STEREO Mission Archive Plan

The STEREO Science Center (SSC), located at the NASA Goddard Space Flight Center, serves as the primary archive for all STEREO data.

We will first discuss the archival of mission-wide data products, and then each of the instruments in turn.

Mission-wide Data and Software

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.

Ephemerides and Attitude History. 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 [Krasinsky, *et al*., 2007]. Information about SPICE, and the SPICE software package can be obtained from the NAIF website at naif.jpl.nasa.gov. The SPICE kernels archived by the STEREO Science Center are in ASCII transfer format, which can then be compiled into machine-readable form for any supported platform. They fall into the following categories:

- Predictive spacecraft ephemerides from either the APL Mission Design team, or from the NASA Flight Dynamics Facility (FDF).
- Definitive spacecraft ephemerides provided by the FDF.
- Spacecraft attitude history files provided by the APL Mission Operations Center (MOC).
- Supporting files, including a planetary ephemeris, a leapseconds file, and spacecraft clock files.

Telemetry. Final level-0 telemetry files are archived by the SSC for each of the instruments and spacecraft subsystems.

SolarSoft. Data analysis software is distributed as part of the Solar Software Library [Freeland and Handy, 1998], 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, and software to manipulate them in a large variety of standard coordinate systems.

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 at http://stereo-ssc.nascom.nasa.gov/ins_resources.shtml.

Mission Documentation. An upcoming special issue of Space Science Reviews will be devoted to the STEREO mission. In that issue will be extensive descriptions of the spacecraft, instruments, and ground systems.

Data Distribution. The STEREO Science Center 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 National Space Science Data Center (NSSDC) which will serve as the Permanent Archive.

The Virtual Solar Observatory (VSO) [Hill et al., 2004] 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. As well as the main VSO search page at www.virtualsolar.org, the SSC is working on mission-specific interfaces into the VSO database. Efforts are also underway to incorporate the STEREO data into the Virtual Heliospheric Observatory (vho.nasa.gov). Data are also available from the individual PI and Co-I institutions. A list of all access sites is maintained at http://stereo-ssc.nascom.nasa.gov/data.shtml.

IMPACT

Scientific Data Products. The IMPACT investigation provides several levels of science data products. The primary science products, called "Level 1", 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.

In addition, the IMPACT team plans to provide higher level data products known as "Level 2" and "Level 3". Level 2 data are a merged data set, including data from the IMPACT, PLASTIC and S/WAVES 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. 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 will be incorporated into the VHO to enable searching on the data.

Currently, the IMPACT investigation provides Level 1 data for the MAG, SWEA, STE, LET, SIT, SEPT and HET instruments. Level 2 data including MAG and PLASTIC moments are being served at UCLA. Development is ongoing to complete the Level 2 set. Work on Level 3 data (event lists) is ongoing. Completion of Level 2 and Level 3 development is expected by then end of 2008.

Documentation: As noted above, an upcoming issue of Space Science Reviews will include complete information regarding the IMPACT instruments and data products. In addition, documentation is being served online through the IMPACT instrument resource page at http://sprg.ssl.berkeley.edu/impact/impact_resources.html. 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 and UC-Berkeley provide tools on the web. At UC-Berkeley, a traditional browse-type, static plot tool is available. This tool links IMPACT, PLASTIC and SWAVES plots and data with images and models and with analogs from the L1 spacecraft. Also, in development at UC-Berkeley is an on-the-fly web-based plotter. This plotter will include functionality beyond that available through the CDAWeb service providing much greater flexibility with all aspects of user-created plots and tight integration with the L1 missions Wind and ACE. This on-the-fly plotter is expected to be public in mid-2008.

Data Distribution: The IMPACT data sets are available through the main IMPACT UC-Berkeley instrument resource web site listed above. In addition, all data is mirrored by the STEREO Science Center and available there. IMPACT data are being included in the Virtual Heliospheric Observatory (VHO) interface. SPASE descriptions of MAG and SWEA data products have been written, and descriptions of the other products will be completed in 2008.

In addition, Caltech hosts a site specific to the Solar Energetic Particle (SEP) suite at http://www.srl.caltech.edu/STEREO/index.html. This site provides SEP and some ancillary data (notably, orbit and attitude information) in ASCII format.

PLASTIC

Scientific Data Products: The PLASTIC investigation provides several levels of science data products. For PLASTIC, Level 1 data refers to the highest-resolution, complete data set. Level 1 data 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. Level 1 data products are produced at UNH within 24 hours of receipt of Level 0 telemetry files from the SSC. Software and calibration/efficiency files to convert the data into physical units, along with appropriate documentation, are delivered electronically to the SSC archive. (This work is ongoing). Level 1 data products are in ISTP-compliant CDF files.

PLASTIC Level 2 data products include the most frequently used quantities from PLASTIC in physical units. These data products are accessible on the UNH web site (http://stereo.sr.unh.edu, menu link to "Resources") and include both browse quality (typically available within 1 day of Level 1) and validated (updated monthly) products. Selected key parameters (such as solar wind bulk parameters) are provided on the UNH-hosted PLASTIC online browser as daily and monthly time series plots. Validated Level 2 products currently available on the UNH site include ASCII files with 1-minute (full resolution), 10-minute and hourly averages of solar wind bulk parameters.

Validated products undergo both automatic and science personnel quality checks. Validated data will be added to ISTP-compliant Level 2 CDFs and mirrored at the SSC. The validated PLASTIC 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. Densities for major solar wind heavy ion species and suprathermal ion fluxes and anisotropies in several energy ranges are among the Level 2 data products that are in the process of being added, with related data processing software and calibration files under development. Level 2 software development is expected to be completed by the end of 2008. Updates to calibration files will be ongoing through the length of mission.

Level 3 data products typically result from directed scientific analysis, and include specific intervals (such as identified ICMEs) and other value-added products. Level 3 development and processing will be ongoing through the length of mission.

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. Meta-data relevant to particular data products are also available within the CDF files. The instrument paper [Galvin et al., 2008] is currently available online, free-of-charge to the public, through the Springer "Open Choice" option.

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 Virtual Heliospheric Observatories (VHO) and the Solar Soft software system. 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 SSC Solar Soft library.

Data Distribution: PLASTIC Level 1 data are available both via the UNH-hosted website (http://stereo.sr.unh.edu) and at the mirrored SSC instrument data site. Level 2 data are currently available at the UNH site, and will be further distributed to the SSC as they are incorporated into ISTP-compliant CDFs. PLASTIC data 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 at the STEREO Science Center (SSC) from the APL STEREO data server (about 2 days from DATE-OBS). The FITS headers contain all information about the instrument parameters used to collect the image as well as the 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 stage, which is called Level-0.5. 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 information is available in a database, accessible from the SECCHI website at http://secchi.nrl.navy.mil, which can be also used to download specific FITS files that a user might be interested in.

In addition to the FITS data, browse images and movies are available in PNG, JPEG, and/or MPEG formats. A subset of data is available as PNG anaglyphs and stereo pairs.

SECCHI Telescope Calibration Status and Source (2008-01-25)

Calibration	EUVI	COR1	COR2	HI1	HI2
Shutterless readout correction	NA	NA	NA	hi_desmear .pro, v1.6	hi_desmear .pro, v1.6
Photometric calibration	get_calfac .pro, v1.1	get_calfac .pro, v1.1	get_calfac .pro, v1.1	planned 2008	planned 2008
Geometric distortion	NA	NA	NA	getsccsecpix .pro, v1.7	getsccsecpix .pro, v1.7
Flat field + vignetting via get_calimg.pro	20060823_ wav	20071003 _ flatfd	20060929_ vignet	20061129_ flatfld	20061129_ flatfld
Sun center	euvi_point .pro, v1.5	cor1_point .pro, v1.9	planned 2008	get_hi_param s .pro, v1.3	get_hi_param s .pro, v1.3

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.

Beacon: SECCHI images in the beacon stream from STEREO are received at the SSC in real-time as antenna partners are available to capture this telemetry. The SSC uses NRL-provided software to process the telemetry into FITS files and processes them further before displaying on the SSC website.

Orbit and Attitude: Ephemerides and attitude information for STEREO, together with the tools to read them, is provided through the SSC in SolarSoft, based on data products from APL. The relevant information is also put into the Level-0.5 FITS header.

Documentation: The following documentation and data products are also available via the SECCHI website: PNG browse images for most data, Javascript movies for user-defined interval, 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, SECCHI Data Management Plan.

A description of the instrument is given in Howard *et al.* (2008), which will appear in the special issue of Space Science Reviews. SECCHI operations and data documentation is maintained in a wiki site (http://secchi.nrl.navy.mil/wiki/). The wiki pages are being updated as information becomes available.

Analysis Tools: SECCHI analysis tools, and most of the pipeline software, are freely available through SolarSoft. SolarSoft is a set of integrated software libraries, data bases, and system utilities which provide a common programming and data analysis environment for Solar Physics. 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.

The SolarSoft library is maintained and distributed through NASA/GSFC solar physics program. The SECCHI portion is updated daily from NRL. 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 if any additional telemetry is 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 is synchronized hourly to the NASA/GSFC STEREO Science Center. In addition, other partner institutions--LMSAL (California), RAL (UK), IAS (France), MPAe (Germany)--mirror STEREO data. These all serve as backups for the complete data set.

Virtual Observatory Access: The STEREO Science Center is now serving SECCHI data through the Virtual Solar Observatory at GSFC/SDAC, which is intended to be the gateway to other Virtual Observatories. The SECCHI team is working with Joe Hourcle and Joe Gurman at SDAC to implement full accessibility to the wider VO community. VSO is committed to community interoperability efforts, such as the Space Physics Archive Search and Extract (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@waves.space.umn.edu).

Daily summary plots showing all frequency-domain receivers and summaries of the time domain receivers are available from the STEREO Science Center and S/WAVES Web page maintained at Goddard Space Flight Center (http://swaves.gsfc.nasa.gov). 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. The CDPP Web site is: http://cdpp.cesr.fr. 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 long-maintained by the Wind/WAVES team and now including STEREO/WAVES data. This site, http://www-lep.gsfc.nasa.gov/waves/wavesII.html, has been in existence since the late 1990s and is a valuable resource for solar researchers.

Documentation. Two papers of importance to S/WAVES data processing are (or will be) published in Space Science Reviews. Bougeret *et al.* (2008) provide a complete description of the S/WAVES instrument and Cecconi *et al.* (2007) describe 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 STEREO Science Center. 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, is available directly from the team's U.S. 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.

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