TWINS Explorer Mission of Opportunity

Project Data Management Plan (PDMP)

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APPROVAL SIGNATURES

David McComas, Principal Investigator
Southwest Research Institute

Lynn Friesen, Host Accommodation
The Aerospace Corporation

Jerry Goldstein, Document Editor and Science Operations Center Lead
Southwest Research Institute

Ruth Skoug, Document Originator and Co-I
Los Alamos National Laboratory

Edwin Grayzeck, Director
National Space Science Data Center

Mei-Ching Fok, TWINS Program Scientist
NASA Goddard Space Flight Center

Reginald Eason, TWINS Project Manager
NASA Goddard Space Flight Center

TWINS PDMP Approval

_____ _____
David McComas Date
Principal Investigator
Southwest Research Institute

_____ _____
Lynn Friesen Date
Host Accommodation
The Aerospace Corporation

_____ _25 Oct 06__
Jerry Goldstein Date
Science Operations Center Lead
Southwest Research Institute

_____ _____
Ruth Skoug Date
Document Originator and Co-I
Los Alamos National Laboratory

_____ _____
Edwin Grayzeck Date
Director
National Space Science Data Center

_____ _____
Mei-Ching Fok Date
TWINS Program Scientist
NASA Goddard Space Flight Center

_____ _____
Reginald Eason Date
TWINS Project Manager
NASA Goddard Space Flight Center

Revision History:

Affected Revision	Section	Heading	Description of Change	Date
	All	All	Changes to accommodate PI move from LANL to SwRI.	11/29/2000
	3.1.3, 4.3.1	Data Acq Table 4.1	Update number of direct events to reflect current ISD values.	11/29/2000
	Approvals		New TWINS Program Scientist	11/29/2000
	cover pages		added Jerry Goldstein's name	June 2004
	1.2		Add Jerry Goldstein's name	June 2004
	2.0, 2.3		Revise projected launch schedule	June 2004
	3.1.2.2		Acknowledge probable overlap of TWINS 1 and IMAGE missions	June 2004
	4.3.2, 4.3.4, 4.4.1. 4.4.3		Add Oracle database discussion	June 2004
	4.3.6		New section discussing ancillary data products	June 2004
	Cover pages		Minor changes to cover pages	Oct 2006
	1.2		Change of title for J. Goldstein	Oct 2006
	2.0, 2.3		Revise TWINS-1 launch and projected data acquisition schedule, TWINS-2 projected launch schedule.	Oct 2006
	2.3		Brief mention of sunlight exposure limitations.	Oct 2006
	3.1.2.2		Discuss IMAGE satellite failure and revised TWINS-1 solo operations and science.	Oct 2006
	3.1.3		Revise Table 3.1	Oct 2006
	3.3		New section added to discuss sunlight exposure analysis	Oct 2006
	4.1		"Data Delivery Hub Processing" List added	Oct 2006
	4.1		TWINS URL updated to current site.	Oct 2006
	4.3		.Update Table 4.1 (for Level 0 data), New Table 4.2 (for Level 1 data)	Oct 2006
	Various		All mention of HDF format removed and replaced with CDF.	Oct 2006
	4.3.3		Update Level 0 Data description.	Oct 2006
	4.3.4		Update Level 1 Data description	Oct 2006
	4.3.5		Update Level 2 Data description	Oct 2006
	4.3.6		Update Ancillary data description	Oct 2006
	4.4.0		Update to Archiving Discussion	Oct 2006
	4.4.5		Update Review Items	Oct 2006
	4.4.3, 4.4.5		Change numbering to Table 4.3 and Table 4.4	Oct 2006
	4.4.2		Update discussion of NSSDC/SPDF	Oct 2006
	Cover pages		Add Reginald Eason as signees (at request of Holmes)	Oct 2006

1.0. Introduction

This document describes the Project Data Management Plan (PDMP) for the Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) mission. TWINS is a Mission of Opportunity selected under NASA's Small Explorer (SMEX) program. The TWINS PDMP is designed to be consistent with the TWINS Program-Level Requirements Document (Appendix MO-2 of the TWINS Explorer Program Plan).

1.1. Purpose and Scope

This data management plan describes the generation and delivery of TWINS science data products, institutional responsibilities for data analysis, and the transfer of archival data products (including data, data documentation, and associated software) to the National Space Science Data Center/Space Physics Data Facility (NSSDC/SPDF). Covered in this plan are:

1. Brief description of the instruments
2. Description of the data flow
3. Description of the science data products
4. Processing requirements and facilities
5. Policies for access and use of TWINS data
6. Data product documentation

It is important to note that the TWINS telemetry system will be provided by the spacecraft sponsor, and thus a detailed discussion of this topic will not be included in this document.

1.2. PDMP Development, Maintenance, and Management Responsibility

The TWINS Principal Investigator (PI), Dr. David McComas and Science Operation Center lead Dr. Jerry Goldstein, both at Southwest Research Institute, are responsible for the development, maintenance, and management of the PDMP throughout the TWINS mission. Data handling and data distribution tasks are the responsibility of both LANL and SwRI personnel. Data analysis tools and capabilities will be developed at both SwRI and LANL. The TWINS PDMP will be modified and updated as required in accordance with the TWINS Configuration Management Plan.

2.0. Project Overview

The TWINS mission was selected as a result of AO-97-OSS-03 for SMEX missions. The Phase B study began in July 1998. The mission Preliminary Design Review (PDR) and Confirmation Assessment Review (CAR) were held on March 10, 1999. The mission Confirmation Review was held on April 12, 1999, and TWINS entered Phase C/D in May 1999. The mission Critical Design Review (CDR) was held on February 23, 2000. The TWINS Flight Model 1 (FM1) Pre-Environmental Review (PER) was held on March 27, 2002 and a combined FM1 Pre-Ship Review (PSR) and FM2 PER were held on August 24, 2004. The TWINS FM1 Mission Readiness Review (MRR) was held on August 23, 2005. The FM2 PSR was held on February 28, 2006, and the FM2 MRR on April 5, 2006. A final TWINS Mission Readiness Brief was successfully held at NASA Headquarters on May 23, 2006.

TWINS-FM1 was delivered to the Host contractor in early 2005 and launched successfully into orbit in the summer of 2006. (The exact launch date is unavailable.) As of the writing of this document, high-voltage science data have not yet been acquired, although instrument high voltage turn-on could occur at any time. Based on the results of UV Sun exposure analysis (*TWINS UV Exposure Study,* Aerospace Report No ATR-2006(7687)-1), it may be early 2007 before we are in a optimal season for science data acquisition. (See Section 3.3.)

TWINS-FM2 was delivered to the Host contractor June 13, 2006 and is scheduled for launch in 2007, with the two-year stereo mission beginning in 2007 or 2008.

2.1. Science Objectives

The overall scientific objective of the TWINS project is to establish the global connectivities and causal relationships between processes in different regions of the Earth's magnetosphere. TWINS will address this objective through stereoscopic neutral atom imaging of the magnetosphere from two widely spaced, high-altitude, high-inclination spacecraft. By imaging charge exchange neutral atoms over a broad energy range (~1–100 keV) using identical instruments on two spacecraft, TWINS will enable the three-dimensional (3-D) visualization of the magnetosphere and the resolution of large scale structures and dynamics within the magnetosphere for the first time. In contrast to traditional in situ measurements, TWINS will provide nearly continuous global, stereo coverage of the magnetosphere.

Specific scientific questions to be addressed by TWINS include the structure and evolution of the magnetosphere and the sources, energization, transport, and sinks of magnetospheric plasma populations. The first level of questions will be addressed by the 3-D images themselves, and the second through inversion of the images to determine the characteristics of magnetospheric ions.

2.2. Spacecraft Description

A description of the host spacecraft is not appropriate for the TWINS Mission of Opportunity. We shall refer to these spacecraft as TWINS-1 and TWINS-2.

2.3. Mission Summary

A summary of the TWINS mission is given in Table 2.1. Mission operations for TWINS will be provided by the spacecraft sponsor. Each spacecraft will be placed in a Molniya orbit, and will be three-axis stabilized and approximately nadir pointing.

In nominal operating mode, the TWINS instruments will acquire image data with time resolution of 60 seconds. Between each image, a 12-second period is required to change the actuator rotation platform travel direction. No data will be collected during this time, giving a duty cycle for data collection of 83%, and effective time resolution of 72 seconds.

Table 2.1. TWINS Mission Summary

Project Name	TWINS
Number of Spacecraft	2
Orbit Description	Molniya orbit Inclination: 63.4° Apogee: 7.2 R_E Perigee: ~1000 km Period: 12 hours
Approximate Launch Dates	TWINS-1: Summer 2006 TWINS-2: Projected 2007 or 2008.
Launch Vehicle	Provided by spacecraft sponsor
Nominal Mission Duration	4 year design lifetime for each instrument 2 year stereo mission
Potential Mission Life	Host spacecraft have 7 year design lifetime
Continuous Data Acquisition Rate	50 kbps
Attitude Control	3-axis stabilized

TWINS will nominally operate only during the apogee portion of each orbit, when the spacecraft is above the radiation belts. Operations are also planned for some perigee passes, providing low altitude observations when the spacecraft is below the radiation belts. Ultraviolet exposure analysis (*TWINS UV Exposure Study,* Aerospace Report No ATR-2006(7687)-1), based in part on UV calibration

(*TWINS Calibration Procedure,* SwRI doc 1609-TCP-01) indicates that sunlight exposure will constrain acquisition of science data such that observation windows will fluctuate with season. (See Section 3.3.)

Telemetry for the TWINS mission will be received by the spacecraft sponsor, who will extract raw data from the telemetry stream and send it to the Aerospace Corporation (henceforth Aerospace) for processing into Level 0 data. Level 0 data will then be sent to SwRI for processing of Level 1 data (images). These data products will be posted on the World Wide Web for use by the TWINS team, the scientific community, and the public, and will be provided to the NSSDC for archiving. Higher level data products will also be posted on the web and archived at the NSSDC, as appropriate.

3.0. Science Instrumentation

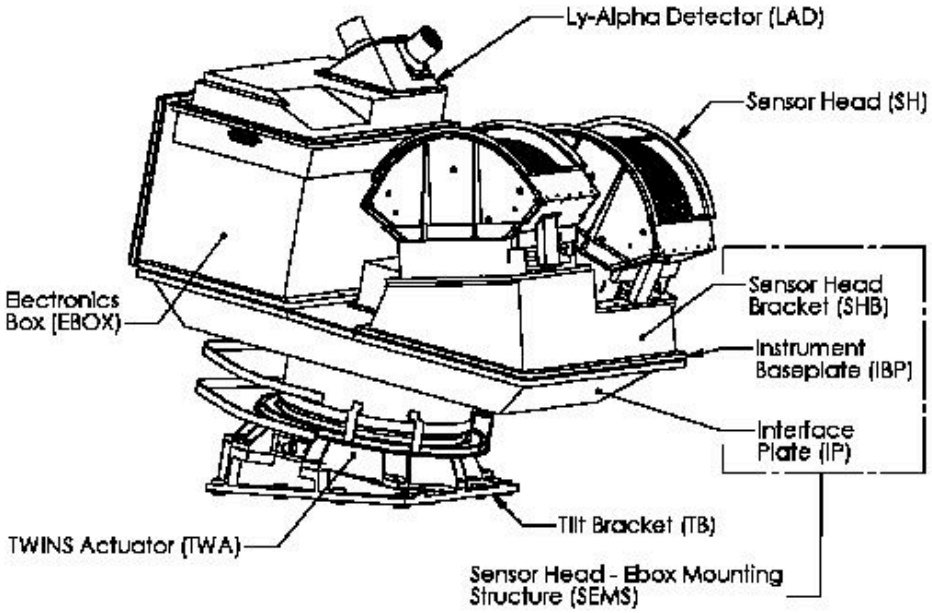
The TWINS instrumentation consists of a neutral atom imager to obtain images of the Earth's magnetosphere and a Lyman-α detector to measure the density of the neutral hydrogen geocorona.

3.1. Neutral Atom Imager

3.1.1. Instrument Description

The TWINS neutral atom imager is based on the MENA imager developed for the IMAGE mission. TWINS combines two sensor heads to provide a field of view of ±60˚ about the rotation direction (10˚ off nadir pointing). The instrument uses alternating biased and grounded collimator plates to reject charged particles and set the instantaneous azimuthal field of view. A carbon foil is used to produce secondary electrons for time of flight (TOF) measurement, and a position sensitive anode provides angular determination. Gold transmission gratings are used to block ambient ultraviolet light, to which the detectors are sensitive. Velocity analysis (from TOF measurements) combined with pulse-height analysis provides statistical mass determination. Since the spacecraft for this mission of opportunity are three-axis stabilized, the instrument will be located on a rotating actuator platform to provide 360˚ azimuthal coverage. Figure 1.1 shows the layout of the TWINS instrumentation package, including the ENA imager sensor heads, the rotating actuator platform, and the single electronics box.

Figure 1.1. TWINS Instrument Layout



3.1.2. Capabilities and Requirements

3.1.2.1. Minimum Science Requirements

The minimum performance requirements for the TWINS neutral atom imagers, taken from the TWINS Program-Level Requirements Document, are given below. The neutral atom imagers on both TWINS spacecraft are required to meet these minimum requirements in order to provide a stereo neutral atom imaging mission.

3.1.2.1.1. TWINS shall obtain at least 300 stereoscopic neutral atom images simultaneously from two independent spacecraft platforms over a period including at least 3 geomagnetic storms and/or substorms.

3.1.2.1.2. Each TWINS instrument shall acquire images of the magnetosphere which cover a field of view of at least 2 steradians centered about the nadir direction.

3.1.2.1.3. TWINS shall measure the energy spectrum of magnetospheric hydrogen at energies from 1–50 keV with energy resolution of $\Delta E/E \leq 1.0$.

3.1.2.1.4. TWINS shall resolve the development of substorms by measuring neutral atom images with 12-minute resolution.

3.1.2.1.5. TWINS shall measure the spatial distribution of magnetospheric hydrogen with resolution of at least 12° x 12° for energies above 10 keV.

3.1.2.2. Expected Performance Levels

Table 3.1 gives the expected performance levels for the TWINS neutral atom imagers. These specifications are in agreement with the Baseline Science Requirements listed in the TWINS Program-Level Requirements Document. TWINS is designed to achieve a two-year stereo imaging mission. As stated in the Baseline Science Requirements, all scientific goals can be met by the acquisition of at least 3,000 stereoscopic neutral atom images simultaneously from the two TWINS spacecraft over a period including at least 30 geomagnetic storms and/or substorms. However, the TWINS mission plan is to collect as much data as possible over both the two years of single spacecraft imaging and the two years of stereo imaging, and perhaps beyond if circumstances permit. It was originally hoped that there would be overlap between TWINS-1 and IMAGE satellite operations, allowing stereo imaging prior to the TWINS-2 launch. However, the IMAGE satellite stopped transmitting data in late 2005. Some failure scenario analysis suggests that in late 2007 when the IMAGE orbit precesses to bring the satellite into full eclipse behind the Earth, a full power down and reboot will occur, and as a result IMAGE might resume data transmission. However, given the uncertainty of this analysis, it is likely that stereo imaging will not be possible until TWINS-2 data are available.

3.1.3. Data Acquisition

The TWINS neutral atom imager will nominally acquire data in only one science mode. The TWINS data set will consist of two major products: 1) neutral atom images in energy, species, and angle space, collected and transmitted with 60-second time resolution every 72 seconds, and 2) raw position, time of flight, and pulse height information for individual events (direct events data). To allow transmission of a significant number of raw events (1253 events per 4° azimuthal bin (1.333 sec)), the image data will be compressed from 16 to 8 bits before transmission, using a lossy compression scheme with error of less than 3% for all instrument count rates. Details of the TWINS telemetry format can be found in Appendix D of the TWINS Interface Specification Document (ISD). Data from the two instrument heads will be transmitted separately and combined on the ground, as will data from the two spacecraft.

Table 3.1. Expected Neutral Atom Imager Specifications

Measurement Type	Neutral atom energy and composition resolved images
Geometric Factor	0.020 cm^2sr
Polar angle resolution	4° FWHM for > 10 keV hydrogen
Azimuthal angle resolution	4° FWHM
Instantaneous FOV	±60° x ±2° FWHM
Total FOV	≥ 3.43 sr centered about axis 10° from nadir
Energy range	1–100 keV hydrogen
Energy resolution (ΔE/E)	0.4
Mass identification	H, O
Time resolution	60 sec image / 72 sec cadence
UV rejection	4 x 10^{-8} (MENA was in the range 10^{-6})
Data Rate	~50 kbps continuous data rate, ~1/3 for image data, 2/3 for raw single events

3.2. Lyman-α Detector

3.2.1. Instrument Description

The TWINS Lyman-α Detector consists of two independent sensors oriented at angles of ±40° with respect to the actuator spin axis. Each sensor has a FWHM field of view of 4°, defined by collimation hole baffles, uses Lyman-α interference filters as narrow band transmissions filters, and applies a KBr or CsI photodiode for photon detection. The Lyman-α detector is located on the rotating actuator platform to provide full 360° azimuthal angle coverage. The Lyman-α detector is shown in the instrument layout diagram given in Figure 1.1.

3.2.2. Capabilities and Requirements

The Lyman-α detector is not included in the minimum science requirements for TWINS as defined in the TWINS Program-Level Requirements Document. Table 3.2 gives the expected performance characteristics of this instrument.

Table 3.2. Expected Lyman-α Detector Specifications

Measurement Type	Geocoronal Lyman-α
Aperture Area	3.2 cm^2
FOV	4° FWHM
Wavelength	1216 Å
Wavelength resolution	±50 Å
Time resolution	60 sec / 72 sec cadence
Sensitivity	0.1-0.5 counts/sec/R
Data Rate	40 bps continuous data rate

3.2.3. Data Acquisition

Lyman-α data are acquired in only one mode. Data from each sensor are collected in 90 azimuthal angle bins, each 2° wide (0.667 sec), with two Lyman-α azimuthal bins for each neutral atom imager azimuthal bin. As is done for the neutral atom image data, a Lyman-α image will be collected with 60-second time resolution every 72 seconds.

3.3. Ultraviolet (UV) Sunlight Exposure Analysis

Guided by the IMAGE MENA instrument response to sunlight at various imaging and spin angles, some limited ultraviolet exposure experiments were conducted as part of TWINS-1 and TWINS-2 calibration (*TWINS Calibration Procedure,* SwRI doc 1609-TCP-01). Based on this measured angular response to UV, it is expected that during several months of the year, sunlight exposure will partially constrain ENA observation times, and that this limitation will become severe for perhaps 1 to 2 months each year. Thus, we expect that each of the TWINS satellites will have "good" and "bad" seasons for observation.

Using TWINS calibration UV testing results (*TWINS Calibration Procedure*, SwRI doc 1609-TCP-01) and TWINS-1 ephemeris information, UV sunlight exposure analysis (*TWINS UV Exposure Study,* Aerospace Report No ATR-2006(7687)-1) indicates that TWINS-1 will view the Sun over extended intervals near apogee during the North American winter ("bad" viewing season), and that North American summer ("good" viewing season) is best for uncontaminated viewing. We do not have a firm projected launch date for TWINS-2, but it is expected that there will be sufficient overlap between the respective optimal viewing seasons of TWINS-1 and TWINS-2 to achieve our science goals. Sunlight exposure studies will be updated periodically during the TWINS mission.

4.0. TWINS End-to-End Data Flow

4.1. Overview

Figure 4.1 shows the flow of TWINS data from the spacecraft through the archiving process. This section describes the processing steps required for the TWINS data. TWINS data will be obtained from the spacecraft through the spacecraft sponsor, who will forward the data to Aerospace for processing. Further processing will then be performed at SwRI, at LANL, and by other members of the TWINS team. The resulting products will be made available on the TWINS web site, and will be forwarded to the NSSDC for permanent archiving and public distribution. The TWINS team will maintain a web page providing information about the TWINS mission, including information about data types and accessibility. This web page is presently located at: http://twinstest.space.swri.edu/.

The following list summarizes the various processes that will occur whenever data are delivered from Aerospace.

4.1.1. Get the Level 0 Data (see Table 4.1): TWINS telemetry data, and Attitude and Ephemeris data will be acquired from Aerospace (every 7-14 days) on CD or DVD.
4.1.2. SwRI will make a copy of the Aerospace CD/DVD and ship it to LANL for backup purposes.
4.1.3. The Level 0 Data will be imported into the database (Section 4.3.2), and validated.
4.1.4. The Level 0 data will be read out of the database, put into CDF format and transmitted (or shipped) to NSSDC.
4.1.5. Lyman-α data files will be generated from the database.
4.1.6. Summary plots will be generated and imported into the database.

The steps 4.1.1—4.1.6 above need to be performed whenever new data are delivered to SwRI. Individual steps will need to be performed iteratively if we update plot times, formats, calibration look-up tables (LUTs), etc.

4.2. Mission and Science Operations

4.2.1. Telemetry Services

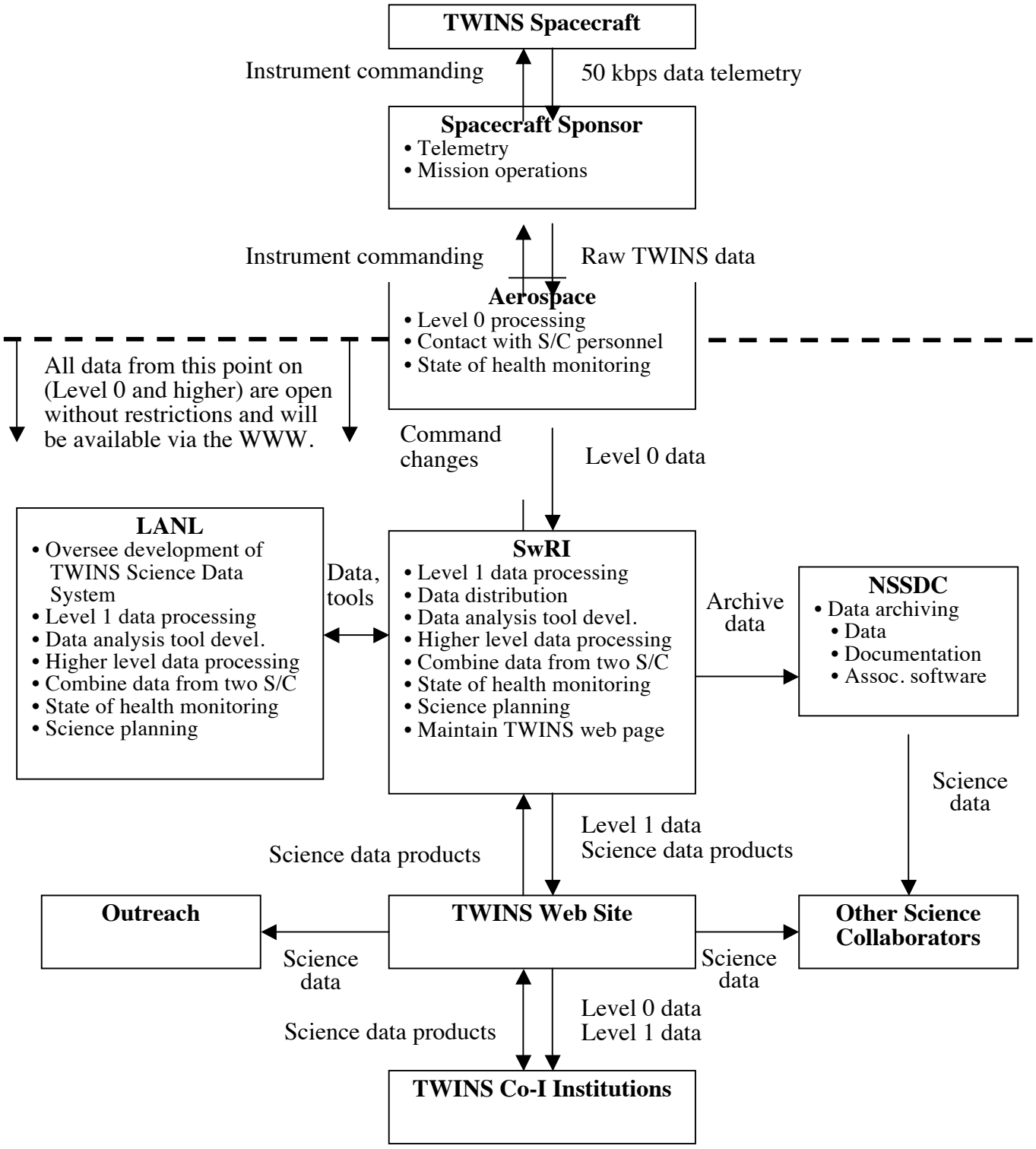
Mission operations for TWINS, including spacecraft tracking, data downlink, and uplink communications with the spacecraft, will be provided by the spacecraft sponsor. A detailed discussion of spacecraft telemetry is therefore not appropriate for this document.

The spacecraft sponsor will receive the raw telemetry on the ground, and will extract the TWINS data and provide it to a dedicated TWINS data processing system, referred to as the "TWINS Ground Station", maintained by Aerospace. The spacecraft sponsor will also provide spacecraft attitude, ephemeris, and timing information to the TWINS Ground Station for inclusion in the TWINS data set. Aerospace will then be responsible for preliminary processing of the data, consisting of organizing the raw data by viewing direction and incorporating ephemeris and attitude data for the TWINS instrument, and of preliminary storage and distribution of these data. The data produced by this procedure will be defined as Level 0 data. Starting from this point, all TWINS data will be open for scientific usage with no restrictions. Raw (pre-Level 0) data will be stored by Aerospace for the period required to determine that Level 0 data are being generated correctly. The TWINS telemetry rate will be 50 kbps. This data rate corresponds to an annual raw data volume (not including attitude and ephemeris data) of 197.1 GBytes per year for each spacecraft.

4.2.2. Mission and Science Control

Because access to the TWINS spacecraft is done through the TWINS spacecraft sponsor, the TWINS mission is designed to require minimum contact with the ground. We intend that the instrument will function autonomously throughout its lifetime, and that at most times will operate in a single mode, reducing the need for instrument commanding. Instrument commanding can be accommodated by the spacecraft sponsor as necessary, and TWINS is designed to include test modes and safe modes, as well as the nominal science data collection mode. During instrument turn-on and check-out, more frequent communication with the spacecraft will be available. Instrument health will be monitored through examination of both the housekeeping and science data by personnel at Aerospace, SwRI, and LANL.

Figure 4.1. TWINS Data Flow



4.3. Data Products

4.3.1. TWINS Data Set

The TWINS data set includes scientific data collected by the instruments, instrument engineering and housekeeping data, and instrument attitude and ephemeris data provided by the spacecraft. A detailed description of the data products can be found in Section 5.2.2 and Appendix D of the TWINS ISD. The TWINS data products are described in Tables 4.1 and 4.2.

Table 4.1. TWINS Level 0 data products (See Section 4.3.3.)

Data Product	Description
ENA image data ("Onboard images")	Sampled in 4° (1.333 sec) azimuthal pixels. Identified by sensor head (2), species (3: H,He,O), polar angle (32: 4° bins), and quasi-logarithmic-spaced time of flight (TOF) bins. Compressed from 16 to 8 bits prior to transmission.
ENA direct events ("DE") data	5-byte data containing raw position, TOF, and pulse height information for valid particle events. Sampled in 4° (1.333 sec) azimuthal sectors. Up to 1253 events transmitted per sector in nominal operating mode.
Lyman-α data	16-bit data sampled in 2° (0.667 sec) pixels. Identified by sensor (2).
ENA singles data	26 16-bit counters, sampled every 1.333 sec. These parameters include start, stop, and valid counts, as well as overflow counters used for engineering purposes.
Instrument status data	Instrument status parameters which are tightly coupled to science data, and so are sampled every 1.333 sec. These parameters include azimuthal sector identification, sector angular boundaries, and actuator voltages.
Housekeeping data	Instrument parameters required less frequently than instrument status data. Sampled at least once per 60-sec scan in normal operating mode.
Spacecraft ephemeris data	Provided by the spacecraft to the TWINS Ground Station. Position information is required to within at least 500 km for high altitude observations, and to within TBD km for any perigee operations, and shall be provided with the highest resolution possible.
Spacecraft attitude data	Provided by the spacecraft to the TWINS Ground Station. Knowledge of the pointing direction of the TWINS sensor heads is required with resolution of at least 0.1°. Data shall be provided with time resolution of 1 minute.

4.3.2. TWINS Data Management

TWINS data management will be accomplished using an Oracle database. This system allows flexible storage and searching capabilities, and is not tied to any specific data format. The Oracle database will be accessed through a front-end user Web Interface (WI), described below. The WI will be used for browsing data, for analysis, and for transfer of data from SwRI to TWINS team members and the larger scientific community. For archiving data at NSSDC, the baseline data format will be CDF (the customary data format used by NSSDC) for digital data, and JPEG or PNG for rasterized images. (For more details, see Section 4.4.) Aerospace will mail DVDs of data to SwRI with an estimated latency of two weeks or less. The format of the data will be as follows. TWINS telemetry data will be in binary format defined by Aerospace (appendix D of the TWINS ISD). Ephemeris data will be in ASCII text format defined by Aerospace.

Table 4.2. TWINS Level 1 data products

Data Product	Description

ENA direct events ("D.E.") Images	Images created using the TWINS Image Maker (TIM) software, analogous to Onboard Images, but created on the ground with more sophisticated look-up tables (LUTs) for binning and assigning fluxes, energies, and species.
ENA D.E. Skymap Images	ENA D.E. images, mapped to geophysical coordinates and presented in a "fish-eye" view, with the Earth in the center, dipole magnetic field lines drawn in, and the Sun direction indicated.
ENA Onboard Skymap Images	Onboard images in geophysical coordinates as for D.E. images.
Lyman-α Parameterized Exospheric Model (PEM)	Hydrogen geocorona model, a 30-parameter fit to observed Lyman-α line-of-sight intensities. PEM should reproduce a full 3D distribution of hydrogen density.
Summary Plots	Various plots designed to give overviews of TWINS data.

4.3.3. Level 0 Data

The basic TWINS Level 0 data product will consist of raw instrument counts data organized by viewing direction (both from the ENA imagers and from the Lyman-α detectors), as well as Onboard Images (See Table 4.1). This procedure will be carried out by Aerospace, using a data processing server dedicated to the TWINS mission. Aerospace will then forward Level 0 data to SwRI (via DVDs or CDs, mailed) for further processing. Aerospace will delete Level 0 data from its local servers only upon confirmation that the current shipment of data has been received and validated by SwRI. The Level 0 data set will also include ENA imager single event data, instrument housekeeping data, and spacecraft attitude and ephemeris data. Level 0 data will be provided to SwRI as quickly as possible after transmission from TWINS to Aerospace, with an expected latency period of no less than one day and no more than one week. Once at SwRI, Level 0 data will be quickly incorporated into the Oracle database and distributed to LANL and NSSDC for archiving (See Section 4.1). Analysis will be performed to provide browse images as a primary TWINS data product. From ingestion of TWINS calibration data, the data ingestion process is estimated to have a latency of 10-20 minutes.

4.3.4. Level 1 Data

The goal of Level 1 data processing is to produce a data product that can easily be used for scientific studies. Level 1 processing will take raw (Level 0) data and create ENA images and a Lyman-α model.

4.3.4.1. ENA Images

Level 1 processing will take raw ENA direct events (D.E.) data and create ENA images. LANL and SwRI have developed a software package called TWINS Image Maker (TIM) that uses look-up tables (LUTs) to bin D.E. data by angle, energy, and species, and to incorporate the instrument response function. (The LUTs are based on calibration data, and will be updated as necessary, as the mission proceeds and we learn more about the data.) TIM creates images in instrument coordinates, and then the skymap procedure maps TIM images onto a geomagnetic coordinate view containing the Earth in the center, with dipole magnetic field lines drawn in and the Sun direction indicated. TIM skymap images can be easily compared to each other and to previous and complementary data sets.

4.3.4.2. Lyman-α Model

Level 0 Lyman-α data will be used to constrain a 30-parameter fitting function designed by the University of Bonn to emulate the Hodges [1994] hydrogen density model of the terrestrial exosphere up to about 60,000 km (or about 10 Earth radii). The coefficients of this Parameterized Exospheric Model (PEM), along with the full 3D distribution they describe, will constitute Level 1 Lyman-α data.

4.3.4.3. Level 1 Data Access and Processing

Level 1 data will be accessible through the Web Interface (WI) to the Oracle database. Also accessible through the WI will be analysis and/or visualization software developed/used to create images. TWINS team members who wish to download data from the database will have a choice of formats for such transfer from the following list: ASCII (text), CDF, JPEG and/or PNG, and Postscript (PS) format plots generated by the WI software. Level 1 data processing will be performed at SwRI by accessing the architecture of the Oracle database, using a data processing server dedicated to the TWINS mission, and will occur immediately upon ingestion into the database of Level 0 data at SwRI.

4.3.5. Level 2 and Higher Level Data Products

Higher level TWINS data products are being designed to illustrate magnetospheric structures and dynamics. In particular, higher level processing at SwRI and LANL will combine data from the two TWINS spacecraft to produce stereo images of the magnetosphere. It is also expected that many of the TWINS Co-Investigators will routinely generate additional higher level data products. For example, the PEM model will be combined with ENA D.E. Images (See Table 4.2) to constrain linear inversion codes designed by Co-Investigators and collaborators at Johns Hopkins Applied Physics Lab (JHUAPL) and Auburn University. These inversions can yield global ion pressure and field-aligned current distributions from single images, and can yield pitch-angle distributions from stereo images.

These data products, and the analysis software developed to create them, will be accessible through the Web Interface. SwRI will ensure that analysis software is optimized for use by the server. SwRI will provide software to TWINS team members on an as-is basis, with no promise to support or modify the software for TWINS team members to use on their own platforms.

4.3.6. Ancillary Data Products

The TWINS database, accessed by TWINS team members through the Web Interface, will also include several useful ancillary data products such as solar wind, geomagnetic indices, etc. Ancillary data will be ingested into the database periodically via an automated updating routine. The list of ancillary data products will evolve with usage and suggestions by the TWINS team members. Ancillary data will be stored for periods of time covered by the TWINS mission, and shall be acquired and updated periodically by enabling automated routines to check for availability of updated data on various remote servers.

4.4. Data Archiving and Distribution

4.4.0 Overview

The goal of archiving is to ensure that TWINS data are available to interested researchers in perpetuity. Therefore, we have adopted a plan in which TWINS data are archived at three separate locations:

SwRI: Aerospace Level 0 data CDs and DVDs will be physically stored at SwRI. Electronic copies of the data will be stored in the Oracle database.

LANL: Copies of the Aerospace CDs and DVDs will be shipped to LANL for physical storage.

NSSDC: TWINS science data will be archived at NSSDC with the following format scheme:

- Level 0: CDF
- Level 1: CDF for digital data
  JPEG/PNG for pre-made images
- Level 2: CDF for digital data
  JPEG/PNG for pre-made images
  Compressed ASCII for software

More details of archiving are given in the following sections.

4.4.1. SwRI Data Archive

SwRI will be responsible for distribution of data to other members of the TWINS team and for making the data available to the scientific community and to the public. We anticipate that most data distribution (to the public and scientific community, and to TWINS team members) will take place through web access to the TWINS Oracle database system. TWINS data archiving at SwRI will be through the database, in binary format.

All data will be archived at SwRI as soon after processing and validation as possible. This time frame will range from hours to months depending on the complexity of the specific data product. Data archiving will include both raw, validated data (Level 0) and histograms corrected for instrument response (Level 1). Higher level data products will also be archived, including both single spacecraft and stereo images.

4.4.2. NSSDC/SPDF Archive

The TWINS Level 0, Level 1, and higher level data products will be provided to the NSSDC/SPDF for permanent archive and additional public distribution of the data. Our plan is to use the first two years of single spacecraft observations as a testing and preparation period. By the time the second spacecraft is launched and the primary mission phase begins, we anticipate that delivery of Level 0 and Level 1 data to the NSSDC/SPDF will occur within one month of collection, and that we will meet or exceed this specification throughout the TWINS stereo mission. Higher level data products will be provided with a time lag appropriate to the individual product. The baseline format for submissions to the NSSDC/SPDF is CDF.

Products provided to the NSSDC/SPDF will include not only the data themselves, but also documentation as to the contents of the data files, and, if appropriate, software to read and/or display the data. Documentation for all products described in Section 4.3 will be provided as necessary to ensure the long term independent usability of the data. CDF format was selected because CDF files can be read by standard software packages, and CDF is the current standard format employed by NSSDC/SPDF

4.4.3. Archival Volume

Table 4.3 shows the estimated volume of data acquired by TWINS over the nominal mission lifetime. The estimated raw data volume for TWINS, based on the expected telemetry rate of 50 kbps, is 197.1 GBytes per year for each spacecraft. Assuming a nominal four-year lifetime for the first spacecraft and a two-year lifetime for the second spacecraft, the total Level 0 data volume for the two TWINS spacecraft will be ~1185 GBytes. Level 1 data products are estimated at 40% of the Level 0 volume, and higher level products at 20% of the Level 0 volume. Based on these estimates, the total TWINS data volume to be archived will be approximately 1900 GBytes over the nominal mission lifetime.

Table 4.3. TWINS data volume estimates.

	Level 0	Level 1	Higher Level
TWINS data volume	1185 GBytes	475 GBytes	240 GBytes

This data volume will easily be accommodated by the TWINS Oracle database, in terms of data storage, processing, and archiving. At the nominal data 50 kbps data rate, Level 0 data is estimated at 540 MBytes per day, requiring approximately 1–2 DVDs (or their equivalent) per spacecraft per week for storage. The data volume will be reduced somewhat since the instrument does not operate continuously (is off in the radiation belts, for example), but attitude, ephemeris, and higher level data products will offset this reduction. As a baseline, we plan that a significant fraction of TWINS data will be continuously stored on hard drives connected to SwRI computers, and will be accessible in this

form to the TWINS team, the NSSDC, and the scientific community. Data will additionally be made available to both the TWINS team and the NSSDC on DVDs, as described in Section 4.4.0.

It is expected that where possible, data transfers will be done electronically, either through the WWW or using FTP. Although the data volume is large, the sizes are comparable to files currently being transferred. For example, daily files from the ACE spacecraft are ~100 MBytes in size, and require at most a few minutes to transfer. With expected improvements in technology, transfer of the 5 times larger TWINS files is not expected to require a significant amount of time. For the occasional transfer of very large amounts of data, such as submission of early mission data to the NSSDC, DVDs will be the standard.

4.4.4. Data Rights and Rules for Data Use

All TWINS data (Level 0 and higher) are open to all scientists and the public without restrictions of any kind. There are no proprietary periods associated with any of the TWINS data products. All TWINS data will be provided to the NSSDC for archiving.

4.4.5. Review Items

Because of the extended time period between the launch of TWINS-1 and TWINS-2, various aspects of data processing and management will need to be reviewed and (where necessary) updated on a rolling basis. Table 4.4 lists these items, all of which were discussed above.

Table 4.4. TWINS data system items to be reviewed after obtaining TWINS-1 science data.

Item	Baseline Plan
TWINS look-up tables (LUTs), etc., including: - Culling - Geometric factors - Head-matching - angle LUTs - energy fits in TIM code	Based on calibration data, but will be updated after launch to take account of knowledge gained from flight data.
TWINS browse plots,	We will review usefulness and optimize displays & formats (e.g., color tables).
TWINS inversion techniques	Test and refine codes provided by, for example, JHUAPL and Auburn University

We note that following the launch of TWINS-1, we have reviewed a number of the items listed in previous versions of this document. Data will be stored in an Oracle database, with a web interface allowing access to data in ASCII or CDF formats, as well as to processed images. CDF format has been selected for file transfer to the NSSDC. Electronic formats will be used for data distribution where possible, with CD/DVD for larger data volumes.