been implemented for EUVI, COR1, and COR2. A paper describing the HI1 calibration factors has been submitted for publication, and this calibration will be implemented once the paper has been accepted. Work is proceeding on the HI2 photometric calibration.

Housekeeping. Selected SECCHI instrument housekeeping telemetry is also available via web interface to a database at NRL. Plots may be extracted from this database of various engineering parameters such as temperatures, currents, voltages, door position, guide telescope pointing and HK events. Table definitions and table structure are described on the SECCHI web site.

Documentation. The SECCHI Website serves: PNG browse images for most data, Javascript movies for user-defined intervals, 3-7 day summary movies (MPEG), Science (FSW) Operations Manual, FSW documentation, image telemetry completeness data, instrument status, image scheduling details, various instrument and operations event logs, software user's guides, SECCHI FITS Keyword Definition, and the SECCHI Data Management Plan. A description of the instrument is given in the SSR special issue. SECCHI operations and data documentation is maintained in a wiki site. The wiki pages are updated as information becomes available.

Analysis Tools. SECCHI analysis tools, and most of the pipeline software, are freely available through SolarSoft. The following tools are currently available via SolarSoft: data browsers, data calibration, movie generation and display, image enhancement and visualization, polarized image processing, star-removal, height-time plots, ray-tracing, CME detection, tomography. As these tools are improved and future tools developed, they will be added to the SolarSoft library. In addition, there are some stereographic visualization tools which currently require specialized hardware. At NRL all software is under Concurrent Versions System management.

Final Data Set. The SECCHI Level-0.5 data is "final" after the FITS files have been updated with any additional telemetry received in the final (+30-day) Level-0 telemetry from APL. Currently, the Level-1 (calibrated) product is the combination of the Level-0.5 FITS images and the SECCHI_PREP IDL routine and data files available in SolarSoft. This allows the user to take advantage of the evolving calibration of the various telescopes. At the end of the mission, the calibration files and parameters that are used in this package will be revalidated to ensure that they are up to date and able to generate Level-1 FITS files of calibrated images, polarized brightness, and brightness images. Calibration will include corrections for instrumental artifacts such as stray light, vignetting, shutterless readout, and conversion to physical units. (Geometric distortion is described by header keywords together with the World Coordinate System standard algorithms.) Complete documentation, transparent software code, and non-proprietary data formats ensure that calibration can be properly applied to Level-0.5 data into the foreseeable future. The final archive will contain both the calibrated Level-1 files and the original Level-0.5 files.

Data availability. The primary site for storage of Level-0.5 FITS image data is the NRL Solar Physics Branch (PI home institution). The primary means of querying data for analysis is by utilizing summary flat-files which are read by SolarSoft tools. Besides being available on-site, the data is freely available (in relatively small quantities) from NRL via database query at the SECCHI website. All of the data are also synchronized hourly to the SSC. In addition, other partner institutions – LMSAL (California), RAL (UK), IAS (France), MPS (Germany) – mirror STEREO data. These all serve as backups for the complete data set.

Virtual Observatory Access. The SSC is now serving SECCHI data through the VSO at GSFC/SDAC, which is intended to be the gateway to other Virtual Observatories. The SECCHI team is working with SDAC staff to implement full accessibility to the wider VO community. VSO is committed to community interoperability efforts, such as the SPASE data model.

S/WAVES

Scientific Data products. The S/WAVES investigation provides several levels of science data products. Access to the Level 0 data is achieved through a processing system called TMlib, based on a similar system (WindLib) successfully used since the early 1990s for the Wind/WAVES (W/WAVES) data. The TMlib can be downloaded from the University of Minnesota (send request to goetz@umn.edu).

Daily summary plots showing all frequency-domain receivers and summaries of the time domain receivers are available from the SSC and S/WAVES Webpage. Both of these sources also serve 1-minute averages in both ASCII and IDL/save format of all frequency-domain receivers. These 1-minute averages are also served by the CDAWeb. The CDAWeb site includes customized plotting capabilities. Both the daily summary plots and the 1-minute averages are produced automatically upon receipt of the data, so are available usually within 24-hours of real-time.

The French Plasma Physics Data Center (CDPP) also serves daily summary plots of the frequency domain receivers in a different format than those from the U.S sites. CDPP will also serve in the future the higher level S/WAVES products associated with direction finding and wave polarization capability. This site requires a password (due to French security regulations), but this is freely given upon request.

Additional higher level data includes the Type II/IV catalog maintained by the Wind/WAVES team and now including STEREO/WAVES data. This site has been in existence since the late 1990s and is a valuable resource for solar researchers.

Documentation. Three papers of importance to S/WAVES data processing are in the SSR special issue, one providing a complete description of the S/WAVES instrument, another discussing the antennas, and a third describing the direction finding technique used by S/WAVES. Pointers to these articles as well as to a description of the 1-minute average data are on the S/WAVES instrument resource page referenced by the SSC. The direction finding and wave polarization parameters, when available, will be documented on the CDPP Web site mentioned above.

Analysis tools. The customized plotting capability available at the CDAWeb is based on the same program used by the S/WAVES team. This original IDL program is available from the instrument resource site at the SSC. Future customized plots of polarization and direction of arrival will be available from the CDPP Web site.

Data Distribution. S/WAVES data, as mentioned above, are available directly from the team's US Web site, from the SSC, from CDAWeb, and from CDPP. The S/WAVES event lists can be obtained from the Type II/IV catalog Web site and through interface with the VSO.

Appendix C. STEREO publication record, 2008 - 2009

STEREO refereed publication rates through the first few weeks of calendar year 2010 can be found in Table C-1.

Calendar Year	Refereed Journals only
2006	2
2007	12
2008	56
2009	135
2010	10
Total	213

Table C-1. STEREO refereed papers

Here, a "STEREO paper" is taken to mean any paper using STEREO data, or concerning models or theoretical interpretations of STEREO measurements.

"Market share." Over 590 individual authors are represented in the 213 papers in the database.

Publication rate. The STEREO publication rate grew dramatically in 2009 as special issues of *Solar Physics* (two issues, with a total of 51 papers) and *Annales Geophysicae* (23 papers based on work first reported at the "Three Eyes on the Sun" conference in 2009 April/May).

***Bibliography**.* A listing of STEREO publications in refereed journals for the years 2005 - 2010 can be found on the SSC Website. A list of just the publications in 2008, 2009, and 2010 January is also available.

Appendix D. Spacecraft and Instrument Status, 2010 February 22

SPACECRAFT

Both spacecraft are performing nominally, except for the failure of am X-axis inertial measurement unit (IMU) gyro on the Ahead spacecraft in 2007 April. STEREO A has been using the backup IMU since the failure without issue, and the mission ops team has crafted and tested a backup attitude control scheme using the SECCHI guide telescope and wheels.

IMPACT

The LET, HET, SIT, and SEPT sensors operate nominally, as designed. The STE-U instruments on both spacecraft, however, are effectively lost, due to sunlight reaching the detectors, probably *via* some second surface reflection not found during spacecraft testing. This loss results in decreased sensitivity to electrons in the few keV range arriving from the solar direction. However, backscattering of these particles into the oppositely directed STE detector and some overlap with SWEA partially fill this important gap.

The SWEA tophats at the end of the boom on each spacecraft have become charged (to ~ 4 V). As a result, solar wind electrons < 45 eV in energy are not accessible, and direct electron core distribution measurements are not possible. At low energies, however, secondary electrons predominate (sweeps have been moved down to 1 eV to enable core proxy measurements), and solar wind electron halo and strahl distribution measurements are still fully possible. The Level-1 requirements involving SWEA in any case involve measurements of only energies above ~ 50 eV.

PLASTIC

Both PLASTIC instrument suites are fully operational.

SECCHI

Aside from "watchdog" resets (13 on Behind, 15 on Ahead over the course of the mission) generated in the SECCHI Electronics Boxes (SEBs) that each result in a few hours' of lost observing time, both SECCHI suites are performing nominally. The resets occur randomly in time, and without any significant effects on scientific data acquisition.

S/WAVES

No change since 2008 proposal. Interference, probably due to a faulty ground wire associated with the IMPACT boom, affects the SWAVES instrument on the Behind spacecraft at 16 and 100 kHz. This limits the S/WAVES ability to carry out three-antenna direction finding on all but the strongest solar events. This is not, however, a serious limitation, as time-of-flight direction finding and the use of Wind/WAVES direction finding mitigate this issue.

Appendix E. Research Focus Areas, NASA Heliophysics Roadmap, 2009 - 2030

Research Focus Areas

F1 Magnetic reconnection

F2 Particle acceleration and transport

F3 Ion-neutral interactions

F4 Creation and variability of magnetic dynamos

Open the Frontier to Space Environmental Prediction

The Sun, our solar system, and the universe consist primarily of plasma. Plasmas are more complex than solids, liquids, and gases because the motions of electrons and ions produce both electric and magnetic fields. The electric fields accelerate particles, sometimes to very high energies, and the magnetic fields guide their motions. This results in a rich set of interacting physical processes, including intricate exchanges with the neutral gas in planetary atmospheres.

Although physicists know the laws governing the interaction of electrically charged particles, the collective behavior of the plasma state leads to complex and often surprising physical phenomena. As the foundation for our long-term research program, we will develop a comprehensive scientific understanding of the fundamental physical processes that control our space environment.

The processes of interest occur in many locations, though with vastly different magnitudes of energy, size, and time. By quantitatively examining similar phenomena occurring in different regimes with a variety of techniques, we can identify the important controlling mechanisms and rigorously test our developing knowledge. Both remote sensing and in situ observations will be utilized to provide the complementary three-dimensional, large-scale perspective and the detailed small-scale microphysics view necessary to see the complete picture.

Research Focus Areas

H1 Causes and evolution of solar activity

H2 Earth's magnetosphere, ionosphere, and upper atmosphere

H3 Role of the Sun in driving change in the Earth's atmosphere

H4 Apply our knowledge to understand other regions

Understand the Nature of Our Home in Space

Humankind does not live in isolation; we are intimately coupled with the space environment through our technological needs, the solar system bodies we plan to explore, and ultimately the fate of our Earth itself. We regularly experience how variability in the near-Earth space environment affects the activities that underpin our society. We are living with a star.

We plan to better understand our place in the solar system by investigating the interaction of the space environment with the Earth and the effect of this interaction on humankind. We plan to characterize and develop a knowledge of the impact of the space environment on our planet, technology, and society. Our goal is to understand the web of linked physical processes connecting Earth with the space environment.

Even a casual scan of the solar system is sufficient to discover that habitability, particularly for humankind, requires a rare confluence of many factors. At least some of these factors, especially the role of magnetic fields in shielding planetary atmospheres, are subjects of immense interest to heliophysics. Lessons learned in the study of planetary environments can be applied to our home on Earth, and vise versa, the study of our own atmosphere supports the exploration of other planets.

Research Focus Areas

J1 Variability, extremes, and boundary conditions

J2 Capability to predict the origin, onset, and level of solar activity

J3 Capability to predict the propagation and evolution of solar disturbances

J4 Effects on and within planetary environments

Safeguard the Journey of Exploration

NASA's robotic spacecraft continue to explore the Earth's neighborhood and other targets in the heliosphere. Humans are expected once again to venture onto the surface of the Moon and one day onto the surface of Mars. This exploration brings challenges and hazards. We plan to help safeguard these space journeys by developing predictive and forecasting strategies for space environmental hazards.

This work will aid in the optimization of habitats, spacecraft, and instrumentation, and for planning mission operation scenarios, ultimately increasing mission productivity. We will analyze the complex influence of the Sun and the space environment, from origin to the destination, on critical conditions at and in the vicinity of human and robotic spacecraft. Collaborations between heliophysics scientists and those preparing for human and robotic exploration will be fostered through interdisciplinary research programs and the common use of NASA research assets in space.

Appendix D. Acronyms

STEREO instrument and instrument subsystem names are in blue.

ACE	Advanced Composition Explorer
AGU	American Geophysical Union
APL	Applied Physics Laboratory
AR	Active Region
ASCII	American Standard Code for Information Interchange
AU	Astronomical Unit
CACTUS	Computer Aided CME Tracking
CCMC	Community Coordinated Modeling Center
CDAWeb	Coordinated Data Analysis
CDF	Common Data Format
CDPP	Centre de Données de la Physique des Plasmas (France)
CIR	Co-rotating interaction regions
CME	Coronal Mass Ejection
Co-I	Co-Investigator
COR1	SECCHI Inner Coronagraph
COR2	SECHHI Outer Coronagraph
COSPAR	Committee On SPAce Research
DSN	Deep Space Network
EGU	European Geosciences Union
EPAM	Electron, Proton, and Alpha Monitor
EPO	Education and Public Outreach
EUV	Extreme UltraViolet
EUVI	SECCHI Extreme UltraViolet Imager
FY	Fiscal Year
GB	GigaByte
GOES	Geostationary Operational Environmental Satellite
GONG	Global Oscillation Network Group
GSE	Geocentric Solar Ecliptic
GSFC	Goddard Space Flight Center
HET	IMPACT High Energy Telescope
HGO	Heliophysics Great Observatory
HI	SECCHI Heliospheric Imager
IBEX	Interstellar Boundary Explorer
IAS	Institue d'Astrophysique Spatiale (France)
ICME	Interplanetary coronal mass ejection
IDL	Interactive Data Language™
IMPACT	In-situ Measurements of Particles and CME Transients Investigation
ISTP	International Solar Terrestrial Physics program
JHU	Johns Hopkins University
kbps	Kilobits per second
L1	First Lagrangian Point
LASCO	SOHO Large Angle and Spectrometric Coronagraph
LET	IMPACT Low Energy Telescope

LMSAL	Lockheed Martin Solar and Astrophysics Laboratory
MAG	IMPACT Magnetometer
MAVEN	Mars Atmosphere and Volatile EvolutioN
Mbits	Megabits
MDI	SOHO Michelson Doppler Imager
MHD	MagnetoHydroDynamics
MO&DA	Mission Operations and Data Analysis
MOC	Mission Operations Center
MPS	Max Planck Institut für Sonnensystemforschung (Germany)
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSSDC	National Space Science Data Center
OMNI	OMNIWeb database
PFSS	Potential Field Source Surface
PI	Principal Investigator
PLASTIC	PLAsma and SupraThermal Ion Composition Investigation
POC	Payload Operations Center
RAL	Rutherford Appleton Laboratory
RBSP	Radiation Belt Storm Probe
RHESSI	Reuven Ramaty High Energy Solar Spectroscopic Imager
SAMPEX	Solar Anomalous and Magnetospheric Particle Explorer
SDAC	Solar Data Analysis Center
SDO	Solar Dynamics Observatory
SDS	STEREO Data Server
SECCHI	Sun Earth Connection Coronal and Heliospheric Investigation
SEP	Solar Energetic Particle
SEPT	IMPACT Solar Electron Proton Telescope
SIR	Stream interaction region
SIT	IMPACT Suprathermal Ion Telescope
SOHO	Solar and Heliospheric Observatory
SOWG	Science Operations Working Group
SPASE	Space Physics Archive Search and Extract
SPICE	Spacecraft, Planet, Instrument, C-Matrix, Events
SPLAT	STEREO PLASTIC Analysis Tool
SSC	STEREO Science Center
SSR	Space Science Reviews
STE	IMPACT Suprathermal Electron Telescope
STEREO	Solar TErrestrial RElations Observatory
STP	Solar Terrestrial Probes
S/WAVES	STEREO Waves Investigation
SWEA	IMPACT Solar Wind Electron Analyzer
SWG	Science Working Group
TOPS	Top Teachers of Physical Science
TRACE	Transition Region and Coronal Explorer
UC	University of California
UNH	University of New Hampshire

VHO	Virtual Heliospheric Observatory
VSO	Virtual Solar Observatory
VSPO	Virtual Space Physics Observatory
WSA	Wang-Sheeley-Arge

STEREO SECCHI COR1 model, constructed from flight spare parts, is presented to the United Nations Office for Outer Space Affairs by lead Co-I J. Davila (center) and US Ambassador the IAEA and United Nations Office in Vienna, Austria, G. Davis (right), 2010 February.