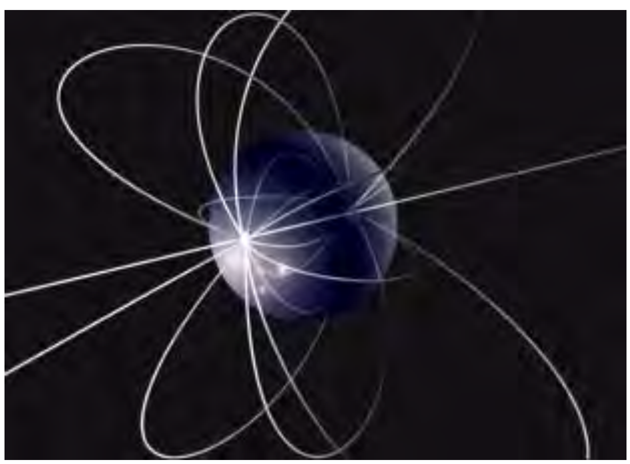
W. W. Hansen Experimental Physics Laboratory

STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305 - 4085

Gravity Probe B Relativity Mission

S1016, Revision -
May 15, 2007

Data Archive Plan



Tom Langenstein ITAR Assessment Performed, ITAR Control Req'd? ☐ Yes ☐ No

Alan Smale
Program Manager, Gravity Probe B
NASA Headquarters

Tony Lyons
Program Manager, Gravity Probe-B
NASA Marshall Space Flight Center

Ed Grayzeck
Head, National Space Science Data Center
NASA Goddard Space Flight Center

Francis Everitt
Principal Investigator, Gravity Probe-B
Stanford University

Bill Bencze
Program Manager, Gravity Probe B
Stanford University

Jennifer Spencer
Data Archive Lead, Gravity Probe-B
Stanford University

Date	Sections/Pages Affected	Reasoning	Revision
2/2006	All	First draft	Preliminary
8/2006	All	Revisions to draft	Preliminary
1/2007	All	Revisions per NSSDC comments	Preliminary
5/2007	Table 6.1, Appendix A	Revisions to Guide Star data, schedule	Preliminary

Table of Contents

Introduction

Purpose

This document provides a high-level description of archival data products and archiving methodology at all levels for the Gravity Probe B (GP-B) Mission.

The data products specified in this document are obtained from the science instruments and subsystems on board the GP-B spacecraft, and include the results of any ground data processing carried out by the GP-B Data Processing team (DP). At all levels of data processing, several additional data are also needed. These may include the results of pre-flight tests or calibration experiments carried out by the GP-B mission. These may also include specifications, acceptance data, drawings and other engineering papers. Further, certain science data are collected by various terrestrial observatories specifically for the GP-B mission, and are acquired through existing, independent data systems outside the GP-B project. All of these data products are discussed in this document. However, standard data products, commonly available to the science community and independently documented, are not specified in this document.

Scope

This document is applicable to all science and supplementary data resulting from the Gravity Probe B spacecraft. This document is subordinate to the GP-B Data Management Plan (S0331). Separate agreements, including a Memorandum of Understanding, established with the National Space Sciences Data Center (NSSDC) and Marshall Space Flight Center (MSFC), broadly address data archiving.

Applicable Documents

Gravity Probe B Data Management Plan (S0331)
Memorandum of Understanding between Gravity Probe B and the NSSDC
Stanford post processing operations for Science Mission Data (S0401)

Document Change Control

This document is under change control once all parties sign it. All signatories must approve each revision.

Mission Overview

Gravity Probe-B was begun in 1959, funded by NASA since 1963 (retroactively from 1964). The purpose of the Gravity Probe B Relativity Mission satellite is to measure two relativistic effects on nearly perfect gyroscopes. Einstein's General Theory of Relativity precisely predicts both of these effects; the spacecraft measurements are an experimental test of the General Theory of Relativity.

The two measured relativistic effects are the geodetic effect, which is due to the gravitational interaction of the spinning gyroscope and its orbital angular momentum about the earth, and the motional or frame-dragging effect which is due to the gravitational interaction between the spinning gyroscope and the angular momentum of the earth. The geodetic effect is predicted to cause a drift rate of 6.6 arc seconds per year in the plane of the orbit for a gyroscope in a ~640 km circular orbit, and the motional effect is predicted to cause a drift of the 41 milli-arc seconds per year in a direction perpendicular to the plane of the orbit.

The requirement for the overall accuracy of the Gravity Probe B Experiment is to measure the drift rate of each of the four gyroscopes to an accuracy of 0.5 milli-arc-seconds per year. At this level, the frame dragging effect will be measured to an accuracy of 1%, and the geodetic effect will be measured to an accuracy of 1 part in 10,000. A measurement of the drift rate of the gyroscopes at this level of accuracy will be the most accurate non-null experimental test of the General Theory of Relativity. Present estimates of the overall accuracy of the experiment indicate that it will be possible to measure the drift rates significantly better than 0.5 milli-arc-seconds per year.

The Gravity Probe B spacecraft was launched aboard a Boeing Delta II launch vehicle at 9:57:24 AM Pacific Daylight Time on April 20, 2004. It went through an initialization and orbit checkout period of 129 days, a science data collection period of 352 days, and a calibration period of 46 days, until September 29th, 2005. The mission lasted for 527 days.

The telemetry from the satellite contains the essential information to determine the gyroscope drift rate as well as the health and safety of the satellite and its subsystems. The Gravity Probe B "Stanford Post-Processing Operations for Science Mission Data" document (S0401D) describes the method for processing and storing this information.

Archive Structure

Archive Terms Defined

Archive - a preservation of data for future use. For this document, archive pertains only to long-term archives with the NSSDC.
Archive medium - a physical device for storing data such as CD, DVD, or tape. For PDS archives, the medium must be acceptable to NSSDC per prior arrangement.
Archive System – The archive system is comprised of hardware, software, procedures, interfaces, and personnel necessary to complete the archiving of science and ancillary data with the NSSDC.
Data Processing – the team of people responsible for processing spacecraft data from raw data through Level 1 data, and the same team members who are responsible for the formal data archive. The group is chartered to create the GP-B archive.
Data product - labeled data resulting from spacecraft or scientific data. Examples of data products include plots from on-board instruments, telemetry from the spacecraft or external orbit determination data. A data product is a component of a data set.
Data set - a labeled grouping of data products, metadata, documentation, and algorithms for applying calibration or further processing data. Software may also be included.
Data Object - A data object is that portion of a data product that contains the actual data that is described in a data object definition within an NSSDC label. It is tangible, and can be physically accessed and manipulated.
Meta Data - a label or file that describes one or more science data objects or products, or indexing information (such as a list of spacecraft mnemonics and their calibrations).
NSSDC – National Space Sciences Data Center. The primary organization within NASA responsible for the permanent archive of all space science data obtained from NASA-sponsored missions. The NSSDC is located at Goddard Space Flight Center in Greenbelt, Maryland.
Science Data – All data acquired which are used to accomplish primary science goals of the Gravity Probe B science teams.
Supplementary Data - Any data necessary to perform analysis of the science data. Sometimes referred to as ancillary data.
Volume - one or several in a series of media containing archive data.

Overview of the Archiving Functions

The purpose of archiving is to provide the GP-B data to the public in a non-proprietary, agreed-upon format in perpetuity.

The work of archiving shall be done using NSSDC archiving guidelines. For the GP-B data, those file formats include: text, cdf (common data format), jpg (for photographs), and pdf (portable document format). GP-B will archive all of its data and supporting documents and photographs in these formats.

GP-B will archive support documentation, photographs and science data per the Data Management Plan (Stanford document S0331A). Science data will generally be preserved in CDF format.

We may also add additional, more robust data in its original format, as long as the content of that data is available also in an archive format. For example, we may include Adobe Photoshop artwork in addition to the same file in a jpg version. Layered GP-B artwork can be reproduced and manipulated more easily by artists if it is available in Photoshop, for the time being.

An instantaneous snap shot of the GP-B web site will be archived at the NSSDC, along with listings of all data available. Data formats and files shall be carefully verified before being sent. CDF data will be sent with a computed CRC (cyclic redundancy check) value so that its data integrity can be verified upon arrival at the NSSDC.

Archive Design

The dataset to be archived from the GP-B project is expected to be approximately two terabytes in size. The archive will be delivered using a RAID array of hard drives, possibly supplemented with CD or DVD deliveries, as appropriate. The science data will be ordered by subsystem first, then by vehicle time and cycle number, and mnemonic. Section 5 discusses, in detail, the organization of the science data files. The details of what components are included in the archive and how they are grouped into data sets, subdirectories, and files comprises the design of the archive. The upper level structure and contents of the archive are described in more detail in Section 5. The arrangement of the final details of the archive down to the file level will not be specified until more detailed information on the data products and other components are available.

Generation of Archive

Responsibility for generating archive components is specified in Section 4. Science data products will be generated in CDF or otherwise accepted archive-compatible formats. This requires that each data file (data table) be in a format recognized by the NSSDC including a header on each file describing the metadata of the data file. Orbit determination and event data necessary to interpret the science data (e.g. spacecraft ephemeris and attitude records, command histories, and operator log files) will be provided as archive components. These supporting data will be provided as text, JPEG, FITS or CDF data, depending on the original format of said data. In addition, files documenting the archive components will be included. In general, all information necessary to interpret and use the data are to be included in the archive.

The NSSDC provides for the preservation of the mission, spacecraft, and instrument information and data products with Archival Information Packages (AIPs). An AIP consists of a data file and an attribute file that describes the data file. AIPs facilitate the long term preservation of archived information and are independent of the underlying media types, including file structures.

Validation of Archive

Data validation falls into two types, validation of the data itself and the compliance of the archive with NSSDC requirements. The first type of validation will be carried out by GP-B archiving staff, and the second will be overseen by the NSSDC, in coordination with GP-B. Test files will be sent from time to time for validation to insure that problems in any early or test deliveries are resolved by the time of the final archive delivery.

Delivery

Delivery of data to the NSSDC shall be in the form of a two-terabyte RAID array of hard disks. For interim deliveries, data shall be sent to the NSSDC in a form mutually agreeable to Gravity Probe B and the NSSDC (See "Responsibilities" in section four).

Further Information

More information on the GP-B data archive can be found in the GP-B Data Management Plan, Stanford document S0331 A.

Roles and Responsibilities

Responsibilities of Gravity Probe B

The GP-B team will provide supporting documentation and other material to ensure the data is usable. GP-B will provide copies of its data to the NSSDC for permanent archiving in formats acceptable to GP-B and the NSSDC (and/or it will ensure a parallel flow of data and supporting material directly to the NSSDC). As GP-B releases new products to the public, these products will be transmitted to the NSSDC in a mutually agreed upon manner. For data releases on CD, DVD, or similar media, GP-B shall provide the NSSDC with a set of these volumes. For data to be sent electronically, the details of such transfer shall be devised and agreed upon by GP-B and the NSSDC.

Responsibilities of the NSSDC

The NSSDC will ensure that the data and supporting material are effectively accessible by potential users from NASA, other research communities, and by the public. It is expected that some user access will be electronic, but the NSSDC will also satisfy most requests for data to be sent offline. Data transferred electronically between GP-B and the NSSDC will be subject to quality assurance by the NSSDC and remote storage of backup copies will be provided by the NSSDC.

The NSSDC will receive NASA-sanctioned GP-B data and supporting material from GP-B, and it will ensure their long-term preservation against both media deterioration and technology obsolescence. The NSSDC permanent archive is not electronically accessible outside the NSSDC. The NSSDC assumes that the data and supporting material provided by GP-B is correct. It is the responsibility of GP-B to ensure this correctness when the data are delivered to the NSSDC.

Upon request from GP-B, the NSSDC will provide copies of data and/or supporting material in the same format it was provided by GP-B at the time of the initial delivery.

Upon request from GP-B or the research or public user community, the NSSDC will replicate and mail data volumes to requesters. It will charge end users a fee just sufficient to cover the incremental cost of satisfying the request.

The NSSDC will point users to the appropriate web page as the source of GP-B data for researchers.

Science Data Archive Products

Raw Data

The Raw Data is simply the data, as telemetered from the satellite, contained in binary files received from SAFS (Goddard Space Flight Center's Standard Autonomous File Server) in "IPDU" format (see the Telemetry Data Processing from Raw data to Level 0 in Stanford document S0401). Raw data may contain duplicates and/or time regression, and may be missing data. It may also be damaged data due to R/F problems. Any questionable data (that is marked with unsuccessful Reed-Solomon encoding, from the wrong spacecraft ID, full of skips and jumps and unidentified packet types) would be found in Raw Data but not the Level 0 data set.

Level 0

"Level 0 Data" is essentially time-ordered data with communication artifacts and duplicate records removed.

- L0 data is as complete a telemetry record as is possible: the time correlation table fills in any missing time stamps and all data duplications have been removed
- All data is kept in order of time-sequence
- All filler data has been removed (APID 2047)
- The data is separated from transfer frames into binary packets with header data
- All APID types of data are stored in the Level 0 database (except APID 2047)
- Bad/invalid data has been filtered out

Level 1

Level 1 data is the analog and discrete programmable spacecraft telemetry:

- APID 100 only (see S0401 and SCSE-16, section 9 for more information)
- Meaningful in form to human beings (not binary). It is time-stamped and time-ordered by mnemonic ID, then by time.

The differences between "Level 0 Data" and "Level 1 Data" are:

- Level 1 data set is the analog and discrete telemetry, which, for GP-B, is the data extracted from the APID series 100 packet data assembled by the spacecraft into telemetry format table frames and sent to the ground. Level 0 holds all APID series data, including packet 100 data.
- Level 1 data is in a meaningful form; source telemetry data numbers may be displayed before or after calibrations are applied via TCAD. Level 0 is largely binary data.
- Level 1 is the most refined source of data that may still be considered untouched for purposes of data reduction. This is the source data to be sent to project engineers and scientists for further analysis, along with a small subset of Level 0 data.

Level 2

Level 2 data is more than a transformation of Level 1 telemetry data. Level 1 data, along with data from outside sources and re-combinations of Level 1 data goes through Science Ops pre-processing algorithms to become Level 2 data.

- A select subset of the Level 1 data is sent to Science Ops. Filters are applied and some additional calibrations are made to the data via pre-processing.
- Other data, such as GPS ephemeris data and Laser Ranging data, are combined with the telemetry (Level 1) data, and some monitors from the Level 1 data are joined together through pre-processing algorithms. Some filtering (lowpass and Kalman filtering for example) and FFT's maybe applied.
- All data is averaged on two-second centers. After all pre-processing algorithms are employed, the resulting data set is put into the Level 2 database.

- Level 2 data is considered the cleanest, most complete science data set. It is a starting point for analysis.

Level 3

Level 3 data is the result of science analysis algorithms being performed on Level 2 data. More about the Level 3 data set will be included in its accompanying delivery documentation.

Format of Science Data Files

Telemetry from the Gravity Probe B spacecraft was processed and stored as detailed in Stanford University document S0401 "Stanford Post-Processing Operations for Science Mission Data". Please see S0401 for specific understanding of the data and data table relationships. Additionally, the orbit determination for the mission is described in S0505, "Interface Definition Document for the Gravity Probe-B Orbit Determination Function".

UNIX binary files were sent from the Central Standard Autonomous File Server (C-SAFS) at Wallops, VA, to the Mission Operations Center at Stanford University for every 32K ground network data pass. These SAFS files are not in CDF format, and may not be acceptable to the archive.

The mission telemetry was stored to a database, and then exported from the database to the format known as CDF (Common Data Format) for purposes of long-term archiving. For more information on CDF file formats and how to use them, please reference the Goddard Space Flight Center web pages at http://cdf.gsfc.nasa.gov/ . This document henceforth assumes that the user has basic knowledge of CDF formats.

There are two different general types of data: static data and dynamic data. Static data corresponds to GP-B project metadata; that is, data about the data. The static (metadata) includes such items as names of GP-B mnemonics, locations in the telemetry data, packet IDs, format IDs, ground station IDs, et cetera. Dynamic data is, essentially the ever-changing spacecraft telemetry from the on-board instruments and spacecraft bus. Most of the static data files are small, and will be necessary (per S0401) to understand and use the dynamic files. Static tables are those data tables that are short, do not change much over time, and contain no direct spacecraft telemetry. Static tables are archived in CDF format.

Static data file names are given below in **bold** and their data fields follow.

Level 0 static data tables

Table name	Fields (in the order archived)
Station_IDs	ID_number ID_ASCII
APIDs	APID APID_Name Num_Bytes -
Files	SCT_Cycle Filename Filesize Time_InL0DB Parse_Time IPDUs_Found IPDUs_Processed VTCW_min VTCW_max p100s p200s p300s p301s p400s p100_bcptime p200_bcptime p300_bcptime p301_bcptime p400_bcptime
MSS	MSSID MSS_Name Date_inDB Date_onSV Date_inITF VTCW_onSV VTCW_inITF
SCtime	SCT_Cycle SCT_VTCW SCT_Period Base_DT Real_DT Comment MSS_Build MSSID
Snap_IDs	Snapshot_ID Snapshot_Name Subsystem Num_Packets Num_Bytes
Formats	Format_ID Format_Name Num_Frames MSSID Initial_MSSID -

Level 1 static data tables:

Table name	Fields (in the order archived)
Mdcals	TMID MSSID Units Type GAIN Min_DN C0 C1 C2 C3 C4 C5 C6 C7

TMavgid	TMID MSSID
Tmcals	TMID MSSID Units Type Min_DN C0 C1 C2 C3 C4 C5 C6 C7
Tmdecom	TMID MSSID Format_ID
Tmderived	DM_TMID MSSID Function_Name SM_TMID TMID1 TMID2 TMID3 TMID4 TMID5 TMID6 TMID7 Lag_Time CalvsRaw Lag_Time2 Lag_Time3 Lag_Time4 Lag_Time5 Lag_Time6 Lag_Time7 PostCvsR rate_mask
Tmlimits	TMID MSSID Red_Low Red_High Yellow_Low Yellow_High Display_Low Display_High
Tmnames	TMID MSSID Initial_MSSID Subsystem Mnemonic Description Datatype Start_Bit Length
Tmstates	TMID MSSID Value State

Level 2 & 3 static data tables:

Table name	Fields (in the order archived)
orbit_times	orbit_num orbit_start orbit_stop gs_valid_start gs_valid_stop gs_capture saa_start saa_stop eclipse_start eclipse_length notch_start notch_stop notch_type orbit_quality comment
l2metadata	pid shortname descrip outputfrom lowerbound upperbound subsystem units
run_info	run_id run_name run_date mod_date username comments T0 Tf VTcycle run_log prms_data
l3metadata	id name descrip units

File naming convention for dynamic data:

TABLENAME_cycle#_StartYearDOY[_EndYearDOY].cdf

where tablename corresponds to the chart of dynamic data tables, following; cycle# refers to the spacecraft cycle number per the SCtime data table; StartYearDOY is assumed to be midnight on the start of the day of year in question (00:00:00.0); EndYearDOY is inclusive (up to 23:59:59.9) and is an optional parameter, in the case that the data spans more than one day. If EndYearDOY is not included, that means that only 24 hours of data are in the file (the 24 hours for StartYearDOY). Note that DOY stands for Day of Year. There may be further file descriptors for some data types, but these will be addressed further with each data type and treated as an exception. It is possible that due to the length of “TABLENAME” in each circumstance, the filename will be longer than 32 characters total, but attempts have been made to keep this circumstance to a minimum.

All dynamic and most static *.cdf files are accompanied by a *.sum ASCII text file of the same prefix. This is a summary file, and it discusses different metadata about the cdf file. For example, a typical *.sum file might include how many records were selected for a given cdf file and the time range used.

Dynamic files are generally indexed by a spacecraft cycle and time stamp. The concept of spacecraft cycle was necessary because a counter “ticker” was needed to differentiate between, say, two vehicle tests that had the same vehicle clock time. This is addressed more fully in S0401. Each cycle number (integer) is detailed in the static SCtime data file, along with specific comments. Dynamic data does not include cycle number intrinsically; rather it is in the filename itself. For example, a typical file name might be: events_12_2005149.cdf , where events would indicate the Level 0 spacecraft event data, 12 would identify the cycle, and 2005149 would be the year and day of year (24 hour period) for the data.

Dynamic files include:

Level 0 dynamic data tables:

Table name	Fields (in the order archived)
Events	SCT_VTCW, Application, Event_Number
Packets	SCT_VTCW VCID Format_ID Frame_Counter Data [Differentiated by SN/TM, whether or not Number of Frames=100, per Formats table] ****Please note that "Packets" has been shortened to PKT in the filename**
DBROs	SCT_VTCW Packet_Number Source_Sequence Segment_Flag Data
MROs	APID SCT_VTCW Packet_Number Source_Sequence Start_Address Total_Length Segment_Address Data
Snapshots	SCT_VTCW Counter Decimation Channel Axis Indx GSS_Spare Length Data [indexed by Snapshot ID]
Tcor_fit	First_ERT First_ERT_Microsecs Last_ERT Last_ERT_Microsecs C0 C1 Chisqr Station SF_Format_ID
Tcor_Raw	SCT_VTCW ERT ERT_Microsecs Station SF_Format_ID

Level 1 dynamic data tables:

Table name	Fields (in the order archived)
Snanalog	TMID, SCT_VTCW, Value
SNdiscrete	These data types are covered by "Special Notes", below
Tmanalog	These data types are covered by "Special Notes", below
Tmdiscrete	These data types are covered by "Special Notes", below
Tmpseudo	These data types are covered by "Special Notes", below
Tmaverage	TMID, SCT_VTCW, Minimum_Value, Maximum_Value, Average_Value, Std_Deviation, Value_Count
GPS_Timing	SCT_VTCW SF_Frame_Count SQ_SciVehTime32 SQ_SciVehTime8 SQ_Sci10HzTime SQ_PPSv16F_Time
GPS_Orbit	SCT_VTCW SF_Frame_Count SP_RecvrMode1 SP_GPS_WeekNum1 SP_GPSTimeWeek1 RP_ECEFPosX RP_ECEFPosY RP_ECEFPosZ RP_ECEFVelX RP_ECEFVelY RP_ECEFVelZ SP_GPS_Digit_B SP_GPS_Fract SP_Time_Trans

Orbit Determination dynamic data tables

Table name	Fields (in the order archived)
Ephem	year time xpos ypos zpos xvel yvel zvel [referenced by ID number contained in filename]
Ephem_Info	id description startyear starttime endyear endtime datatype
Header	id name value
Solution	id label value
Covariance	id row column value
Mean	id year time instant i omega A B a phi

Level 2 and Level 3 dynamic data tables:

Table name	Fields (in the order archived)
L2data	pid run_id vtime pvalue (each run ID is stored, for the mission, in its own file)
l2data_flag	3 vtime last_updated GSvalid InSAA GPSdropout flag4 Gyro1_jump Gyro2_jump Gyro3_jump Gyro4_jump Gyro1_oddres Gyro2_oddres Gyro3_oddres Gyro4_oddres SQ1_ff SQ2_ff SQ3_ff SQ4_ff A115 A117 A121 A126 A129 A131 A140 A148 A149 A152 A156 Aflag1 Aflag2 Aflag3 Aflag4 AnyAnomaly
L3data	Id vt value (each run ID is stored, for the mission, in its own file)

Special notes on the Level 1 dynamic TM/SN tables:

Grouped as TMdata and SNdata, where TM data is 32K data rate, "full resolution" data, and SN data is the 1K/2K TDRSS data (non-science). Each of these data groups have a similar structure and the primary difference between them is that since it had a faster telemetry rate, TM data contains a lot more data points. TM data was used for science; SN data was used only for health and safety.

The SN and TM data files are each grouped (respectively) by subsystem, one week at a time. The file nomenclature is like the following example:
ECU_12_YYYYDOY_YYYYDOY__TM.cdf where ECU represents the on-board electronics subsystem (as detailed in the Tmnames table). 12 represents the cycle number (12 was the cycle number for all IOC and science mission data, as detailed in the SCtime table). The first YYYYDOY represents the start year and day of year, and the second YYYYDOY represents the end year and day of year for this data file. Note these dates are inclusive and it is assumed that the day starts at 00:00:00.0 and ends at 23:59:59.9. The "TM" is for 32K data, and will be "SN" in the case of 1K/2K data. .cdf represents the fact that these files are using the NSSDC's "Common Data Format" for archival storage.

Each data file includes a header with the start and end time, and then proceeds directly to the data for each TMID (mnemonic number) in the subsystem.

Table name	Fields (in the order archived)
TM/SNdata	TMID #, a list of SCT_VTCW's, a list of corresponding values. This pattern is repeated over and over for each TMID in the subsystem.
	If the TMID is a 'discrete' or 'Boolean' data type, its value is saved as a 1-byte field, otherwise it is an 8 byte floating-point number.
Sndata	Note that most SN data is saved as subsystem "ALL" because it such a small data set by comparison

A sample TM/SN data file might look something like:

Standard NSSDC CDF header	
Cycle 12	
Space Craft GPB	
Start time (integer, vehicle time clock word)	
Stop time (integer, vehicle time clock word)	
TMID 1234 (See Tmnames for this mnemonic name)	
ROWS 8 (# of rows for this TMID)	
SCT_VTCW	VALUE
2013456987	367.5
2013456988	367.4
2013456989	367.9
2013456990	331.36
2013456991	330.7145
2013456992	370.1
2013456993	335.77
2013456994	372.4468
TMID 1236	
ROWS 5	
SCT_VTCW	VALUE
2013456987	0.043
2013456988	0.5009

2013456989	1.223
2013456990	1.445
2013456991	-1.568
…	…
…	…
…	…
ET CETERA	

The Tmpseudo data structure is identical to the above. The Tmaverage data is similar in structure to the above, except that it contains more columns, which include, as detailed above, Minimum_Value, Maximum_Value, Average_Value, Std_Deviation, Value_Count.

Documents

There is considerable documentation available for the Gravity Probe B mission. This mission was one of the first to put all of its Acceptance Data Packages online, and has scanned and digitized thousands of drawings, papers and supporting documents. GP-B will work on a best-effort basis to include as much of this material in the archive, in common non-proprietary formats, as possible.

Specifications

Specifications include Stanford University documents and those from major subcontractor, Lockheed Martin Corporation. The document archive shall include all contract-deliverable documents from both agencies, and those documents shall be in PDF (Portable Document Format) format.

Drawings

Drawings include Stanford University design drawings in creating the science instrument assembly and supporting electronics, and design drawings from Lockheed Martin for the space vehicle and its components. These drawings were scanned from original printings and shall be in PDF format.

Test Documents/As-Run Procedures

Test documentation and recorded test results shall be archived on a best-effort, as-available basis.

Photographs

The Gravity Probe B mission has saved thousands of photographs and created artwork as needed for the mission's Education & Public Outreach department. The photographs mostly document the assembly of the science instrument, its integration into the probe and then the dewar, final spacecraft integration, several important pre-flight tests and the necessary moves of the payload and vehicle, along with the launch. All of these photographs will be archived in JPEG, GIF, or TIFF format, though artwork may be archived in both Adobe proprietary format in one of the common standard image formats to facilitate future use of the art by others.

Web Site

Upon conclusion of the Gravity Probe B mission, the mission web site pages shall be transferred to the NSSDC for re-posting or archiving, at their discretion.

Schedule for Archive Generation, Validation, and Delivery.

The principal archive elements, namely the science data products defined in Section 5, will be generated following completion of the science data collection period.

The timeline for archive delivery to NSSDC is shown in Table 6.1. There is one additional NSSDC data delivery date planned: approximately 70 gigabytes of Level 2 Data (April 2007). The final archive delivery may include the 70 gigabyte subset data in its entirely if delivered as a new version.

Table 6.1 GP-B Archive Generation, Validation, and Release Schedule

Date	Event
April 20, 2004	Launch, On-orbit checkout
August 2004	Science data collection
September 2005	End of data collection
November 2005	Draft MOU
January 2006	Final Draft MOU complete
February 2006	Draft Archive Plan
October 2006	Nominal end of mission
November 2006	Delivery of ITAR sensitive documents on DVD
January 2007	Final Draft Archive Plan complete
April 2007	Delivery of subset 70 GBytes Level 2 science data, delivered to NSSDC
April 2007	• GP-B first results announcement
June 2007	• Primary delivery of science data
	• Delivery of Mission Support Software LMCO database
	• Delivery of pre-launch spacecraft test data
	• Delivery of spacecraft orbit ephemera
	• Delivery of GP-B web site snap shot
December 2007	Nominal end of no-cost extension • Delivery of Level 3 data
December 2007	Delivery of any remaining SAO Guide Star Data

GP-B Data Release Policy.

There are no proprietary data rights for the GP-B Mission data. Uncalibrated data (Level 0 and Level 1) and reduced (Level 2) data will be publicly released. Fully reduced, calibrated and corrected data products (Levels 2 and 3) will be produced under the direction of the science team for delivery to the NSSDC per the schedule given in table 6.1.

Appendix A: Guide Star Data from the SAO

The Smithsonian Astrophysical Observatory (SAO) is a "research institute" of the Smithsonian Institution. It is joined with the Harvard College Observatory (HCO) to form the Harvard-Smithsonian Center for Astrophysics (CfA).

• Guide Star data

Excerpted from http://www.spaceref.com/news/viewpr.html?pid=13995 :

> "The [GP-B] satellite measurements have to be adjusted for at least one very significant astronomical effect. We [at the CfA] are using radio telescopes to measure the required adjustment," says Smithsonian radio astronomer Michael Ratner (CfA), who works with [then-]CfA Director Irwin Shapiro on the project.
>
> Gravity Probe B carries a telescope that focuses on a guide star [IM Pegasi, also known as HR8703 and IM Peg] in order to provide a reference point for measuring tiny deflections in the gyroscopes' spin axes. The whole spacecraft is continually kept aligned to this star. Yet the star shifts its apparent position as both it and the Sun independently orbit the center of the Milky Way. As seen from the GP-B spacecraft, the apparent position of the guide star also is affected by the spacecraft's orbit around the Earth and the Earth's orbit around the Sun.
>
> To compensate for those effects, Shapiro and his colleagues have monitored the GP-B guide star for several years using a variety of radio telescopes. That monitoring will continue through the lifetime of Gravity Probe B. Only after all of the spacecraft data have been collected will the calculations be made that will test Einstein's theory.

Previously Shapiro and Ratner observed IM Peg using the Hubble Space Telescope (HST). They have also recruited a team of optical astronomers to make other types of observations of this star.

Guide Star data is being organized and delivered to Gravity Probe B at Stanford University by personnel currently or formerly at the Center for Astrophysics, York University, University of California at Berkeley and ETH Zurich. The time of archive-appropriate data delivery from CfA personnel is still to be determined at the time of this writing. All of the above personnel have agreed to package up relevant guide star data using archival formats and including brief documentation. They will provide that data to Gravity Probe B, so that GP-B can then provide the data to the NSSDC. GP-B will ensure that CRC checks have been performed on the data. The data is split into two categories: optical and radio data observations.

• Optical Observations

The optical deliveries include images, astrometric, spectroscopic, and photometric measurements and certain results derived from those observations. Each data set will be accompanied by one or more "readme" files which describes the data set, the instrument, observations made, data content, data format, calibrations and/or data reduction, information about data source and use, and a CRC32 checksum for each file contained in the data set.

Observations in the following list grouped under a single number will be sent to Stanford University by a single astronomer who reduced or used the group of observations.

The data to be archived include:

1) AEOS, WIYN Speckle, and HST data to be sent by Paul Hemenway (CfA)

The data to be archived for the three data sets will consist of data reduced to a level useful in determining limits to the detectable sources of background radiation around the GP-B guide star, IM Pegasi (a.k.a. HR 8703, Hipparcos 112997, and HD 216489). The Hubble Space Telescope (HST) files are archived at the HST Space Telescope Science Institute, and pointers will be given to those archives, in addition to including the specific files used for GP-B analysis. Some specifics about the individual data sets is given below:

a) AEOS adaptive optics images of IM Peg:
  ~11 FITS files

b) WIYN speckle images of IM Peg:
  ~7 CDF format images

c) HST multiband WFPC2 images of IM Peg and surrounding field:
  30 FITS files of pipeline-calibrated a images
  30 FITS files of the associated "images" containing the pixel flags for the pipeline-calibrated images
  Up to 14 FITS files of derived images used for GP-B studies

2) Coronagraphic images made at the U. of Hawaii 2.2 m telescope of the IM Peg field in R band:
  ~4 FITS images

3) Images made at the USNO Flagstaff Station of IM Peg and the surrounding field in B band:
  ~25 FITS images
  ~20 ASCII files of derived B magnitudes for background stars within or near the GP-B field of view

4) To be sent by Stephen Marsden (University of Southern Queensland)

a) Multiband photometry of IM Peg (and a check star) obtained at Fairborn Observatory and by Fairborn personnel:
  18 ASCII files

b) IM Peg spectra from Fairborn Observatory:
  ~700 ASCII files containing the calibrated spectra
  ~700 ASCII files containing the calibrated spectra with "spliced orders"

c) IM Peg spectra from the Anglo-Australia Telescope:
  24 ASCII files

d) IM Peg spectra from the Crimean Astrophysical Observatory:
  44 ASCII files

e) IM Peg spectra from Lick Observatory:
  165 ASCII files

f) IM Peg spectra from Lick Observatory with photometric calibration:
  ~20 ASCII files

g) IM Peg spectra from the Nordic Optical Telescope:
  142 ASCII files

h) The IM Peg spot maps computed at ETH Zurich from the above spectra:
  ~30 ASCII files containing the pixel values of the maps, spaced every ~25 days
  ~30 PDF's displaying the above maps

i) Daily modeled IM Peg spectra computed at ETH Zurich from the above maps:
14 ASCII files, each containing spectra for 25 consecutive days

j) Mean angular offset between light centroid and primary disk center, computed at ETH Zurich, for each of the maps above:
1 ASCII file

- ## Radio Observations

Raw correlated VLBI data from VLBI observations of IM Peg and two or three calibration sources conducted by the CfA and York University is stored at the National Radio Astronomy Observatory archive (in FITS files). The NRAO online archive contains the complete raw correlated VLBI data from 1999 May 16 on (http://archive.nrao.edu/archive/e2earchive.jsp). Earlier observations are also available from the NRAO.

1) York will deliver, in FITS format, the visibilities of the multi-source files for each of the 35 epochs between 1997 and 2005 as well as the four earlier epochs between 1991 and 1994. Attached to these files are the calibration and flag tables. The data will be delivered in a "ready to process" format. In addition will be delivered ASCII files describing the contents of the data files.

2) For each epoch there will be one to two gigabytes of data. Total estimated size of archived radio data: ~70 gigabytes.

Appendix B: GP-B Acronyms

ACE	Attitude Control Electronics
ACO	Administrating Contracting Officer
ADP	Acceptance Data Package
AGS	GN station in Poker flats, Alaska
AIP	Archival Information Package
AIPS	Astrological Image processing system
AOS	Acquisition of Signal
APID	Application Process Identification
ATC	Attitude & Translation Control Subsystem
BPS	Bits Per Second
C&DH	Command & Data Handling
CCCA	Command/Control Computer Assembly
CCSDS	Consultant Committee for Space Data Systems
CD	Compact disc
CDR	Critical Design Review
CDRL	CDRL Contractor Data Requirements List
CfA	Harvard-Smithsonian Center for Astrophysics
COBE	Cosmic Background Explorer
CSTOL	Colorado Spacecraft Test and Operations Language
DBRO	Database Readout
DES	Data Encryption Standard
DMA	Detector Mount Assembly
DP	Data Processing
DSN	Deep Space Network
E&PO	Education and Public Outreach
ECU	Experiment Control Unit
EM	Engineering Memo
EU	Engineering Unit
FEP	Front end processor
FFT	Fast Fourier Transform
FSW	Flight Software
GB	Gigabyte
GMT	Greenwich Mean Time
GN	Ground network controlled by WFF
GP-B	Gravity Probe B
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
GSS	Gyro Suspension System
GUI	Graphical User Interface
HEPL	Hansen Experimental Physics Labs at Stanford
HEX	Hexadecimal
IOC	Initial Operations Capability
IONet	NASA's IP Operational Network
IPDU	Internet Protocol Data Unit
kbps	Kilobits per Second
LASP	Laboratory for Atmosphere and Space Physics
LMMS	Lockheed Martin Missiles & Space
MGS	Mcmurdo Antarctica Ground Station
MB	Megabyte
MOC	Mission Operation Center
MRO	Memory Readout- A type of data packet from the spacecraft
MSFC	Marshall Space Flight Center
N/A	Not Applicable

NIST	National Institute of Standards & Technology
NOAA	National Oceanic and Atmospheric Administration
NRAO	National Radio Astrometric Observatory
NSSDC	National Space Sciences Data Center
OASIS	Operations and Science Instrument Support
OD	Orbit Determination
PCB	Program Control Board
POD	Not an acronym, it's a cluster of computers
QA	Quality Assurance
QUIKSCAT	Quick Scatterometer, a NASA Earth satellite
REE	Responsible Equipment Engineer
R/O	Readout
RTworks	Real-Time monitoring, display, logging & cntrl s/w by Talarian Corp
SAA	South Atlantic Anomaly
S/C	Spacecraft
SN	Space Network (TDRSS)
S/V	Space Vehicle
SWSI	SN Web Service Interface
SADM	Solar Array Deployment Mechanism
SAFS	Standard Autonomous File Server
SAO	Smithsonian Astrophysical Observatory
SGI	Silicon Graphics, Inc.
SIM	Simulation
SIA	Science Instrument Assembly
SLR	Satellite Laser Ranging
SQUID	Superconducting Quantum Interference Device
SSR	Solid State Recorder
STK	Satellite Tool Kit
SU	Stanford University
Sybase	Relational Data Base Management Software
TBD	To Be Determined
TCAD	Telemetry Checking, Analysis and Display
TDP	Telemetry Data Processing Software
TDRSS	Tracking and Data Relay Satellite System
TQSM	Telemetry Quality and Status Monitoring
TRE	Telescope Readout Electronics
UT	Universal time
VAFB	Vandenberg Air Force Base
VLBI	Very Long Baseline Interferometry
WFF	Wallops Flight Facility
WGS	Wallops Ground Station (Wallops island)
WSC	White Sands Complex (TDRSS)
WOTIS	Wallops Orbital Tracking Information System

Appendix C: ITAR

The U.S. State Department's International Traffic in Arms Regulations (ITAR) classifies spacecraft systems and scientific satellites -- and all related data, components, software, parts and material -- as "significant military equipment" subject to tight control. ITAR bars the disclosure of unclassified technical data by American companies or universities to foreign students, faculty and collaborators if they are from countries listed as "sensitive" or "terrorist exporting."

The Gravity Probe B spacecraft and instrument fell under ITAR restriction in late 1999, more than 35 years after the project's inception. Anything considered public knowledge about Gravity Probe B before its re-classification (e.g. published papers, newspaper articles), remains outside the ITAR restriction. However, some internal publications and schematics are considered ITAR restricted as determined by the U.S. State Department Statute.

Gravity Probe B, and their major subcontractor, Lockheed Martin Corporation, has made a considerable effort to classify all documents and schematics appropriately.

The NSSDC is the final entity responsible for distribution of Gravity Probe B data and its supporting materials (including internal publications and schematics). The NSSDC has agreed to seek re-classification of ITAR restricted materials, and to make available ITAR cleared material as appropriate.