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Solar Dynamics Observatory

Project Data Management Plan

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Greenbelt, Maryland

National Aeronautics and
Space Administration

CM FOREWORD

This document is a Solar Dynamics Observatory Project controlled document. Changes to this document require prior approval of the SDO Project CCB Chairperson. Proposed changes shall be submitted to the SDO Project Configuration Management Office (CMO), along with supportive material justifying the proposed change.

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Project Data Management Plan

DOCUMENT CHANGE RECORD

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1.0 Introduction

This document describes the Project Data Management Plan (PDMP) for the Solar Dynamics Observatory (SDO) mission. SDO is a National Aeronautics and Space Administration (NASA) Living With a Star (LWS) mission scheduled for launch in November 2009. This PDMP is designed to be consistent with the SDO Level-1 Requirements in the LWS Program Plan (Reference 1) and the Level-2 SDO requirements as defined in the SDO Mission Requirements Document (MRD, Reference 2).

1.1 Purpose and Scope

This document describes the generation, delivery, and serving of SDO mission data and science data products and associated responsibilities for the provision of data access and data analysis.

Covered in this plan are:
1. Summaries of the SDO mission and instruments
2. Description of the data flow
3. Description of the science data products
4. Processing requirements and facilities
5. Data service requirements
6. Policies for access and use of SDO data

1.2 PDMP Development, Maintenance, and Management Responsibility

The SDO Project Scientist, currently Dr. William D. Pesnell at the Goddard Space Flight Center (GSFC) is responsible for the development, maintenance, and management of the PDMP through the life of the mission. The PDMP applies to the “Science” or “nominal” mission phase, which begins when the instruments are on orbit, checked-out, and gathering science data.

1.3 Change Control

The SDO PDMP will be modified and updated as required in accordance with the Configuration Management Plan for the SDO mission and the NASA Science Mission Directorate's Heliophysics Division PDMP.

The final PDMP will be signed at the time of the Flight Operations Readiness Review, which will be held three months before launch.

1.4 Relevant Documents

Reference 1. SDO Level-1 Science Requirements, NASA Headquarters Living With a Star Program Plan, Appendix A.

Reference 2. SDO Mission Requirements Document, NASA-GSFC, 464-SYS-REQ-0004, November 18, 2005.

Reference 3. NASA Science Mission Directorate, Heliophysics Division Program Data Management Plan.

Reference 4. SDO Project Operations Concept Document, NASA-GSFC, 464-GS-PLAN-0010, March 2, 2004.

Reference 5. SDO Configuration Management Plan, 464-PROJ-PROC-0010. January 18, 2005.

Reference 6. Guidelines for Development of a Project Data Management Plan (PDMP), NASA Office of Space Science and Applications, March 1993.

Reference 7. The SDO Science Definition Team Report, October 2001.

Reference 8. Interface Control Document between the SDO Mission Operations Center and the Science Operations Centers. 464-GS-ICD-0001, April 27, 2006.

Reference 9. Interface Control Document between the SDO Data Distribution System (DDS) and the Science Operations Centers. 464-GS-ICD-0010, June 16, 2006.

2.0 Project Overview

The Solar Dynamics Observatory (SDO) is the cornerstone mission within the LWS program. SDO's mission is to understand the nature and source of the solar variability that affects life and society. It must make accurate measurements of those solar parameters that are necessary to provide a deeper physical understanding of the mechanisms that underlie the Sun's variability on timescales ranging from seconds to centuries. Using remote sensing techniques, it will monitor and record those aspects of the Sun's variable outputs that have the greatest impact on the terrestrial environment and the surrounding heliosphere.

An Announcement of Opportunity (AO 02-OSS-01) to provide instruments for the SDO mission was published on January 18, 2002 by NASA Headquarters. The SDO Project office at GSFC has overall responsibility for the mission. For the purposes of this document, "spacecraft" refers to the bus subsystems without instruments, while the spacecraft plus instruments will be referred to as an "observatory."

Three science investigations were selected for development:

- Atmospheric Imaging Assembly (AIA) led by Lockheed Martin Solar and Astrophysics Laboratory (LMSAL), Palo Alto, CA.
- EUV Variability Experiment (EVE) led by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder, CO.
- Helioseismic and Magnetic Imager (HMI) led by Stanford University, Stanford, CA.

The SDO implementation schedule is based on a launch date of November 2009. The Phase A study began in September 2002, and the Mission Systems Requirements and Concept Reviews were held in April 2003. The Phase B study began in September 2003 and the Preliminary Design Review was held in March 2004. The Critical Design Review was held in April 2005, while individual instrument Pre-Environmental Reviews were held in late 2006. The Flight Operations Readiness Review is scheduled for July 2009.

2.1 Science Objectives

SDO has four science goals:

1. Understand how magnetic fields appear, distribute, and disappear from their origin in the solar interior
2. Understand the magnetic topologies that give rise to rapid high-energy release processes
3. Study and gauge the dynamic processes that influence space weather phenomena
4. Study the variations in irradiance and solar structure that occur on short timescales, as well as over the solar cycle

Seven key science questions, first listed in the SDO Science Definition Team Report (**Reference 7**), are the Level 1 Science Questions for SDO:

1. What mechanisms drive the quasi-periodic 11-year cycle of solar activity?
2. How is active region magnetic flux synthesized, concentrated, and dispersed across the solar surface?
3. How does magnetic reconnection on small scales reorganize the large-scale field topology and current systems? How significant is it in heating the corona and accelerating the solar wind?
4. Where do the observed variations in the Sun's EUV spectral irradiance arise, and how do they relate to the magnetic activity cycles?
5. What magnetic field configurations lead to the Coronal Mass Ejections (CME), filament eruptions, and flares that produce energetic particles and radiation?
6. Can the structure and dynamics of the solar wind near Earth be determined from the magnetic field configuration and atmospheric structure near the solar surface?
7. When will activity occur, and is it possible to make accurate and reliable forecasts of space weather and climate?

SDO will address these objectives with helioseismic and magnetic field measurements, EUV images, and EUV spectral irradiances.

2.2 Mission Summary

The SDO mission will observe the Sun from an inclined geosynchronous orbit. A summary of the mission is presented in Table 2-1

Table 2-1. SDO Mission Summary

Orbit Description	Geosynchronous Circular, inclined at 28.5 degrees
Launch Date	November 2009
Launch Vehicle	Atlas-V 401 EELV
Nominal Mission Duration	5 years after check-out and commissioning
Potential Mission Life	10 years (assuming a 5-year margin on fuel)
Mission Duty Cycle	Continuous observations with 2 eclipse seasons per year with max duration of 23 days and daily shadows of < 72 minutes
Spacecraft + Instrument Mass	3200 kg at launch (wet)

SDO will be launched into a geosynchronous transfer orbit by an Atlas-V expendable launch vehicle. Mission check-out and commissioning activities will commence, including deployments, outgassing, instrument check-out, and subsystem commissioning, and other early-orbit checkout activities. Some of these activities will be concurrent with the orbit circularization phase, which will raise the orbit to geosynchronous.

Figure 2.1: Simplified Orbital Configuration of SDO. The orbital radius is scaled to the radius of the Earth, the distance and size of the Sun are not to scale.

Table 2-2. SDO Data Acquisition Parameters

Continuous Data Acquisition Rates	129 Mbps for science data 55 Mbps for HMI 67 Mbps for AIA 7 Mbps for EVE 32 to 64 Kbps for Housekeeping data (nominally)
On-Board Data Storage Capacity	Minimal for Housekeeping data (24 hours) None for Science data
Target Pointing Duration	Continuous Sun center pointing
Target Re-orientation Period	N/A
Attitude Control Accuracy	Sun center pointing with an absolute accuracy of 10 arcsec in the Y and Z axis
Attitude Determination	Roll angle from star trackers Fine pointing from Guide Telescope as part of AIA investigation

SDO is designed to operate with a continuous science downlink and no on-board science data storage. The continuous nominal science data return from the observatory will be approximately 130 Mbps. A ground system designed and allocated specifically for SDO will be receiving data continuously throughout the nominal mission.

Instrument operations will be routine for the majority of the mission with each instrument continuously running in its primary science mode. Periodic interruptions to routine science operations are expected. These would include spacecraft maneuvers for momentum dumping and station keeping and instrument calibration maneuvers. Two eclipse seasons of about 23 days per year cause the science instruments to be occulted from the Sun on a daily basis for periods of up to 72 minutes. Data outages are expected due to rain at the ground site and other causes. However, these data interruptions are budgeted to satisfy the high-level mission requirements for data completeness.

Onboard communication for commanding, and health and safety telemetry between the spacecraft subsystems and the instrument electronics boxes is through a MIL-STD 1553 bus. Science data is placed on a MIL-STD 1355 bus. All data is formatted into CCSDS packets. Each spacecraft subsystem and each instrument have an assigned range of Application Identifiers (ApID) to identify science data as well as housekeeping data. Before downlink, all data packets are formatted into Virtual Channel Data Units (VCDU) and assigned to certain Virtual Channels (VCs).

The science telemetry will be downlinked on the Ka-band to the SDO ground tracking station and routed to the Data Distribution System (DDS), which distributes it to the Science Operations Centers (SOC). To compensate for dropouts in the transfer of data on the ground network, the SDO ground system will maintain temporary archives at the antenna site and at the DDS.

Housekeeping telemetry data is downlinked on the S-band and transferred directly from the antenna site to the Mission Operations Center (MOC), which then distributes it to the appropriate SOC. The MOC archives all the observatory housekeeping data for the life of the mission. Flight dynamics products, such as ephemeris information, are generated at the MOC and forwarded to the SOCs as needed. The predicted ephemerides and the tracking data are stored in the MOC for the life of the mission. The SOCs are expected to archive any other products that may be needed for future science data processing.

3.0 Science Instrumentation

The SDO observatory includes a complement of three instruments:

1- Atmospheric Imaging Assembly (AIA), Principal Investigator (PI) Alan Title, at LMSAL in Palo Alto, CA.
2- EUV Variability Experiment (EVE), PI Tom Woods, at LASP, in Boulder, CO.
3- Helioseismic and Magnetic Imager (HMI), PI Philip Scherrer, at Stanford University in Stanford, CA.

Summary Properties of Instruments				
	Mass (kg)	Size (LxWxH) (in)	Data Rate (Mbps)	Power (W) Normal/eclipse
AIA	155	60.1 x 64.6 x 19.3	67	190/207
EVE	55	33.1 x 23.9 x 15.4	7	76/76
HMI	77	48.0 x 25.2 x 12.0	55	111/122

3.1 Atmospheric Imaging Assembly (AIA)

3.1.1 Instrument Description

AIA consists of four multi-wavelength telescopes with the spatial resolution of the TRACE heritage telescopes (0.6 arcsec/pixel) with a full-Sun view. AIA will provide images of the solar chromosphere and corona at 10 wavebands (or temperatures). Three of the telescopes have 2 sectors with 2 different mirror coatings which center on a particular waveband, while the fourth telescope has four sectors. To capture all ten wavebands, the telescopes each cycle through one waveband sector then proceed to another, so that eight of the ten wavebands are imaged within ten seconds, and all ten wavebands are imaged within a nominal 30 second interval. The time cadence of less than 10 seconds will capture the initiation and progression of dynamic processes in the solar atmosphere.

3.1.2 Capabilities and Requirements

The summary parameters of AIA are shown in **Table 3-1**.

Table 3-1. Summary Parameters for AIA

Parameter	Value
Parameters Measured	Images of the Sun in seven EUV wavelengths every 10 seconds, with 3 UV and visible channels every 30 seconds
Number and Type of Detectors	Four 4096 × 4096 CCDs
Sensitive Area	4096 × 4096 pixels
Field of View	40′ (solar disk has a diameter of 32′)
Energy/Wavelength Range	10 channels with central wavelengths of 94, 131, 171, 193, 211, 304, 335, 1600, 1700, and 4500 Å
Energy/Wavelength Resolution	
Time Resolution	≤10 sec for EUV wavebands
Positioning	
Sensitivity	
Data Rate	Science data (Ka-band): 67 Mbps HK data (S-band): 2 kbps

3.1.3 Data Acquisition

AIA will return full-disk images of the Sun with a pixel resolution of 0.6″. These images are taken every 10 seconds through most of the filters, although the three long-wavelength filters are exposed less frequently such that images in eight of the 10 possible wavelength are collected each interval. The image is transferred into the camera electronics, where it is compressed, and then transmitted to the ground. There are no special requirements for data acquisition. Special operating modes will be used occasionally that will increase the data rate, but decrease the areal coverage on the sun or decrease the number of wavelengths collected each cycle.

3.2 EUV Variability Experiment (EVE)

3.2.1 Instrument Description

EVE will measure the EUV spectral irradiance from 0.1 to 105 nm, plus hydrogen Lyman-alpha at 121.6 nm at a cadence of one spectrum every 10 seconds. EVE will measure the spectral irradiance with a sensitivity that allows us to gauge and model the energy input into the complex processes of the Earth's atmosphere and near-Earth space.

Its temporal resolution will allow us, for the first time, to understand the flare-induced impacts on these processes.

EVE combines the measurements from two grating spectrographs (MEGS-A, MEGS-B) to produce a EUV spectrum covering the 5-105 nm wavelength range. A pinhole camera with single photon detection (MEGS-SAM) obtains a 1-nm spectrum of the 0.1-7 nm wavelength region, and it also makes a low-resolution image of the Sun at wavelengths between 0.1 and 7 nm, while the MEGS-P photometer provides measurements from 120-122 nm covering the hydrogen Lyman-alpha line.
Several broadband (3-20 nm) photometer measurements (ESP) provide calibrations for the spectrographs and provide information at a higher time cadence (0.25 seconds).

3.2.2 Capabilities and Requirements

The summary parameters are EVE are shown in Table 3-2.

Table 3-2. Summary Parameters for EVE

Table 3.2: Summary Parameters for EVE	
Parameter	**Value**
Parameters Measured	Spectral irradiance covering 0.1-105 nm and 121.6 nm every 10 seconds
Number and Type of Detectors	2 1024 × 2048 CCDs 2 Si photodiodes in MEGS; 9 Si photodiodes in ESP
Sensitive Area	2048 (wavelength/spectrum) × 1024 (slit image) for each CCD
Field of View	2° ± 1°
Energy/Wavelength Range	0.1 to 105 nm
Energy/Wavelength Resolution	0.1 nm (5-105 nm); 1 nm (0.1-5 nm)
Time Resolution	≤ 20 sec between spectra
Positioning	Uncertainty < 60″ over 10 second intervals
Sensitivity	
Data Rate	Science data (Ka-band):7 Mbps HK (S-band): 2 kbps

3.2.3 Data Acquisition

EVE data are obtained using observation sequences that define the time cadence and filter positions in the filter wheel mechanism. The primary mode is to take solar observations every 10 seconds for the spectrographs. The calibration modes include flat-field measurements of the CCDs using on-board LEDs, dark measurements, and solar measurements using order-sorting filters. The photometer data are taken at a constant rate of 0.25 seconds without any software control of their time cadence. All of the EVE science data is sent to the SDO High-Speed Bus, which is directly transmitted to the SDO ground station.

3.3 Helioseismic and Magnetic Imager (HMI)

3.3.1 Instrument Description

HMI will observe "filtergrams" of the Sun through a series of optical filters that are combined to produce 5 or 6 filter positions straddling a spectral absorption line of Fe I at 6173 Å. Each filtergram is a measurement of the spectral line radiance at a known polarization. Combinations of these filtergrams will provide measurements of the line-of-sight Doppler velocity of the solar photosphere and the Stokes parameters needed to create the line-of-sight and vector magnetic field in the photosphere. Analysis of time series of filtergrams using techniques of helioseismology can provide information about sub-photospheric dynamics with the goal of a better understanding of magnetic field growth and decay processes on time scales of hours to years.

3.3.2 Capabilities and Requirements

HMI is required to obtain Dopplergrams, which measure the Doppler shifts due to oscillation velocities over the entire visible disk, and to make high-resolution magnetograms, measurements of the longitudinal and vector magnetic field over the whole visible disk of the Sun. The summary parameters are shown in Table 3-3.

Table 3-3. Summary Parameters for HMI

Parameter	Value
Parameters Measured	Line-of-sight velocity and magnetic field (vector and longitudinal.)
Number and Type of Detectors	2 4096 × 4096 CCDs
Sensitive Area	4096 × 4096
Field of View	2000″
Energy/Wavelength Range	Spectral line of Fe I (6173 Å), at least five positions on and off-band
Energy/Wavelength Resolution	Filter width of 76 mÅ (FWHM)
Time Resolution	Dopplergrams, 50 secs; Line-of-sight magnetograms, 50 secs;

	Vector magnetograms, 10 min; Continuum proxy, 50 secs.
Positioning	Uncertainty < 0.1″ over 0.5 sec intervals
Sensitivity	
Data Rate	Science data (Ka-band): 55 Mbps HK (S-band): 2 kbps

3.3.3 Data Acquisition

HMI will continually acquire filtergrams that are sent to the ground and combined to give the listed observables. The data acquisition modes are expected to have little variation during the operational phase of the mission.

4.0 *SDO Project Data Flow*

This section will summarize the data flow within the project. A diagram of the generalized architecture for Mission Operations and Data Analysis in shown in Figure 4.1.

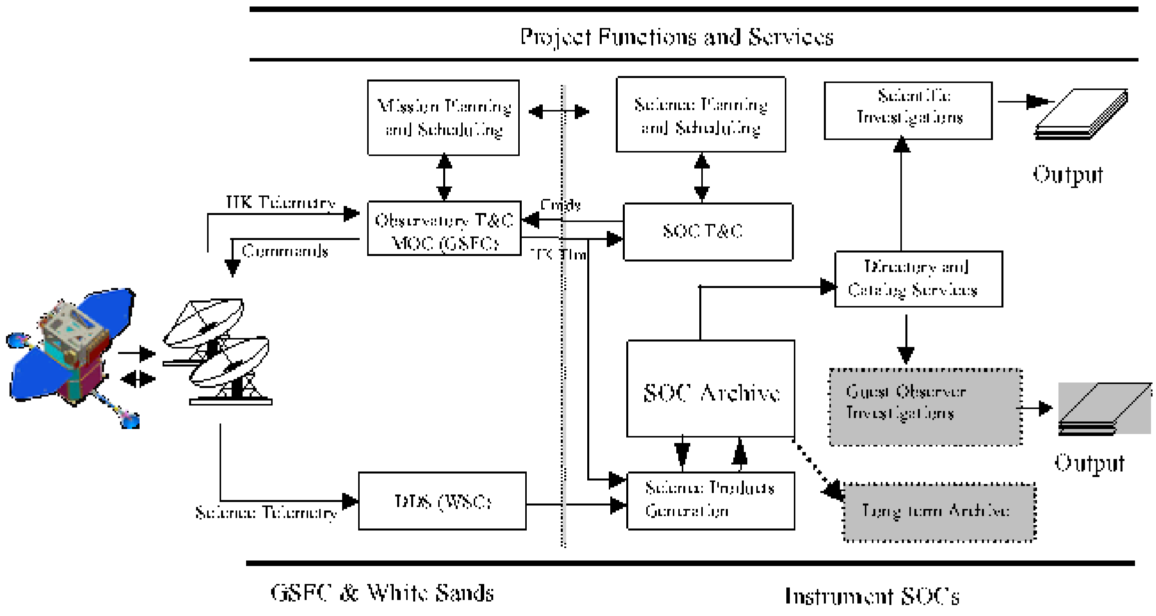


Figure 4-1. Summary of SDO Project Data Flows

Shaded areas in Figure 4-1 represent activities that are not directly supported by the SDO Project.

4.1 Mission Operations

This section summarizes the responsibilities of each SDO Ground System facility.

SDO Ground Tracking Stations responsibilities

- Receive Ka-band telemetry from spacecraft and forward it to DDS
- Receive S-band Housekeeping telemetry and forward it to the MOC.
- Receive commands from the MOC, uplink them to the spacecraft and monitor uplink.

DDS responsibilities

- Capture science telemetry and distribute science telemetry files to SOCs in near-real

time
- Maintain a thirty-day archive of science telemetry data and associated metadata
- Retransmission of science telemetry upon request by SOCs

MOC responsibilities

- Monitor and control observatory health and safety
- Route instruments commands from SOC to antenna for uplink
- Receive housekeeping telemetry from the antennas and distribute to the appropriate SOCs
- Maintain archive of housekeeping telemetry and trending data for the life of the mission.
- Maintain activity timelines for spacecraft and instruments.
- Provide Flight Dynamics products for use within the project
- Provide mission support data for use within the project

SOC responsibilities

- Produce, serve, and archive Level 0-3 science products for the instrument. This includes producing calibrated radiance and irradiance data as well as the derived data products.
- Provide data processing support, including hardware and software, for the science team associated with their instrument.
- Maintain an accessible database containing the instruments planned and as flown status information.
- Maintain an accessible database containing science metadata, instrument calibration data and analysis tools.
- Maintain an accessible database containing data product generation status information.
- Serve and archive analysis products generated by the science team associated with the instrument. Requests for large volumes of AIA or HMI data will be handled as feasible given the resources at the JSOC, which may delay data delivery or dictate that the data be delivered via mass-storage hardware rather than via the internet.
- Develop and support the Web-based interface that provides access to the instrument data products by the science community
- Participate in the design of the final archive.

4.2 Project Data

4.2.1 Project Data Repositories

Project data repositories are located at and maintained by the instrument SOCs. HMI and AIA will maintain a Joint SOC (or JSOC) that will ingest the data from the DDS and process the TLM files into Level 0 and Level 1 files.

Table 4-2 summarizes storage requirements by instrument over the life of the mission. The data sets are identified as Level 0, Level 1, and higher-level products. The first two columns of values represent the estimated amount of storage without compression. The next two columns show the requirements if the CCD images (the Level 0 and Level 1 data) are compressed by 50%. Products with a "0 TB*" are generated from lower level data upon request. In addition to the data shown in Table 4-2 the SOCs will maintain two copies of the raw telemetry data amounting to up to AIA: 528TB/yr, EVE: 55TB/yr, and HMI: 435 TB/yr.

Table 4-2. Estimated Storage Requirements

Instrument/Data Set	Annual	5-Year Total	Annual (Compressed)	5-Year Total (Compressed)
AIA				
Level 0 Data	805 TB	4025 TB	403 TB	2015 TB
Browse Data	3 TB	15 TB	3 TB	15 TB
Level 1 Data	0 TB*	0 TB*	0 TB*	0 TB*
Higher level Products	0 TB*	0 TB*	0 TB*	0 TB*
AIA TOTAL	808 TB	4040 TB	406 TB	2030 TB
EVE				
Level 0 Data	54 TB	270 TB	27 TB	135 TB
Level 1 Data	0.5 TB	2.5 TB	0.25 TB	1.25 TB
Space Weather Data	0.028 TB	0.14 TB	0.028 TB	0.14 TB
Higher level Products	0.5 TB	2.5 TB	0.25 TB	1.25 TB
EVE TOTAL	55 TB	275 TB	27.5 TB	137.5 TB
HMI				
Level 0 Data	512 TB	2560 TB	256 TB	1280 TB
Level 1 Data	150 TB	750 TB	75 TB	375 TB
Higher level Products	15 TB	75 TB	15 TB	75 TB
HMI TOTAL	677 TB	3400 TB	346 TB	1655 TB
Total	2.450 PB	12.25 PB	1295 TB	6.4 PB

4.3 Continued Accessibility

4.3.1 Directories and Catalogs

This section of the PDMP addresses metadata and the associated mechanisms for the identification and location of data sets and data analysis tools.

1. Metadata: Instrument observation parameters and ancillary information that is needed for the analysis of the data
2. Catalogs: A web-searchable compilation of relevant metadata, combined with additional indexing for available data products, calibration data, and (if applicable) analysis tools. SDO data will be available for searching through the Virtual Solar Observatory (VSO), as well as by user interfaces hosted at the PI SOCs.
3. Browse Products: Web-accessible catalog of data compiled from a subset of the science data that allows the user to quickly browse and perform a preliminary assessment of the data. Browse data are typically used to determine a time or wavelength range for a request of higher-level science data.
4. Calibration Data and Analysis Tools: Additional derived or calibration data, software routines, version numbers and information that are necessary for the quantitative analysis of the data
5. Inclusion in the NASA Master Directory (MD) or other directories and catalogs at the time of, or prior to, the delivery of data to the archives.

4.3.2 Standards and Policies

Projects and investigators will archive data conforming to those standards and policies that will facilitate subsequent data access and use. The specifics of each data set are provided in section 5. SDO will use FITS formatted files to serve science data.

4.3.3 Scientific Computing Resources

Each SOC is responsible for providing computing resources sufficient for achieving the goals of their scientific investigation(s). The resources will be sited at the PI institutes and controlled by the PI teams. External resources, such as those provided by the NASA Center for Computational Sciences (NCCS) at GSFC, and non-NASA resources, such as those available from the National Science Foundation and the Department of Energy, can be utilized if they are obtained at no additional cost to the project and do not delay the delivery of data projects to the user communities. However, these external resources will not be used to create the standard data products.

4.3.4 Networking Requirements

SDO uses dedicated commercial links to transfer the data from White Sands to the SOCs and from GSFC to the SOCs. The network configuration is defined in the applicable SDO Ground System Design documents. Each SOC has sufficient network capability to serve the requested data.

4.4 Mission Support Data

The availability, distribution, format and archiving of mission support data is described in the DDS-to-SOC ICD (Reference 8) and MOC-to-SOC ICD (Reference 8).

The MOC-to-SOC ICD also defines the FDS products that are made available to the SOCs.

5.0 Science Data

Science data products include data sets generated by the project. This section of the PDMP identifies and describes all data sets expected to be generated, and how these data sets are to be made available to the user community. This includes the science data itself, associated ancillary data, and orbit/attitude data of the spacecraft. The science data products for each of the instruments on SDO are summarized in sections 5.1 through 5.3 below.

5.1 AIA Science Data Products

This section summarizes the science data products produced by AIA. The AIA/HMI Joint Science Operations Center (JSOC), supported by Stanford University and LMSAL, serves the data to the science community and other users. Nominally, all AIA and HMI data will be served from Stanford University.

AIA data levels are defined below in Table 5-1. The AIA routine processing for Level 0 data will consist of steps that are considered to be well understood and which are reversible. The Level 0 data, combined with the AIA metadata and calibration data, are stored on the JSOC data server.

Level 1 data products will be assembled by the data system to suit the user requests. This is because we anticipate a wide range of data requests, and because the characterization of the instrument itself and therefore the calibration will change throughout the mission. The data server will assemble each data product request from the Level 0 data and the metadata using the most recent calibration information. All possible pixel-level calibrations are applied to generate Level 1 data. The only exception is that the bad pixel maps are created, but not applied at this stage. These maps include both those due to detector imperfections and cosmic rays. All higher products are based on Level 1 data. Levels 1.5 and 1.6 have all geometric corrections with all images sharing common plate scales and centers and rotation angle from Solar North. In addition, Level 1.6 has a quick FFT-based PSF correction to provide the cleanest images for browse products. Higher-level products for general distribution are reductions of these three series. Browse and synoptic products are generated from Level 1.5. Research data cubes are subsets of Level 1.5. These levels are maintained as data series in the JSOC DRMS/SUMS environment. These calibrated data products will be distributed as part of normal data operations, and only to the extent that existing facilities and resources will allow. Large data requests may be delayed or may require the requestor to supply media or other resources.

Higher-level data products can be divided into two main areas: more-highly processed images, such as Differential Emission Measure maps (with temperature inversions) or field extrapolations, and metadata which can be used to locate and interpret the data. The later could include processed movies, event and feature catalogues, and derived coronal structures. AIA Level 2 data products will generally be generated and archived by the LMSAL.

Browse data, consisting of summary images and movies, will be available to assist users in identifying subsets of the data for analysis. Additionally, the AIA data system will serve some Assembled Data products, chiefly data cubes of image subsets tracking regions of interest, or assemblies of popular data subsets. Assembled Data products that are not accessed on a regular basis will be migrated off the server.

To aid researchers in finding appropriate data, and to reduce the demand on the Level 1 archive, a variety of metadata products will be generated and maintained. These include descriptions of observed events, along with associated thumbnails and compressed movies, and pointers to the Level 1 archive (including bracketing time intervals and region of interest) and associated modeling or higher-level products. These events are described in XML documents based upon the VOEvent standard (for further detail see http://www.ivoa.net/twiki/bin/view/IVOA/IvoaVOEvent), with extensions developed by the Heliophysics Knowledgebase project. These events are ingested into a separate database server maintained at LMSAL.

Table 5-1. Science data product summary parameters for AIA

Level	Description	File Format	Rate (Gb/day)	Rate (TB/year)	Cache (day)	Archived (%)
Raw	Telemetry	Packets	674	250	30	100
0	Raw images with header information, in instrument units (DN)	FITS	1200	440	100	100
1.0	Calibrated images (using best-available calibrations)	FITS	1200*	0	60	0
1.5	Scaled, registered, and aligned images (DN)	FITS	0*	0	0	0
2	Irradiance curves, reconstructed temperature maps, etc.	FITS	1	0.4	0	100
Browse Data	Compressed images and movies	jpeg, mpeg	10	4	0	100
Synoptic	Low-resolution images	FITS	10	4	0	100
Data Cubes	Resampled, cropped data samples	FITS	Var.	100	30	100

Table 5- 1: Data level definitions, with anticipated volume for the AIA instrument. A * indicates that individual data products are not stored on the server; it is assembled from the Level 0 data and metadata by the data system upon request.

The AIA data server is continually populated with the most recent Level 0 data and browse data. After receipt from the DDS, AIA Level 1 near-realtime data will be available with a latency of less than one hour; browse data will be available within two hours. Once the DDS confirms all data has been received, nominally within 24 hours of the original downlink, Level 1 data will be generated, released for general distribution, and used to generate higher-level products. These products will be available within three days.

5.2 EVE Science Data Products

5.2.1 EVE Data Products Functional Description

This section describes the public science data products produced by the EVE SPOC (Science Processing Operations Center).

Level 0C

Level 0C products include MEGS photometer, ESP, MEGS-A and MEGS B products,

The Level 0C processing produces Space Weather products that are intended to be "quick & dirty." With this understanding, these products will be uncalibrated and contain only engineering units (counts). These shall only be minimally processed since products must be produced in near-real-time.

Level 1

Level 1 processing is performed on an hourly basis for all channels (SAM, MEGS-P, ESP, MEGS-A, MESG-B). The result of a single Level 1 processing task is a file containing data from individual integrations from the nominal operating mode over one UT hour. Data are fully calibrated, degradation corrected, 1-AU corrected irradiance.

Level 2

Level 2 processing is performed on an hourly basis for only MEGS-A and MEGS-B channels. The result of a single Level 2 task is a file containing data from the individual integrations from the nominal operating mode over one UT hour. Data are integrated using the trapezoid method onto a fixed wavelength scale to allow meaningful comparisons between integrations. Specific solar emission lines will be extracted from the fixed wavelength spectra.

Level 3

Level 3 processing is performed on a daily basis. Level 3 merges the data from each channel into a daily averaged EVE measurement. The following data are used to create the Level 3 product: Level 1 SAM, Level 1 ESP, Level 1 MEGS-P, Level 2 MEGS-A, and Level 2 MEGS-B. The result of the Level 3 task is a file containing averaged data from all EVE channels from the nominal operating mode over one UT day. Two spectra will be produced: a 0.1 nm spectrum from merged MEGS-A and MEGS-B spectrum, and a 1 nm spectrum that includes the SAM spectral measurement. Daily averages from the ESP, SAM total irradiance, MEGS-A extracted lines, MEGS-B extracted lines, and MEGS-P will also be reported.

For Level 3 the units will be watts per square meter for photometer and SAM total band pass irradiance measurements, and watts per square meter per nanometer for spectral measurements.

All measurement will contain the date and at least three different types of uncertainty:

- Precision: fractional Poissonian statistical uncertainties (1/sqrt[counts])
- Accuracy: fractional total uncertainty including propagated calibration uncertainties
- Standard deviation: one-sigma statistical spread of the measurement over the day

5.2.2 EVE Science Data Distribution

Table 5-2. Data Product Overview

Level	Components	Time resolution	Time span	Processing cadence	Daily Volume (MB)	Public release of day N data
L0A	All	Highest	~1 min	NA	75000	NA
L0B	All	Highest	~1 min	1 min	75000	NA
L0C	ESP MEGS-P MEGS-A, B	1-sec 1-sec 10-sec	~1-min	Each TLM file (~1/min)	2.2 1.1 34	~15 min after receipt
L1	ESP SAM MEGS-P	1-sec 1.5-min 1-sec	1-hour	24-hour	13 0.075 9	Hour 1-2 on day N+1
L1	MEGS-A, B	10-sec	1-hour	24-hour	1100	NA
L2	MEGS-A, B	10-sec	1-hour	After L1	1200	Hour 23-24 on day N+1
L3	ESP, SAM, MEGS-A, MEGS-B, MEGS-P	1-day	1-day	1/day	0.026	Hour 0-1 on day N+2

EVE Science Data Storage

All data stored on the RAID is redundant except for the plots, catalog files, database files, and user registration information. This information is backed up periodically to the Archival subsystem. Approximately 500 GB of additional hard drive space will be required per year. Only the newest version/revision combination will be kept online. A weekly purge routine will automatically delete old versions/revisions.

Data product files will be stored in a compressed form (like gzip) to reduce the download time for users, and reduce storage costs. Plots will be stored in a format that is highly compressible, and widely recognized by most web browsers (likely PNG).

EVE Science Data Catalog

Catalog files are flat ASCII files that contain a list of data product files that are available in sequential time order. There will be one catalog file per data product type. This allows users to search and identify specific data product file names that were collected at certain times of interest. Additional information may be determined through the database. This structure will allow queries to be performed through most virtual observatories, including the Virtual Solar Observatory.

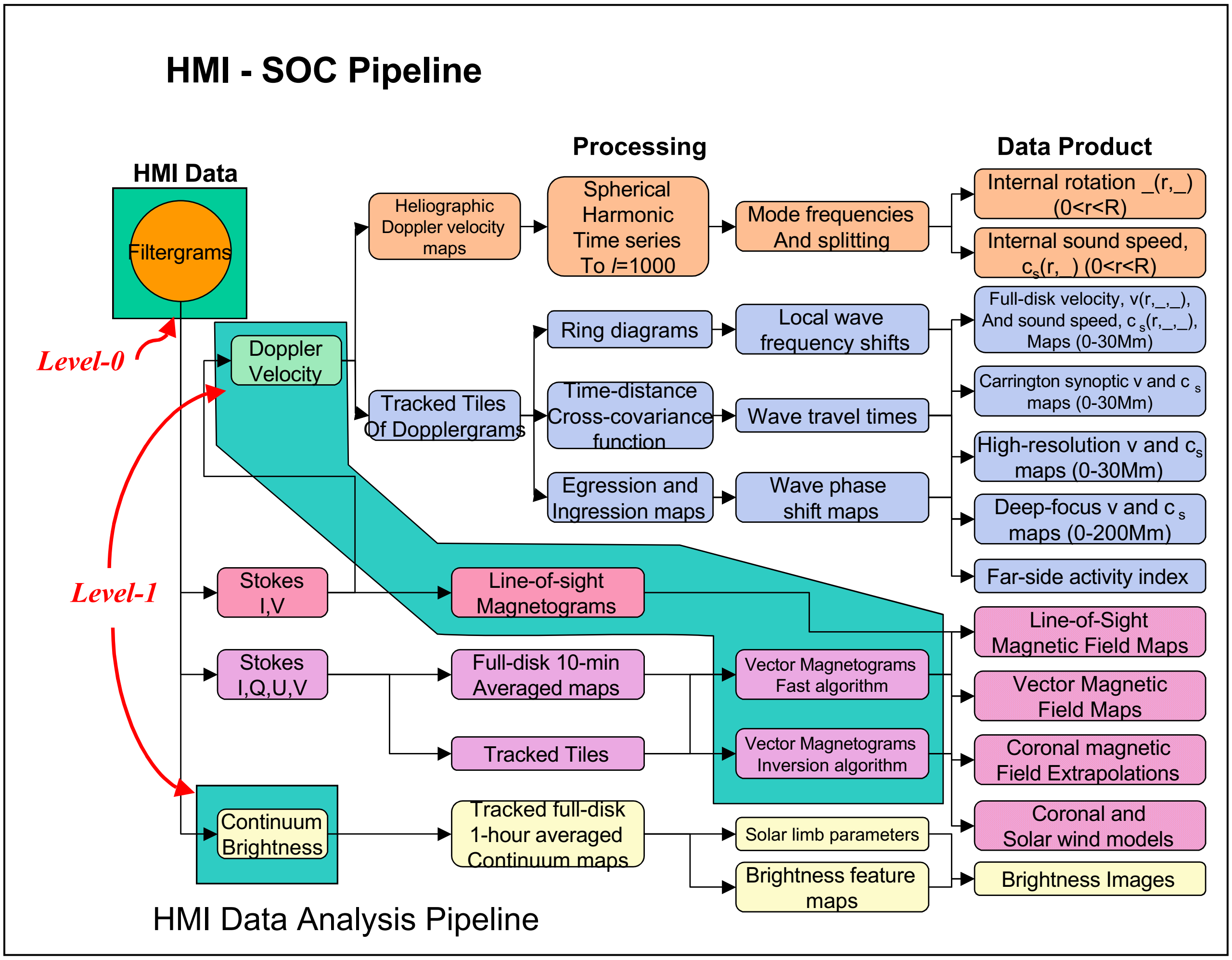
5.3 HMI Science Data Products

This section summarizes science data products to be generated by HMI. This data is archived at the JSOC located at Stanford University, along with the AIA data. For a full listing of HMI data see http://jsoc.stanford.edu.

Table 5-3: HMI Science Data Products

Level	Description	Examples	Cadence	Rate (Gb/day)	Rate (TB/year)	Cache (day)	Archived (%)
Raw	Telemetry	—		553	220	30	100
0	Filtergrams	—		530	200	100	100
1	Observables	Doppler velocity, line-of-sight magnetic field, continuum proxy	45 sec.	130	15	600	30
1	Observables	Vector field parameters	10 min.	130	15	600	30
2	Higher Level Data Products	Spatial/temporal averages, synoptic maps, spherical harmonic decomposition, frequencies	Var.	20	8	3000	100

The following diagram illustrates the proposed production and relationship of data products within HMI.



6.0 Glossary

Ancillary Data	Non-science data needed to generate Level 1 data sets. Consists of instrument gains, offsets; pointing information for scan platforms, etc.
Browse Data	Web-accessible subset of the science data that allows the user to quickly browse and perform a preliminary assessment of the data. Browse data are typically used to determine a time or wavelength range for a request of higher-level science data.
Catalog	The instrument source catalog is a compilation of derived parameters and scientific results about observed sources.
Continued accessibility	The derivation and dissemination of useful science knowledge and insight resulting from the data collected. The functions and services provided during continued accessibility include directory and catalog services, scientific computing resources, discipline data archives, and other archives and databases.
Correlative data	Other science data needed to interpret space-based data sets. May include ground-based data such as Hα images or other space-based measurements of the solar irradiance.
Data Analysis	Process by which higher-level data products are derived from basic data acquired by instruments. Data analysis functions include modeling, manipulation, data interpretation, and data presentation.
Data Directory	Top-level index containing information about location, ownership, contents of data. Used as first step in determining what types of data exist for given time, period, location, etc.
Data Handling	The process of data acquisition including onboard encoding and compression of data generated by flight sensors, data preprocessing on the ground to remove the artifacts of data transmission and conversion of raw data to Level 0 data, and management of this process to assure completeness and accuracy of the science data.
Data Set	The accumulation of data products, supplemental data, software, and documentation that will completely document and support the use of those data products. A data set can be part of a data set collection; can reside on a single physical volume or across multiple volumes.
Decommutation	Process whereby the downlink data stream is split into data streams that contain data from only one or from select payloads or systems.
Discipline Data Archive	Long-lived collections of science, operational and related ancillary data, maintained as a national resource at a discipline data center, supported with adequate cataloging, protection, and distribution functions. It provides long-term access to data by the general space science community.
Guest Observer	Has access to observation, to generate specific space science data to conduct independent investigations, although seldom participate in initial mission planning or instrument design.
High-Level Processed Data	Products of detailed processing including instrumental calibrations and background corrections.
Level 0 Data	Reconstructed unprocessed instrument data at full resolution. Edited data corrected for telemetry errors and split or decommutated into a data set for a given instrument. Sometimes called Experimental Data Record. Data are also tagged with time and location of acquisition.
Low-Level Processed Data	Data products of "automatic" pipeline processing. These data are generally produced within a few months of acquisition.
Metadata	Descriptions of database contents in sufficient detail to allow retrieval of subsets of data.
Mission Operations	The safe and efficient operation of the spacecraft and associated payloads during the active flight portion of the investigation. The principal functions and services associated with

	mission operations include telemetry services, mission planning and scheduling, and mission control.
Non-Science User	General public, Public Affairs/Outreach or curious individuals seeking data for information purposes rather than for scientific investigation.
Primary User	Includes science investigators who plan and design the experiments, and have an immediate need for access to the data being generated. This includes principal investigators, guest observers, and investigator team members. They represent the first scientists with access to the data.
Principal Investigator (PI)	Often work with co-investigators, are responsible for planning, development, and integration of experiments and instruments, data analysis, and the selection and preparation of the analyzed data for archiving. Principal Investigators are usually tied to a particular instrument.
Production Time	This is the processing time required to generate a data product in usable form after data acquisition.
Project Data Repository	Short-term database that serves as a way station or clearinghouse for data - such as a mission data base to support operations and compilation of initial results. Temporary buffers for new data, usually existing only as long as the mission producing the data.
Public Release Time	This is the time when a data product becomes public domain after its production and can be accessed by a researcher without exclusive rights to the data.
Raw Data or raw telemetry	Telemetry data with data embedded
Science Operations	The functions and services required to ensure the production of valuable science data or samples during the active flight portion of the investigation. Principal functions and services provided as science operations include science planning and scheduling, science control, project data archive, and science data analysis.
SDO Science Working Group	This group is responsible for scientific direction of the SDO mission. It is composed of the project scientist, the principal investigators of each of the SDO instruments, and one representative from the Space Weather community.
Secondary User	A member of the general science community, which could include discipline peers or interdisciplinary scientists, who usually conduct their analysis using data that has been archived, as well as data provided or published by the PI. Secondary users also work in collaboration with primary users. A researcher not involved with instrumentation design, development, or data acquisition. A secondary user would normally go to a data archive to obtain the required data set. Also referred to as retrospective investigator.
Status	Data products that contain information about the SDO spacecraft or data products
Telemetry Services	Those activities required to convert the spacecraft downlink into data that is useful to the experimenter or investigator.
Test SOC	Science Operations Center employed during integration and test.

7.0 ACRONYM AND ABBREVIATION LIST

See also http://sdo.gsfc.nasa.gov/resources/acronyms.php

AIA	Atmospheric Imaging Assembly
CCB	Change Control Board
CCSDS	Consultative Committee for Space Data Standards
CI	Collaborative Investigator
CME	Coronal Mass Ejection
Co-I	Co-investigator
DDS	Data Distribution System
EELV	Evolved Expendable Launch Vehicle
EVE	Extreme ultraviolet Variability Experiment
EUV	Extreme Ultraviolet
FITS	Flexible Image Transport System
FOT	Flight Operations Team
FTP	File Transfer Protocol
GB	Gigabyte
GSFC	Goddard Space Flight Center
HMI	Helioseismic and Magnetic Imager
I&T	Integration and Test
ICD	Interface Control Document
LASP	Laboratory for Atmospheric and Space Research
LMSAL	Lockheed Martin Solar and Astrophysics Laboratory
MB	Megabyte
MOC	Mission Operations Center
PB	Petabyte (10^{15} bytes)
PI	Principle Investigator
SDO	Solar Dynamics Observatory
SOC	Science Operations Center
SWG	Science Working Group
T&C	Telemetry & Control
TBD	To Be Determined
TLM	Telemetry
TRACE	Transition Region and Coronal Explorer
VCDU	Virtual Channel Data Unit
VSO	Virtual Solar Observatory
WSMR	White Sands Missile Range

8.0 Appendix A. Data Rights and Rules for Data Use

The SDO science investigators agree to abide the Rules of the Road developed for the Sun-Earth Connection and its successor, the Heliophysics Division. These are:

1. The Principal Investigators (PI) shall make available to the science data user community (Users) the same access methods to reach the data and tools as the PI uses.
2. The PI shall notify Users of updates to processing software and calibrations via metadata and other appropriate documentation.
3. Users shall consult with the PI to ensure that the Users are accessing the most recent available versions of the data and analysis routines.
4. Browse products are not intended for science analysis or publication and should not be used for those purposes without consent of the PI.
5. Users shall acknowledge the sources of data used in all publications and reports.
6. Users shall include in publications the information necessary to allow others to access the particular data used.
7. Users shall transmit to the PI a copy of each manuscript that uses the PI's data upon submission of that manuscript for consideration of publication.
8. Users are encouraged to make tools of general utility widely available to the community.
9. Users are also encouraged to make available value-added data products. Users producing such products must notify the PI and must clearly label the product as being different from the original PI-produced data product. Producers of value-added products should contact the PI to ensure that such products are based on the most recent versions of the data and analysis routines. With mutual agreement, Users may work with the PI to enhance the instrument data processing system, by integrating their products and tools.
10. The editors and referees of scientific journals should avail themselves of the expertise of the PI while a data set is still unfamiliar to the community, and when it is uncertain whether authors have employed the most up-to-date data and calibrations.