ROSETTA
MARS EXPRESS
VENUS EXPRESS

Radio Science Experiments
RSI / MaRS / VeRa

Geometry and Position Index
Software Design Specifications

Issue:	**draft**
Revision:	**4**
Date:	**20.06.2005**
Document:	**MEX-MRS-IGM-DS-3046**

Prepared by

Markus Fels

Approved by

Martin Pätzold (MaRS Principal Investigator)

page left free

Document Change Record

Issue	Rev	Sec	Date	Changes	author
draft	0	all	8.5.2005		MF
draft	1	2.3	11.5.2005	Flow Diagram update	MF
draft	2	2.3	1.6.2005	Definition of sample interval for footprint computation	MF
draft	3	2.3	10.6.2005	Update for occultation measurements	MF
draft	4	2.4	20.6.2005	Update of observation types	MF

Page left free

DISTRIBUTION LIST

Recipient	Institution	No. Of Copies
MaRS.RSI VeRA Team		
Martin Pätzold	IGM	1
Markus Fels	IGM	1
Bernd Häusler	Universität der Bundeswehr München	2
ESA/ ESOC/ ESTEC		
Joe Zender	ESA	1
Jorge Diaz del Rio Garcia	ESA	1

Page left free

ACRONYMS

A/D	Analog/Digital
AGC	Automatic Gain Control
AGVTP	Archive Generation, Validation and Transfer Plan
AOL	Amplitude Open Loop
ATDF	Archival Tracking Data Format
CD-ROM	Compact Disk - Read Only Memory
CL	Closed-Loop
DDS	Data Delivery System
DSN	Deep Space Network
DVD	Digital Versatile Disk
ESA	European Space Agency
ESOC	European Space Operation Center
ESTEC	European Space Technology Center
FOL	Frequency Open Loop
G/S	Ground Station
HGA	High Gain Antenna
IFMS	Intermediate Frequency Modulation System
JPL	Jet Propulsion Laboratory
LCP	Left Circular Polarization
LGA	Low Gain Antenna
LOS	Line Of Sight
MaRS	Mars Express Radio Science Experiment
MGA	Medium Gain Antenna
MGS	Mars Global Surveyor
NASA	National Aeronautics and Space Administration
ODF	DSN Original Data File
ODR	Original Data Record
OL	Open-Loop
ONED	one-way dual-frequency mode
ONES	One-way single-frequency mode
PDS	Planetary Data System
POL	Polarization Open Loop
RCP	Right Circular Polarization
RSR	Radio Science Receiver
RX	Receiver
S/C	Spacecraft
SIS	Software Interface Specification

S-TX	S-Band Transmitter
SPICE	Space Planet Instrument C-Matrix Events
TBC	To Be Confirmed
TBD	To Be Determined
TWOD	Two-way dual-frequency mode
TWOS	Two-way single-frequency mode
USO	Ultra Stable Oszillator
X-TX	X-band Transmitter

Contents

page left free

1 INTRODUCTION

1.1 SCOPE

This document specifies the requirements for the development of the Geometry and Position Index software. This software creates index tables, which contain geometry and position information for each data product within the archive volume. This geometry and position information is described by a set of parameters required in the Geometry Index file. Besides, other PDS keywords are also included in this index file to supply additional information about the data product. Additional the document describes the appropriate PDS labels.

1.2 REFERENCED DOCUMENTS

	Reference Number	Title	Issue Number	Date
[1]	MEX-MRS-IGM-IS-3016	Radio Science File naming Convention	9.6	22.10.2004
[2]	SOP-RSSD-TN-010	Geometry and Position Information	3.5	4.5.2005

1.3 SOFTWARE CONFIGURATION CONTROL

This document addresses the software package

GEOINDEX_SOFTWARE_L02
Version 1.0

After release, the software is under configuration control which will be documented in this section.

Version number	Changes/Action	New version	Release date

1.4 ACTION ITEM LIST

Action item	Description	Due date	actioneer	closed

2 SPECIFICATIONS FOR GEOMETRY AND POSITION INDEX GENERATION

2.1 MAIN PROGRAM SPECIFICATIONS

2.1.1 General specifications

GEOINDEX-SPEC-2110: This software shall

- Read Level 2 IFMS, RSR and ODF Data Labels
- Determine the path and filename for each processed L2 data file
- Compute following geometric parameters:
    - Solar related parameters
    - Spacecraft related parameters
    - Instrument related parameters
- Output the results as an INDEX file, called GEO_TARGET.TAB
- Generate PDS label file for the output file, called GEO_TARGET.LBL

TARGET: Reference Target Name (e.g. Mars, Venus, Chury…)

GEOINDEX-SPEC-2120: the software language is FORTRAN.

2.1.2 Definition of constants

GEOINDEX-DEF-2130: ASTRONOMICAL UNIT (AU)

1 AU = 149,597,870 kilometers

GEOINDEX-DEF-2140: SPEED OF LIGHT

c = 299,792,458 m/s

GEOINDEX-DEF-2150: RANGE UNIT (RU)

1 RU = 0.30 m

GEOINDEX-DEF-2152: PHYSICAL CONSTANTS

Constant		Value	SI units
Electron charge	e	$1.6022\ 10^{-19}$	A s
Electron mass	m_e	$9.1094\ 10^{-31}$	kg
Electric field constant	ε_0	$8.8542\ 10^{-12}$	$s^4\ A^2\ m^{-3}\ kg^{-1}$
Plasma constant	$\frac{1}{2}\frac{1}{4\pi^2}\frac{e^2}{m_e\varepsilon_0}$	40.30924	$m^3\ s^{-2}$

GEOINDEX-DEF-2160: CARRIER FREQUENCIES Mars Express

Mars Express:

frequency band	uplink	downlink
S-band	2114.676 MHz	2296.482 MHz
X-band	7116.936 MHz	8420.432 MHz

GEOINDEX-SPEC-2170: Transponder constants and ratios

Mars Express:

frequency band uplink	transponder ratios downlink/uplink	
	S-band	X-band
S-band	240/211	880/211
X-band	240/749	880/749

2.2 INPUT FILES

2.2.1 Data file types

GEOINDEX-SPEC-2210: the following table defines the input file types and the logical file names used in this specification and within the software:

File Description	Logical name within program
Ranging L2 Label file	RNG_LBL
Doppler L2 Label file	DOP_LBL

GEOINDEX-SPEC-2212: input file names will be accepted via a Perl Graphical User interface.

2.2.2 File names

GEOINDEX-SPEC-2220 Level 2 label file names are defined in [1] section 4.1

For the range files:

rxxtypeL02_RGS_yydddhhmm_qq.LBL
rxxtypeL02_RGX_yydddhhmm_qq.LBL

For the doppler files:

rxxtypeL02_D1S_yydddhhmm_qq.LBL
rxxtypeL02_D1X_yydddhhmm_qq.LBL
rxxtypeL02_D2S_yydddhhmm_qq.LBL
rxxtypeL02_D2X_yydddhhmm_qq.LBL

2.2.3 File formats

GEOINDEX-SPEC-2230: File formats are defined in [1] and [2].

2.3 GEOINDEX SOFTWARE SPECIFICATIONS

The main structure of the GEOINDEX software is described in the flow diagramm of Figure 2.1.

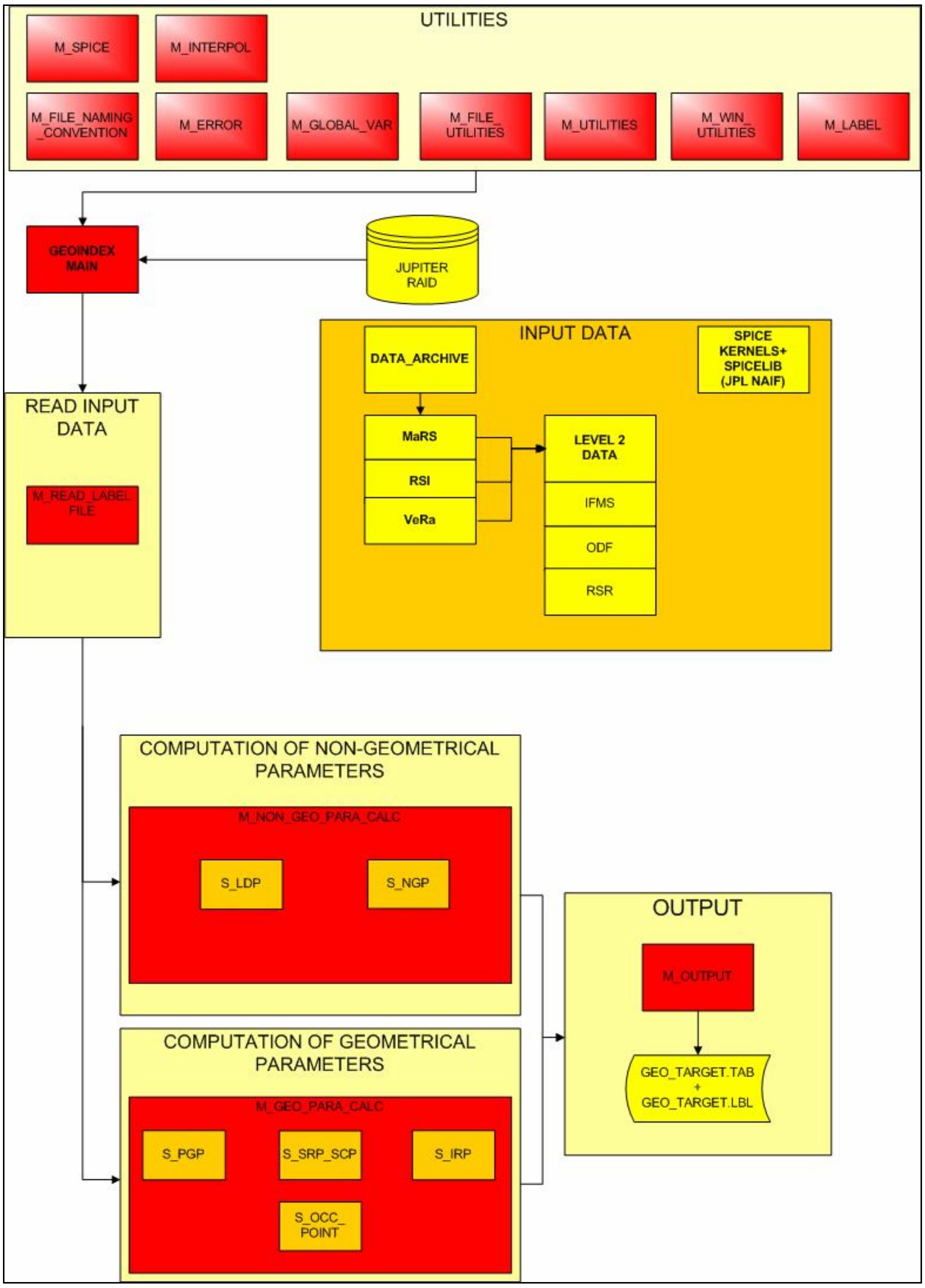


Figure 2-1: GEOINDEX Main Flow Diagramm

2.4 OBSERVATION TYPES

2.4.1 Occultations

In case of occultation measurements (investigation of atmosphere and ionosphere), all the GEOINDEX position parameters are computed only for one point on the target's surface, for which the vertical profiles of temperature, density, electron content, etc. can be calculated (F_{occ}, see Figure below). This point is determined with the help of the subroutine S_OCC_POINT, which makes use of a SPICE function OCCPT to determine the time stamp of the beginning of the occultation. This is done iteratively with an sample interval of 0.1s.

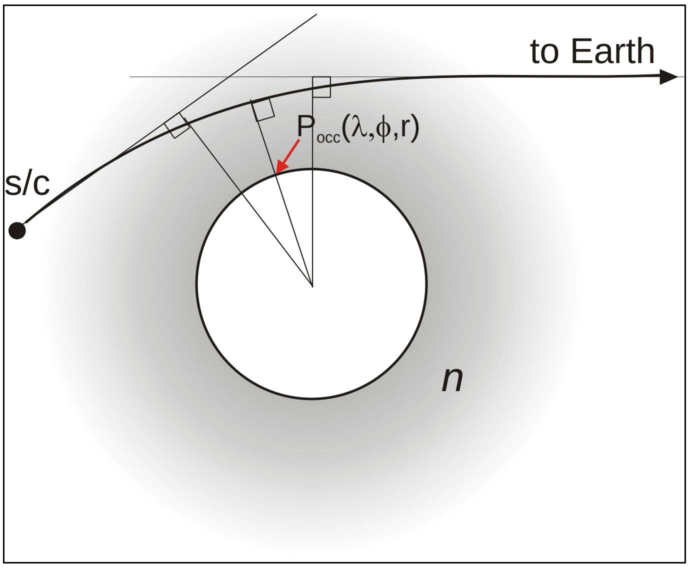


Figure 2-2: Observation geometry for occultation measurements

2.4.2 Gravity

In case of gravity measurements, all the GEOINDEX position parameters are computed for the ground track of the satellite on the target body (computation of the subsatellite coordinates $F_{i,grav}$, see Figure 2.3). This footprint computation is done with an sample interval of 10s.

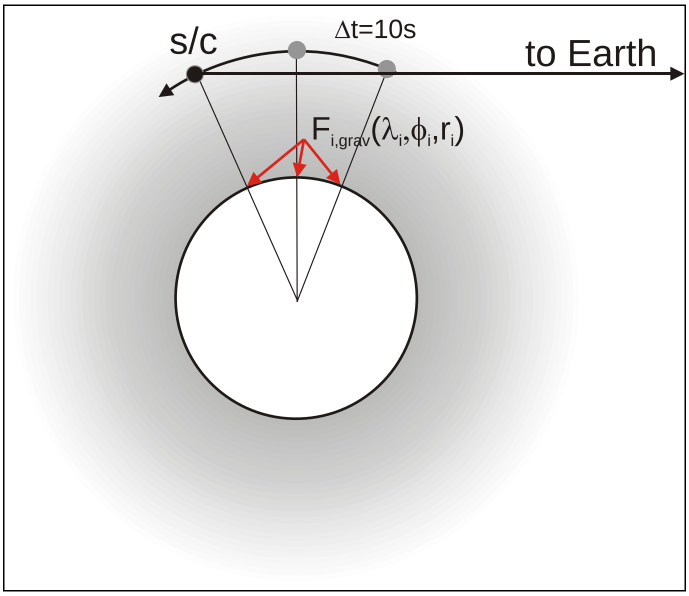


Figure 2-3: Observation geometry for garvity measurements

2.4.3 Bistatic Radar

TBD

2.4.4 Solor Corona

TBD

GEOINDEX-SPEC-2235: sample interval of footprint computation

Observation type	Computation interval
TARGET GRAVITY	10s
GLOBAL GRAVITY	10s
OCCULTATION	Only one observation point on the target
BISTATIC RADAR	TBD
SOLOR CORONA	TBD

2.4.5 MODULE M_READ_LABELFILE

GEOINDEX-SPEC-2240: M_READ_LABELFILE accepts all MaRS, RSI and VeRa Level 2 label files as input: It finds the information needed for the computation of the geometric parameters and stores it into the data structure LABEL_INFO:

1. Pathname of the label file
2. Filename of the label file
3. Pathname of the appropriate data file
4. Filename of the appropriate data file
5. Number of samples of the appropriate data file
6. Target
7. Observation Type
8. Product ID
9. Dataset ID
10. Start time of the appropriate data file
11. Stop time of the appropriate data file

2.4.6 MODULE M_NON_GEO_PARA_CALC

MODULE M_NON_GEO_PARA_CALC contain two subroutines, which compute non geometrical related parameters

2.4.6.1 Subroutine S_LDP

GEOINDEX-SPEC-2245: S_LDP generates the line description for the geometrical footprints:

1. Number of lines describing the footprint (N)
2. Number of the current line (I)

2.4.6.2 Subroutine_S_NGP

GEOINDEX-SPEC-2247: S_NGP generates parameters for additional information, which are not related with either the geometry or the position information.
These parameters are:

1. Change Mode (CM)
2. Pathname (P)
3. Filename (F)
4. Product ID (PID)
5. Data Set ID (DID)
6. Release ID (RSID)
7. Revision ID (RVID)

If the release/revision concept is not implemented in the data set, the columns Release ID and Revision ID are set to “N/A” values.

2.4.7 MODULE M_GEO_PARA_CALC

MODULE M_GEO_PARA_CALC contain three different subroutines, which compute geometrical related parameters for the spacecraft, the instrument, the target body and the sun.

2.4.7.1 Subroutine S_PGP

GEOINDEX-SPEC-2250 : M_PGP computes position generic parameters, which are completely independent of any other parameters but time:

1. Geometry Epoch (GE)
2. Orbit Number (ON)

2.4.7.2 Subroutine S_SRP_SCP

GEOINDEX-SPEC-2260 : S_SRP_SCP computes solar (SRP) and spacecraft (SCP) related geometric parameters:
The solar related parameters are those that can be computed without any additional information about the spacecraft, and therefore only the time is needed.
The spacecraft related parameters are those that are related only with the spacecraft and the reference target body or the sun, but completely independent of the instruments, orientation, attitude and viewing directions.

SRPs:

1. Solar Longitude (SL)
2. Sub-Solar Latitude (SLAT)
3. Sub-Solar Longitude (SLON)

SCPs:

1. · Spacecraft-Sun Distance (SD)
2. · x/y/z components of the Spacecraft-Sun Position Vector (XSP,YSP,ZSP)
3. · x/y/z components of the Spacecraft-Sun Velocity Vector (XSV,YSV,ZSV)
4. · x/y/z components of the Spacecraft-Target Position Vector (XTP,YTP,ZTP)
5. · x/y/z components of the Spacecraft-Target Velocity Vector (XTV,YTV,ZTV)
6. · Spacecraft Altitude (SA)
7. · Sub-Spacecraft Latitude (SCLAT)
8. Sub-Spacecraft Longitude (SCLON)

2.4.7.3 Subroutine S_IRP

GEOINDEX-SPEC-2270 : S_IRP computes instrument viewing related parameters (IRP):

1. Target Name (T)
2. Local True Solar Time (LTST)
3. Latitude of the Start Point (SPLAT)
4. Longitude of the Start Point (SPLON)
5. Latitude of the End Point (ELAT)
6. Longitude of the End Point (ELON)
7. Central Latitude (CLAT)
8. Central Longitude (CLON)
9. Phase Angle (PA)
10. Incidence Angle (IA)
11. Emission Angle (EA)
12. Slant Distance (SLD)
13. North Pole Azimuth Angle (NPAA)
14. Sub-Spacecraft Azimuth Angle (SCAA)
15. Sub-Solar Azimuth Angle (SAA)
16. Horizontal Pixel Scale (H)
17. Vertical Pixel Scale (V)

GEOINDEX-SPEC-2330: output files
The format of the output files is specified in GEOINDEX-SPEC-2780 and 2781.

3 OUTPUT FILES

3.1 MODUL M_OUTPUT

GEOINDEX-SPEC-2760: The GEOINDEX_OUTPUT file names are defined as

GEO_TARGET.TAB
GEO_TARGET.LBL

Where TARGET represents the reference target of the mission:

placeholder	description	example
TARGET	67P/Tschurjumow-Gerasimenko Mars Venus	TSCHURI MARS VENUS

GEOINDEX-SPEC-2780: A detailed description of the format of the GEOINDEX_OUTPUT file is given in section 4 of document SOP-RSSD-TN-010 (ANNEX A). An overview is given Figure 3-1.
If one value is not computed or not available, it is set to an invalid constant -99999.9 in case of number values or to “N/A” in case of characters.

LDP		NGP							PGP		SRP		
N	I	CM	P	F	PID	DID	RSID	RVID	GE	ON	SL	SLAT	SLON

SCP															
SD	XSP	YSP	ZSP	XSV	YSV	ZSV	XTP	YTP	ZTP	XTV	YTV	ZTV	SA	SCLAT	SCLON

IRP																
T	LTST	SPLAT	SPLON	ELAT	ELON	CLAT	CLON	PA	IA	EA	SLD	NPAA	SCAA	SAA	H	V

Figure 3-1: Format of a record line in the GEO_INDEX file

4 ANNEX A

4.1 PLANETARY SCIENCE DATA ARCHIVE TECHNICAL NOTE GEOMETRY AND POSITION INFORMATION (SOP-RSSD-TN-010)

European Space Agency
Research and Scientific Support Department
Planetary Missions Division

Planetary Science Data Archive Technical Note
Geometry and Position Information

SOP-RSSD-TN-010

Issue 3
Revision 5

4 May 2005

Prepared by: J. Diaz del Rio

this page intentionally left blank

CHANGE RECORD SHEET

Date	Iss.	Rev.	Description/Authority
2 Dec 2002	Draft	01	First draft in excel spreadsheet
5 Dec 2002	Draft	02	Revised version
21 Feb 2003	1	0	Merge of geometry and positional information into one table, deleted all ranking information from the instrument team. Added 4 keywords proposed by OMEGA: MINIMUM_LATITUDE, MAXIMUM_LATIDUE, EASTERNMOST_LATITUDE, WESTERNMOST_LATITUDE
19 Mar 2003	1	1	Moved excel file into word file, created doc number
10 Jul 2003	2	-	Inclusion of all the new definitions and the new division of the geometry and positional parameters defined in the 7th DAWG, 20th & 21st, May 2003. Distribution of the keywords in four groups and restructuration of the document.
22 Jul 2003	2	1	Corrections for ambiguous definitions in some keywords.
22 Oct 2003	2	2	Inclusion of the PDS required keywords that must be in the Geometry Index File. Filename scheme for these files related with the RELEASE Object concept.
13 Apr 2004	3	0	Inclusion of the PSA Index definition concept. Redefinition of all instrument-related parameters to be usable by all the planetary mission's teams with the same meaning (when applicable). Reformatting of tables and inclusion of parameter's format and applicable values.
20 Sep 2004	3	1	Discussion about the sampling frequency and the Geometry's Data Set description. Clarification of open points pointed out by ASPERA team.
27 Sep 2004	3	2	Discussion about the centre of a "line". Update of the longitude ranges from [-180,180] to [0,360] where required. Update the remark fields of several keywords as all longitude related ones, and NORTH_POLE_AZIMUTH_ANGLE, SUB_SPACECRAFT_AZIMUTH_ANGLE and SUB_SOLAR_AZIMUTH_ANGLE. Updates and corrections in the File Naming Scheme chapter, Geometry Index Label Format and Geometry Index Table Format chapters and in the Release/Revision Concept and Geometry Index File chapter. Correction in the 'Formation Rule' of PATH_NAME data element.
08 Sep 2004	3	3	Discussion REFERENCE_TARGET_NAME and TARGET_NAME. Update of File Name Scheme based on RELEASE/REVISION concept and on a Data Set Delivery. Update of maximum length of all LONGITUDE related keywords, all S/C state vector related keywords and all Azimuth Angle related keywords.
09 Nov 2004	3	4	Increase of CENTER_LATITUDE and CENTER_LONGITUDE resolution from 3 to 5 decimal digits. Clarification of "left-hand" and "right-hand" points definition and center point definition. Definitions of N, I, START_POINT, END_POINT and CENTER in the chapter 4.
27 Apr 2005	3	5	New column in the Geometry Index File: TARGET_NAME. Discussion about the use of the REFERENCE_TARGET_NAME. Open Issue 09-Nov-2004 Closed. Discussion about the number of Geometry Index Files to be provided to PSA per data set. Clarification on the use of RELEASE_ID, REVISION_ID and CHANGE_MODE in the Geometry Index Table. Chapter 2. Coordinate Systems and Cartographic Standards included.

DISTRIBUTION LIST

Recipient	Experiment	Recipient	Organisation
Duxbury, T.	IDS	Bibring, J. P.	
Guiness, E.	PDS Geoscience	Neukum, G.	HRSC
Jaumann, M.	HRSC	Bertaux, J. L.	
Martin, P.	MEX-PST	Paetzold, V.	MaRS
Seu, R.	MARSIS	Formissano, A.	PFS
		Picardi, G.	MARSIS
		Pillinger, C.	
		Chicarro, A.	MEX-PST
		Martin, P.	MEX-PST
		Ocampo, A.	MEX-PST
Maturilli, A.	PFS Archive	Koschny, D.	MEX-PST
Fels, M.	MaRS	Zender, J.	MEX-PST
Carone, L.	MaRS	Diaz del Rio, J.	MEX-PST
Stanzel, C.	MaRS		
Reberac, A.	SPICAM Archive		
Roatsch, T.	HRSC Archive		
Alanis, R.	HRSC Archive		
Jeffers, S.	ASPERA Archive		
Orosei, R.	MARSIS Archive		
Plautt, J.	MARSIS Archive		
Huff, R.	MARSIS Ionos. Archive		
Gondet, B.	OMEGA Archive		
Langevin, Y.	OMEGA Archive		

Open Issues

Date	Description
~~09-Nov-2004~~	~~How to deal with Geometry Index files for data sets with several targets, i.e. a data set containing data products for Mars, Phobos and Deimos. In the current approach, Phobos and Deimos data products will not be referenced in the Geometry Index File.~~
04 May 2005	Geometry Index describing LIMB Observations. How should we handle this kind of observations?

1 Introduction

1.1 Purpose

The data archiving working group identified the need of one geometry index file per logical archive volume (or per release/revision of a logical archive volume) to collect all the required geometry and position information for each data product within the logical archive volume to preserve the necessary information. This geometry and position information will be described by a set of parameters required in the Geometry Index file. Besides, other PDS keywords must be also included in this index file to supply additional information about the data product. The collection of this information outside the data products allows easier updating of the values.

The teams are encouraged to use the appropriate keywords in the label of the data products, but noting in a PDS standard comment that the given information may be updated in the geometry index file.

This document describes the concept, purpose and format of the geometry index file, giving some guidelines for its implementation, as well as a detailed description of all the parameters required to allow future users of the PSA to query and identify data products of interest.

1.2 Intended Readership

- Experimenter archive working group members.
- Inter-disciplinary scientists.
- PSA Development Team.

1.3 Naming Conventions

None

1.4 Acronyms

IAU, International Astronomical Union

PSA, Planetary Science Data Archive

PDS, Planetary Data System

SI, International Standard for Units

1.5 References

[1] Planetary Science Archive. Experiment Data Release Concept. Technical Proposal SOP-RSSD-TN-015

[2] Planetary Data System Standards Reference. October 12, 2002. Version 3.5 Jet Propulsion Laboratory. California Institute of Technology. Pasadena, California.

[3] ESA Planetary Missions Science Archive (PSA). User Requirements Document (URD). SOP-RSSD-RS-006

[4] Report of the IAU/IAG Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites: 2000," Sheidelmann et al., Celestial Mechanics, 2000.

2 Coordinate Systems and Cartographic Standards

The following cartographic standards are used in the generation of the Geometry Index files (For further information please refer to [4]):

2.1 Inertial Reference Frame, Time and Units

The Earth Mean Equator and Equinox of Julian Date 2451545.0 (referred to as the J2000 system) is the standard inertial reference frame.

The standard format for time tags is UTC in year, month, day, hour minute and decimal seconds.

The standard units are SI metric units, including decimal degrees.

2.2 Spin Axes and Prime Meridians

The IAU-defined spin axes and prime meridians defined relative to the J2000 inertial reference system are the standard for planets, satellites and asteroids where these parameters are defined.

2.3 Body-Fixed Rotating Coordinate System

The Planetocentric coordinated system is the standard Body-Fixed Rotating Coordinate System. The planetocentric system has an origin at the center of mass of the body. Planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined as positive in the northern hemisphere of the body, where north is the direction of Earth's angular momentum vector, i.e., pointing toward the north hemisphere of the solar system invariant plane. Longitudes increase toward the east, i.e., counterclockwise with respect to the North pole direction of the invariant plane.

3 The Geometry Index File

3.1 Introduction

Data archiving is one of the important phases of every scientific mission. The access to these data is sometimes complex and time consuming and therefore, ESA has designed a set of online services to help the scientific community to get the required data in a fast and reliable way. Originally it was intended to offer the data sets on physical media, but it became obvious that the scientific exploitation of the planetary data would increase by offering these online services that are provided by the Planetary Missions Science Archive. PSA shall allow multi-instrument searches across scientific disciplines and even between different missions.

A broad range of search possibilities will be offered to the PSA user. A scientist or an instrument team member may search on detailed instrument specific parameters, combining his/her detailed search with a more general query on another instrument of the same mission. But he/she may also combine his/her initial search query with a query on another mission.

The amount of archived data from planetary missions is growing with every new mission and the detailed search is becoming more and more complex, hence there is a need for a reliable filtering engine that reduces the number of data products to be analyzed and searched in detail.

Furthermore, for outstanding planetary missions, we intend to be able to ingest future data sets with minimal database re-engineering and software changes, and that implies a common mission independent searchable list of parameters. Each data product within a data set shall be described by these parameters contained in the geometry index file.

3.2 The Geometry Index Concept

Index files in PDS are used to describe the data stored on an archive volume and to point to the data products containing these data. This is to help the end user to locate data of interest. To provide geometry and position information about the data, a geometry index is used. Although the Geometry Index File is for providing geometry and position information, it is meant to locate the data within the data set being an index table, and therefore it shall be placed in the INDEX directory. Moreover, within the PSA, the geometry index files are read by the database software and allow the ingestion of additional searching parameters into the database. For further information about this topic, refer to [1].

Due to the big amount of data stored in a database, and the diversity of them in terms of instruments, targets, missions, geometry conditions…, there is a need for reducing the data to be searched using more specific queries. This is done in the PSA by searching the entire database looking for some general conditions in terms of geometry and position information parameters among others. The geometry and position information parameters for each data product shall be stored in the geometry index file.

Since the first query will be applied to all the data sets the geometry index file shall have a mission and instrument independent format, therefore it is required to have a common set of parameters that can be computed for all missions and all instruments in most of the cases. The geometry index file shall include geometrical and position information to describe the observations/measurements performed by any instrument in any planetary mission at a given time.

In principle it is possible to consider two general types of instruments: those mapping the surface of a body and those that perform space/spacecraft environment measurements. To describe the data products it is needed to "sample" information contained in them, either in terms of "*lines*" (for mapping instruments) or "*points*" (for environmental measuring instruments). Hereafter we will refer to these samples as "*lines*". The index file will be made of one or several lines for each data product and will contain a single physical record for each of the samples ("*lines*"). The number of lines per data product shall be configurable to allow different accuracy in the description of the different data products of a data set.

The set of parameters that shall be included in the Geometry Index will be described in the following sections. Formatting, file naming conventions, labeling and some additional comments and guidelines will be given in this document as well.

3.3 Number of Geometry Index Files to be delivered to PSA

Data sets may contain data for different targets, such as Earth, Moon, or Mars, Phobos and Deimos. The reference target used to compute spacecraft related parameters might be different between missions, or even between mission phases.

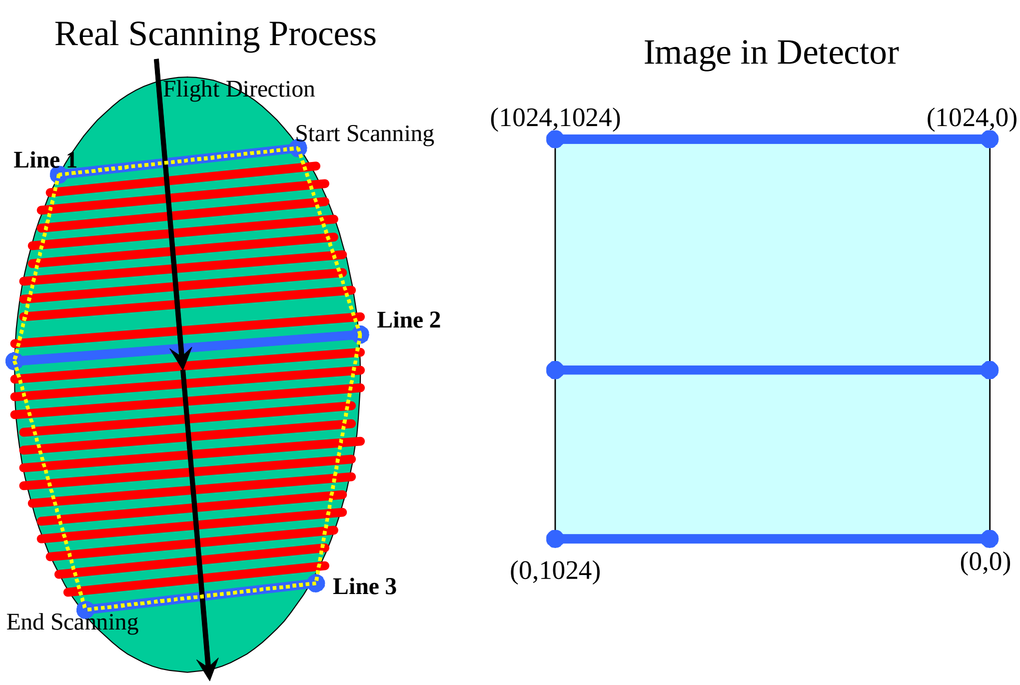
Although PSA has decided to use a single Geometry Index File per reference target (see Chapter 3.7 for the file naming scheme) this file may point to more than a single target. For example, it would be possible to have an Index File with the Earth as Reference Target, indexing data products for both the Earth and the Moon. Another example would be a Mars Index File containing information about data products for Mars, Phobos and Deimos.

PSA, therefore, requires as many Geometry Index Files as Reference Targets used within a data set.

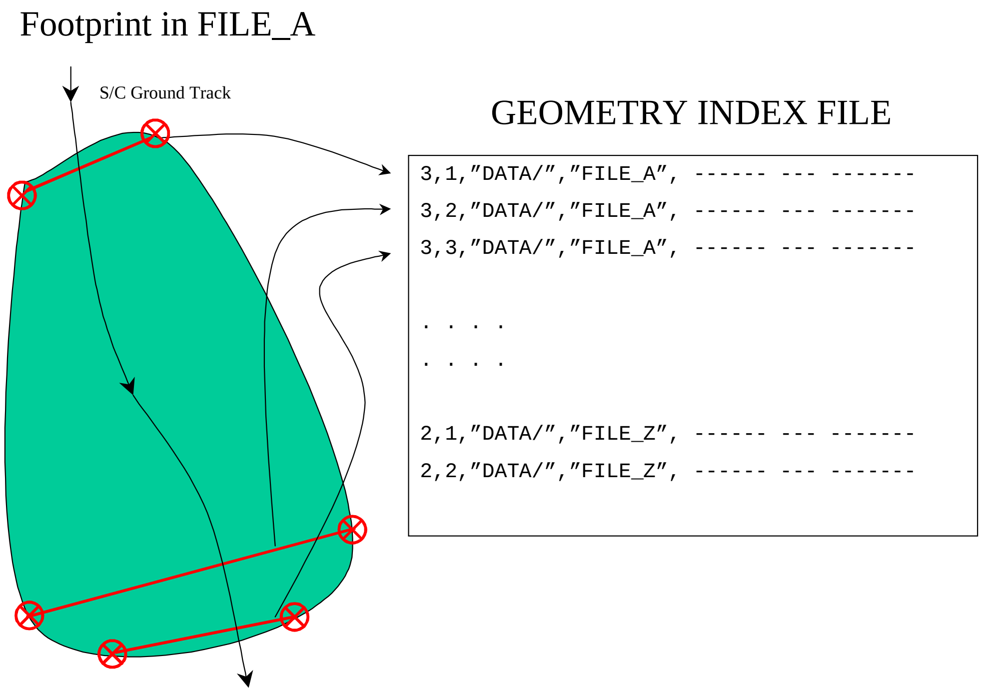
3.4 The “Line” Concept: Footprint Description

The main objective of the geometry index file is to describe the geometry associated with a data product in an instrument and mission independent way. This is a complex task due to the huge diversity of instruments flying in all the different missions. Each instrument maps the surface or measures the environment of a body in a different way. The observed region of a body depends on the instrument characteristics and performance. Moreover, a data product can hold any number of observations, each of which can also contain any number of samples. For some instruments there is not even a footprint (i.e. environment measurement instruments). Therefore, a simple instrument independent way of describing a footprint is required.

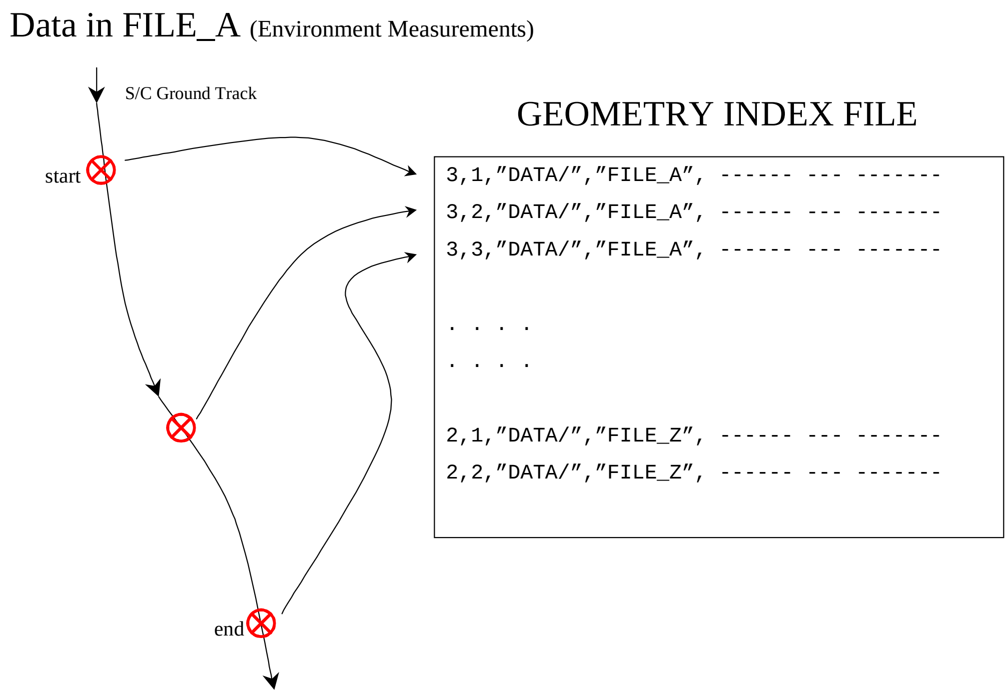
For mapping instruments, the geometry index will describe each observation using a set of “*lines*” to describe the shape of the footprint. Each line will be defined by identifying two points, one at either end. The footprint will be reconstructed by joining all the left-hand points to get the left side of the footprint and all the right-hand points to get the right side. It is important to distinguish between the footprint and its mapping in the instrument detector. When speaking about left-hand and right-hand points, these points are referring to the mapping itself and not to the footprint. For example, let’s consider a push-broom camera scanning from left to right with respect to the flying direction. The detector stores the data from pixel (0,0) to pixel (1024, 1024) and the camera starts the scanning in the top right side of the footprint, as shown in the following image. Red strips correspond to the scanned lines. Each of these scanned lines is stored in the detector as 1024 bits. In this example, the footprint is described by three “lines” (blue strips in the image). The latitude and longitude of the scanning start point corresponds to the point (0,0) in the image, and therefore to the right-hand point of the “line” 1. The latitude and longitude of the scanning end point corresponds to the point (1024,1024) in the image, and therefore to the left-hand point of “line” 3. The reconstructed footprint corresponds to the yellow dashed box in the image.



The description of the footprint will be completed by providing all of the instrument-related parameters for the “central point” (See Chapter 3.4.2 for a definition of center point) of the each line. These parameters provide the necessary information to locate the footprint in the database. The figure below provides a visual representation of the schema.



For environment measurement instruments the situation is even simpler. It is not possible to provide any lines since there is no surface mapping and the description of the observation will therefore be based on single points. Nevertheless, we will consider these single points as lines as well, since each single point will also correspond with a single record (row) in the index file. It is clear that all the parameters to be computed for the central point of a line in a mapping instrument cannot be computed in this case. However, all the rest (those related to the spacecraft, Sun, etc.) shall be given for each of the points or “lines” that describe the observation. The figure below provides a visual representation of the schema.



The teams shall use at least one line/sample per observation, which means that if a file contains two different observations, there shall appear at least two records in the Geometry Index File. The instrument team shall define themselves the number of lines/samples used for each data product. This number will determine the level of uncertainty in the description of the observation, as the succession of rectangles defined by two consecutive lines will never define exactly the projection of the instrument's field of view.

3.4.1 Sampling Frequency

The number of "*lines*" for each data product in the Geometry Index File is related with the sampling frequency. This number shall be chosen to provide a good description of the instrument's data product. The sampling frequency shall be defined by the team, which means the teams have the possibility to select the sampling frequency that better suits their instrument and their instrument's operation mode. PSA does not impose any constraint in the number of lines required to describe an observation.

The sampling frequency can be different between data products, even within the same data set. It is also possible to have different sampling resolutions within a data file. This will help to define more precisely the data product's field of view. Three different possibilities can be used for the establishment of the sampling frequency: a fix sampling frequency for the whole data set, a fix sampling frequency for each data product but variable within the data set, and finally a variable sampling frequency even within data products. PSA recommends to use this last option which describes more accurately the surface mapped (environment measured) by the instrument.

3.4.2 Center of a "line"

Each "line" used to describe the footprint of a mapping instrument is defined by identifying two points, one at either end. The center of that line is defined as the geometrical center point in latitude and longitude, as seen from the instrument. The plane defined by the instrument position and the start and end points of the line may differ from the plane defined by the center of the planet and the same two end points. Therefore, the center of the line from the instrument perspective may differ from the geometrical center as seen from the center of the planet, and may also differ from the mathematical center of a straight line connecting both end points.

This center point has a time associated corresponding to the epoch when this measurement has been acquired. There are different options for this time, depending on the instrument operation. For example, a snapshot camera will have the same time for the start, end and center points for every line of its footprint, while a frame camera using integration will have the same time for start, end and center points of a line, but different between lines. The complexity increases when trying to get this time for a push-broom camera since start, end and central times of a line are different and do not have to be equally time spaced.

3.5 Release/Revision Concept and Geometry Index File

The Release Object allows the incremental ingestion of data in the PSA. See [1] for further details.

The first delivery of data to be ingested in the PSA shall contain all the required/necessary directories and files and, therefore a geometry index file. All further deliveries shall contain also geometry index files referring to all data in the data set, and not only those data products that have been modified, updated, deleted or added to the data set. Every time a new ingestion in the PSA is accomplished a geometry index file shall be produced from the all data products contained in the data set and the result of this will be a new release or revision of the geometry index file and label. Therefore, the Geometry Index Label File shall have always the release/revision keywords assigned to the latest release/revision identifiers of the data set.

Should a data set contain two different Geometry Index Files, i.e. one for the data with the Earth as reference target and another one with Mars, and only the data related to Mars have been included/modified/removed, then only the Mars Geometry Index Files (table and label) shall be delivered along with the new data, with the corresponding update in the release/revision keywords. The Earth Geometry Index Files will remain unchanged.

In the case of implementing the Release/Revision Concept in a data set, the Geometry Index File shall contain information about the Release and Revision of each of the data products by means of the columns `RELEASE_ID` and `REVISION_ID`, and information about the last modification of the data product itself by using the `CHANGE_MODE` column (The format and meaning of these columns is explained in the chapter 4.2).

The values of the columns `RELEASE_ID` and `REVISION_ID`, and `CHANGE_MODE` shall remain unchanged until the data product described by this entry is modified. Once this happens, the new values remain as is, until a new update is applied to the data product.

3.6 The Geometry Index Format

3.6.1 Geometrical Description of a Data Set

The Geometry Index File is overall an index file, which means that it is meant to locate data files. The team shall define the sorting of the data files within the index file. There are several possibilities such as by archiving time, name, file-size, etc. PSA only imposes a constraint to sort the data files: all the information about a data file must be together. It is also recommended to include a line for begin time and another for end time of every single observation in each data file, whilst the time resolution and number of lines per observation can be variable. In the case of data files with overlapping times, the files can be sorted in whatever way the team may decide, but placing all the information referring to a file together.

There is a set of required parameters that shall be contained in the index file. This is the minimum number of columns that shall be provided in the Geometry Index File, but in case of additional geometry and/or position information, additional columns can be added to the Geometry Index File, after the last required column. PSA recommends the additional information to be added in the Geometry Index File rather than have separate files. These additional columns shall be described in the label of the Geometry Index File in the appropriate location within the INDEX_TABLE object.

3.6.2 The Geometry Index Table Format

The Geometry Index Table file is based on fixed length rows. Each of the rows will describe a footprint *line*, and therefore there could be as many lines per data product as required. The table is formatted so that it may be read directly by many data management systems: all columns are separated by commas and have the same length; character fields are enclosed in double quotation marks and each record (row) ends in a carriage return/line feed sequence.

The geometry index file shall contain the values of a complete set of parameters that will allow the user to search the data set for specific files of interest and identify the exact location and the status of the file.

These parameters can be split in several groups as follows:

1. Line Description Parameters (**LDP**)
   - Number of *lines* describing the footprint (N)
   - Number of the current *line* (I)
2. Non Geometrical Parameters (**NGP**)

   All the geometry index files shall include several parameters not related with either the geometry or the position information. These keywords shall point to and give additional information about the file that is being described by the geometry and position keywords. These parameters are:
   - Change Mode (CM)
   - Pathname (P)
   - Filename (F)
   - Product ID (PID)
   - Data Set ID (DID)
   - Release ID (RSID)
   - Revision ID (RVID)

   Please note that even if the release/revision concept is not implemented in the data set, the columns Release ID and Revision ID shall be included, giving to them the “N/A” values.
3. Position Generic Parameters (**PGP**)

   Generic parameters are those that are completely independent of any other parameters but time. The Position Generic Parameters are:

- Geometry Epoch (GE)
- Orbit Number (ON)

4. Solar Related Parameters (**SRP**)

   The solar related parameters are those that can be computed without any additional information about the spacecraft, and therefore only the time is needed. These parameters are computed always for the reference target body described in the Geometry Index Label using the REFERENCE_TARGET_NAME keyword (The definition of this keyword is in chapter 3.6.3). The Solar Related Parameters are:

   - Solar Longitude (SL)
   - Sub-Solar Latitude (SLAT)
   - Sub-Solar Longitude (SLON)

5. Spacecraft Related Parameters (**SCP**)

   The spacecraft related parameters are those that are related only with the spacecraft and the reference target body or the sun, but completely independent of the instruments, orientation, attitude and viewing directions, and, in some cases, even the data product target. Because of this, these parameters are applicable to all the instruments onboard the spacecraft. They describe the state of the spacecraft with respect to the reference target body and the sun, in terms of position and velocity. It is possible to have different targets within a data set, with the same reference target body, i.e. Mars, Phobos and Deimos would have for the same reference target: Mars. The reference target body used for these parameters shall be described using the REFERENCE_TARGET_NAME keyword in the Geometry Index Label. This keyword is used as the reference to help define a particular vector component (The definition of this keyword is in chapter 3.6.3).

   The Spacecraft Related Parameters are:

   - Spacecraft-Sun Distance (SD)
   - x/y/z components of the Spacecraft-Sun Position Vector (XSP,YSP,ZSP)
   - x/y/z components of the Spacecraft-Sun Velocity Vector (XSV,YSV,ZSV)
   - x/y/z components of the Spacecraft-Target Position Vector (XTP,YTP,ZTP)
   - x/y/z components of the Spacecraft-Target Velocity Vector (XTV,YTV,ZTV)
   - Spacecraft Altitude (SA)
   - Sub-Spacecraft Latitude (SCLAT)
   - Sub-Spacecraft Longitude (SCLON)

6. Instrument Viewing Related Parameters (**IRP**)

   The instrument viewing related parameters are those related with not only the spacecraft, but also with the target, the instrument type, mounting and alignment, and its field of view. A detailed description of each instrument is required to compute these parameters. These parameters may be not applicable for some instruments or targets but they must appear in the index file, using, in this case, the non-applicable accepted value. The Instrument Viewing Related Parameters are:

   - Target Name (T)
   - Local True Solar Time (LTST)

- Latitude of the Start Point (SPLAT)
- Longitude of the Start Point (SPLON)
- Latitude of the End Point (ELAT)
- Longitude of the End Point (ELON)
- Central Latitude (CLAT)
- Central Longitude (CLON)
- Phase Angle (PA)
- Incidence Angle (IA)
- Emission Angle (EA)
- Slant Distance (SLD)
- North Pole Azimuth Angle (NPAA)
- Sub-Spacecraft Azimuth Angle (SCAA)
- Sub-Solar Azimuth Angle (SAA)
- Horizontal Pixel Scale (H)
- Vertical Pixel Scale (V)

The format of a record line in the geometry index file is described as follows:

LDP	NGP	PGP	SRP	SCP	IRP

A detailed description of the format can be found in the following tables:

LDP		NGP							PGP		SRP		
N	I	CM	P	F	PID	DID	RSID	RVID	GE	ON	SL	SLAT	SLON

SCP															
SD	XSP	YSP	ZSP	XSV	YSV	ZSV	XTP	YTP	ZTP	XTV	YTV	ZTV	SA	SCLAT	SCLON

IRP																
T	LTST	SPLAT	SPLON	ELAT	ELON	CLAT	CLON	PA	IA	EA	SLD	NPAA	SCAA	SAA	H	V

3.6.3 The Geometry Index Label Format

The PDS object INDEX_TABLE shall be used to describe the geometry index. This object has a set of required keywords that must be included as well as the description of all the columns in the geometry index table file. Each of the columns will correspond to a parameter described in this document.

The required keywords of the INDEX_TABLE object are:

- INTERCHANGE_FORMAT: always **ASCII**
- ROWS
- COLUMNS: always **46**

- ROW_BYTES: Even though PDS recommends that ROW_BYTES be an even number, which means rows with an even number of bytes, PSA will accept Geometry Index Tables with ROW_BYTES as even or odd numbers.
- INDEX_TYPE: always **SINGLE**

A COLUMN object must be used for each column, with the following required keywords:

- NAME[1]
- DATA_TYPE[1]
- START_BYTE
- BYTES[1]
- DESCRIPTION[1]
- FORMAT (optional keyword in the PDS standard)

Those parameters that could have a non-applicable value, their values are referred to some units, or they have a maximum or minimum value, the appropriate keyword shall be used in the COLUNM object:

- UNITS[1]
- VALID_MAXIMUM[1]
- VALID_MINIMUM[1]
- NON_APPLICABLE_CONSTANT[1]

Beside all the above mentioned keywords and objects, the geometry index label file shall contain also the following general keywords:

- PDS_VERSION_ID
- LABEL_REVISION_NOTE
- RECORD_TYPE: always **FIXED_LENGTH**
- RECORD_BYTES: equal to ROW_BYTES (from INDEX_TABLE object)
- FILE_RECORDS: equal to ROWS (from INDEX_TABLE object)
- FILE_NAME
- LABEL_RECORDS
- DATA_SET_NAME
- DATA_SET_ID
- PRODUCT_ID
- REFERENCE_TARGET_NAME: The name of the target body being used as the reference to help define the spacecraft/sun related parameters. Since there is no other way to identify the target body being used as a reference within the Geometry Index File, REFERENCE_TARGET_NAME shall have a single value. In the case of several reference targets being used for a data set, several Geometry Index Files shall be provided, one for each different Reference Target used (e.g. GEO_MARS.TAB / GEO_MARS.LBL for a Reference Target of Mars, GEO_EARTH.TAB / GEO_EARTH.LBL

[1] The values of these parameters shall be picked from the geometry index file parameter's definitions (Chapter 4).

for a Reference Target of Earth etc.).

- INSTRUMENT_HOST_ID
- INSTRUMENT_ID
- START_TIME
- STOP_TIME
- SPACECRAFT_CLOCK_START_COUNT
- SPACECRAFT_CLOCK_STOP_COUNT
- PRODUCT_CREATION_TIME
- ^INDEX_TABLE: pointer to the INDEX_TABLE object.
- RELEASE_ID (if the release/revision concept is used): The RELEASE_ID shall be the same in the Geometry Index and Label file names as well as within the labels. The value of this keyword shall correspond to the latest release of the data in the data set.
- REVISION_ID (if the release/revision concept is used): The REVISION_ID shall be the same in the Geometry Index and Label file names as well as within the labels. The value of this keyword shall correspond to the latest revision of the latest release of the data in the data set.

3.7 File Naming Scheme

3.7.1 Delivery Using the Release/Revision Concept

The file-naming scheme proposed for the INDEX files to be ingested in the PSA is defined in [1]. Therefore, for the Geometry Index file, the file name shall be:

GEO_{*REFERENCE_TARGET_NAME*}.LBL

GEO_{*REFERENCE_TARGET_NAME*}.TAB

where {*REFERENCE_TARGET_NAME*} is the same as the REFERENCE_TARGET_NAME value given in the label file, (i.e. if REFERENCE_TARGET_NAME = MARS in the label file, then the geometry index files shall be named GEO_MARS.LBL and GEO_MARS.TAB)

These filenames would be the same in case of using a delivery based on a data set. When using Release/Revision concept to deliver data to the PSA, the keywords RELEASE_ID and REVISION_ID shall be contained in the GEO_{*REFERENCE_TARGET_NAME*}.LBL file with the appropriate values.

Please note that the GEO_{*REFERENCE_TARGET_NAME*}.TAB shall contain all entries in the data set referring to a given reference target body, i.e. it shall refer to every single data product included in the data set which is being described by the REFERENCE_TARGET_NAME body, and not only those delivered in the current Release and/or Revision of the data set.

3.7.2 Delivery based on a Data Set

The file-naming scheme proposed for the INDEX files to be ingested in the PSA is defined in [1]. Therefore, for the Geometry Index file, the file name shall be:

GEO_{*REFERENCE_TARGET_NAME*}.LBL

GEO_{*REFERENCE_TARGET_NAME*}.TAB

where {*REFERENCE_TARGET_NAME*} is the same as the `REFERENCE_TARGET_NAME` value given in the label file, (i.e. if `REFERENCE_TARGET_NAME = MARS` in the label file, then the geometry index files shall be named GEO_MARS.LBL and GEO_MARS.TAB)

Please note that the GEO_{*REFERENCE_TARGET_NAME*}.TAB shall contain all entries in the data set referring to a given reference target body, i.e. it shall refer to every single data product included in the data set which is being described by the `REFERENCE_TARGET_NAME` body.

4 Geometry Index File Parameters. Definitions

4.1 Line Description Parameters

Keyword	`N`			**Max. Length**	
Data Type	`ASCII_INTEGER`	**Units**	*none*	**N/A Value**	*required*
Max. Value		**Min. Value**	`1`		
Description	The `N` element gives the number of lines used to describe the current observation. This number can be different for each data product within a data set and even different between observations within the same data product.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	`I`			**Max. Length**	
Data Type	`ASCII_INTEGER`	**Units**	*none*	**N/A Value**	*required*
Max. Value		**Min. Value**	`1`		
Description	The `I` element gives the position of the current line in the complete set of lines used to describe the current observation.				
Formation Rule	*none*				
Remarks	The values of `I` go from 1 to `N`.				

4.2 Required Non-geometrical Parameters

Keyword	`CHANGE_MODE`			**Max. Length**	`1`
Data Type	`CHARACTER`	**Units**	*none*	**N/A Value**	`X`
Max. Value	*none*	**Min. Value**	*none*		
Description	The CHANGE_MODE element represents the additional information about the type of data contained in the new release/revision.				
Formation Rule	The CHANGE_MODE element has a set of accepted values: **N** for new data product, **U** for updated data product and **D** for deleted data product.				

Remarks	The CHANGE_MODE does not need to be the same in every line in a new delivery. If, for example, the RELEASE 0001 REVISION 0000 is delivered and two data products need updating, but a third is completely wrong and should be removed, then in RELEASE 0001 REVISION 0001 the updated products shall be sent to the PSA with a new index table. This index table shall contain references to all data products within the data set, but only those lines referring to the products that have changed from the previous release/revision shall change the value of this keyword, so two products will have a **U** for updated and one will have a **D** for deleted, and the rest shall have exactly the same value they had in the previous release/revision. If the CHANGE_MODE element has been set to **D,** all the information concerning the file that has been deleted shall be the same as in the previous revision of the data set. Therefore, the line in the index file shall remain the same with the only exception of the CHANGE_MODE element value and the RELEASE_ID and REVISION_ID.

Keyword	PATH_NAME				**Max. Length**	72
Data Type	CHARACTER	**Units**	*none*		**N/A Value**	*required*
Max. Value	*none*		**Min. Value**	*none*		
Description	The PATH_NAME data element identifies the full directory path – excluding the file name -- used to locate a file on a storage medium or online system. To allow the indication of the full path and file name within a descriptive label, this data element shall be used in conjunction with the FILE_NAME data element.					
Formation Rule	The PATH_NAME data element is expressed according to the UNIX convention, using forward slashes to delimit directories. While the leading slash denoting the root directory is omitted, the final slash is used. It shall be based in a concatenation of directory names. A directory name must consist of only uppercase alphanumeric characters and the underscore character (i.e. A-Z, 0-9, or "_". A directory name must not exceed 29 characters in length, to comply with the ISO 9660 level 2 media interchange standard. In the case of using the maximum number of directory levels (7 subdirectories), this maximum length shall be reduced up to 8 characters in order to comply with the maximum length of the PATH_NAME data element. For further details, please refer to [2].					
Remarks	The PATH_NAME data element may consist up to eight directory levels and it is a relative path.					

Keyword	FILE_NAME				**Max. Length**	31
Data Type	CHARACTER	**Units**	none		**N/A Value**	*required*
Max. Value	*none*		**Min. Value**	*none*		
Description	The FILE_NAME element provides the location independent name of a file. It excludes node or volume location, directory path names, and version specification.					
Formation Rule	The FILE_NAME shall be limited to 27-character base name, plus a dot (".") and 3-character extension, following the so called the "27.3" convention. The FILE_NAME must consist of only uppercase alphanumeric characters and the underscore character (i.e. A-Z, 0-9, or "_"), to comply with the ISO 9660 level 2 media interchange standard. For further details, please refer to [2].					
Remarks	*none*					

Keyword	PRODUCT_ID	**Max. Length**	40

Data Type	CHARACTER	**Units**	*none*	**N/A Value**	*required*
Max. Value	*None*	**Min. Value**	*none*		
Description	The PRODUCT_ID data element represents a permanent, unique identifier assigned to a data product by its producer.				
Formation Rule	*none*				
Remarks	In the PDS, the value assigned to PRODUCT_ID must be unique within its data set.				

Keyword	DATA_SET_ID			**Max. Length**	40
Data Type	CHARACTER	**Units**	*none*	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*none*		
Description	The DATA_SET_ID element is a unique alphanumeric identifier for a data set or a data product. The DATA_SET_ID value for a given data set or product is constructed according to flight project naming conventions. In most cases the DATA_SET_ID is an abbreviation of the DATA_SET_NAME.				
Formation Rule	The values for DATA_SET_ID are constructed according to standards outlined in the Standards Reference (Ref. [2]).				
Remarks	*none*				

Keyword	RELEASE_ID			**Max. Length**	4
Data Type	ASCII_INTEGER	**Units**	*none*	**N/A Value**	-1
Max. Value	9999	**Min. Value**	0001		
Description	The RELEASE_ID indicates the release number of the data described by the entries in the geometry index table.				
Formation Rule	*none*				
Remarks	RELEASE_ID is required for every file in every line because there could easily be a situation where, in revision of a new release, just a few data products are updated, deleted or new. In this case, only those lines in the Geometry Index Files that are relevant to those products will have a different Release or Revision ID in the final Geometry Index Table. This way, the end user has a way of tracking the changes that have been made in the data set.				

Keyword	REVISION_ID			**Max. Length**	4
Data Type	ASCII_INTEGER	**Units**	*none*	**N/A Value**	-1
Max. Value	9999	**Min. Value**	0000		
Description	The REVISION_ID indicates the revision number for the release indicated in the RELEASE_ID.				
Formation Rule	*none*				
Remarks	REVISION_ID is required for every file in every line because there could easily be a situation where, in revision of a new release, just a few data products are updated, deleted or new. In this case, only those lines in the Geometry Index Files that are relevant to those products will have a different Release or Revision ID in the final Geometry Index Table. This way, the end user has a way of tracking the changes that have been made in the data set.				

4.3 Position Generic Parameters

Keyword	GEOMETRY_EPOCH			**Max. Length**	24
Data Type	TIME	**Units**	seconds	**N/A Value**	*required*

Max. Value	*none*	**Min. Value**	*none*
Description	The GEOMETRY_EPOCH element is the time when the geometrical and position parameters are computed. The GEOMETRY_EPOCH is the time associated with the central point of an observation's sample (See Chapter 3.4.2 for further details).		
Formation Rule	*YYYY-MM-DD*T*hh:mm:ss.sss*		
Remarks	The GEOMETRY_EPOCH shall be expressed in UTC.		

Keyword	ORBIT_NUMBER			**Max. Length**	5
Data Type	ASCII_INTEGER	**Units**	*none*	**N/A Value**	-999
Max. Value	99999	**Min. Value**	1		
Description	The ORBIT_NUMBER element is the number of the orbit around the target body.				
Formation Rule	*none*				
Remarks	The ORBIT_NUMBER shall be obtained for the given GEOMETRY_EPOCH.				

4.4 Solar related Parameters

Keyword	SOLAR_LONGITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	*required*
Max. Value	359.999	**Min. Value**	0.000		
Description	The SOLAR_LONGITUDE element provides the value of the angle between the body-Sun line at the time of interest and the body-Sun line at the vernal equinox. This provides a measure of season on a target body, with values of 0 to 90 degrees representing northern spring, 90 to 180 degrees representing northern summer, 180 to 270 degrees representing northern autumn and 270 to 360 degrees representing northern winter.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	SUB_SOLAR_LATITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	*required*
Max. Value	90.000	**Min. Value**	-90.000		
Description	The SUB_SOLAR_LATITUDE element provides the latitude of the sub-solar point. The sub-solar point is that point on a body's reference surface where a line from the body center to the sun center intersects the surface.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	SUB_SOLAR_LONGITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	*required*
Max. Value	359.000	**Min. Value**	0.000		
Description	The SUB_SOLAR_ LONGITUDE element provides the latitude of the sub-solar point. The sub-solar point is that point on a body's reference surface where a line from the body center to the sun center intersects the surface.				
Formation Rule	*none*				
Remarks	Longitude increases towards the East.				

4.5 Spacecraft related Parameters

Keyword	SC_SUN_DISTANCE			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**			
Description	The SC_SUN_DISTANCE element provides the distance from the spacecraft to the center of the sun.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	X_SC_SUN_POSITION_VECTOR			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*Required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The X_SC_SUN_POSITION _VECTOR element indicates the x component of the position vector from the spacecraft to the sun, center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	Y_SC_SUN_POSITION_VECTOR			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*Required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The Y_SC_SUN_POSITION _VECTOR element indicates the y component of the position vector from the spacecraft to the sun, center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	Z_SC_SUN_POSITION_VECTOR			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*Required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The Z_SC_SUN_POSITION _VECTOR element indicates the z component of the position vector from the spacecraft to the sun, center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	X_SC_SUN_VELOCITY_VECTOR			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	KM/S	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The X_SC_SUN_VELOCITY_VECTOR element indicates the x component of the velocity vector form the spacecraft to the Sun, center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	Y_SC_SUN_VELOCITY_VECTOR			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	KM/S	**N/A Value**	*required*

Max. Value	*none*	**Min. Value**	*None*
Description	The Y_SC_SUN_VELOCITY_VECTOR element indicates the y component of the velocity vector form the spacecraft to the Sun, center expressed in J2000 reference frame, and corrected for light time and stellar aberration.		
Formation Rule	*None*		
Remarks	*None*		

Keyword	Z_SC_SUN_VELOCITY_VECTOR			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	KM/S	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The Z_SC_SUN_VELOCITY_VECTOR element indicates the z component of the velocity vector form the spacecraft to the Sun, center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	X_SC_TARGET_POSITION_VECTOR			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*Required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The X_SC_TARGET_POSITION_VECTOR element indicates the x component of the position vector from the spacecraft to the target center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	Y_SC_TARGET_POSITION_VECTOR			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*Required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The Y_SC_TARGET_POSITION_VECTOR element indicates the y component of the position vector from the spacecraft to the target center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*None*				
Remarks	*None*				

Keyword	Z_SC_TARGET_POSITION_VECTOR			**Max. Length**	14
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*None*		
Description	The Z_SC_TARGET_POSITION_VECTOR element indicates the z component of the position vector from the spacecraft to the target center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	X_SC_TARGET_VELOCITY_VECTOR			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	KM/S	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*none*		
Description	The X_SC_TARGET_VELOCITY_VECTOR element indicates the x component of the velocity vector from the spacecraft to the target center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				

Formation Rule	*None*
Remarks	*None*

Keyword	Y_SC_TARGET_VELOCITY_VECTOR			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	KM/S	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*none*		
Description	The Y_SC_TARGET_VELOCITY_VECTOR element indicates the y component of the velocity vector from the spacecraft to the target center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	Z_SC_TARGET_VELOCITY_VECTOR			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	KM/S	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	*none*		
Description	The Z_SC_TARGET_VELOCITY_VECTOR element indicates the z component of the velocity vector from the spacecraft to the target center expressed in J2000 reference frame, and corrected for light time and stellar aberration.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	SPACECRAFT_ALTITUDE			**Max. Length**	
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	*required*
Max. Value	*none*	**Min. Value**	0.000		
Description	The SPACECRAFT_ALTITUDE element provides the distance from the spacecraft to a reference surface of the target body measured normal to the surface.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	SUB_SPACECRAFT_LATITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	90.000	**Min. Value**	-90.000		
Description	The SUB_SPACECRAFT_LATITUDE element provides the latitude of the sub-spacecraft point that is the point on a body that lies directly beneath the spacecraft.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	SUB_SPACECRAFT_LONGITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	359.999	**Min. Value**	0.000		
Description	The SUB_SPACECRAFT_LONGITUDE element provides the longitude of the sub-spacecraft point that is the point on a body that lies directly beneath the spacecraft.				
Formation Rule	*none*				
Remarks	Longitude increases towards the East.				

4.6 Instrument Viewing related Parameters

Keyword	TARGET_NAME			**Max. Length**	120
Data Type	CHARACTER	**Units**	*none*	**N/A Value**	required
Max. Value	*none*		**Min. Value**	*none*	
Description	The TARGET_NAME element provides the name of an observed target. The Target might be a planet, satellite, ring, region, feature, asteroid, comet, etc.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	LOCAL_TRUE_SOLAR_TIME			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	359.999		**Min. Value**	0.000	
Description	The LOCAL_TRUE_SOLAR_TIME element provides a measure of the instantaneous apparent sun position at the center of the observation. The LOCAL_TRUE_SOLAR_TIME is the angle between the extension of the vector from the Sun to the target body center and vector from the target body's planetocentric center to the spacecraft projected on the target body's ecliptic plan. This angle is measured in a counterclockwise direction when viewed from north of the ecliptic plane.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	START_POINT_LATITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	90.000		**Min. Value**	-90.000	
Description	The START_POINT_LATITUDE element provides the latitude of the left-hand corner point of the current “line” in the instrument detector.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	START_POINT_LONGITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	359.999		**Min. Value**	0.000	
Description	The START_POINT_LONGITUDE element provides the longitude of the left-hand corner point of the current “line” in the instrument detector.				
Formation Rule	*none*				
Remarks	Longitude increases towards the East.				

Keyword	END_POINT_LATITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	90.000		**Min. Value**	-90.000	
Description	The END_POINT_LATITUDE element provides the latitude of the right-hand corner point of the current “line” in the instrument detector.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	END_POINT_LONGITUDE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999

Max. Value	359.999	**Min. Value**	0.000
Description	The END_POINT_LONGITUDE element provides the longitude of the right-hand corner point of the current "line" in the instrument detector.		
Formation Rule	*none*		
Remarks	Longitude increases towards the East.		

Keyword	CENTER_LATITUDE			**Max. Length**	9
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.99999
Max. Value	90.00000	**Min. Value**	-90.00000		
Description	The CENTER_LATITUDE element provides the reference latitude for the observation. This is the latitude that corresponds with the central point of the observation, as seen from the instrument on the spacecraft.				
Formation Rule	*none*				
Remarks	The plane defined by the instrument position and the start and end points of the line may differ from the plane defined by the center of the planet and the same two end points. Therefore, the center of the line from the instrument perspective may differ from the geometrical center as seen from the center of the planet, and may also differ from the mathematical center of a straight line connecting both end points.				

Keyword	CENTER_LONGITUDE			**Max. Length**	9
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.99999
Max. Value	359.99999	**Min. Value**	0.00000		
Description	The CENTER_LONGITUDE element provides the reference longitude for the observation. This is the longitude of the central point of the observation, as seen from the instrument on the spacecraft.				
Formation Rule	*none*				
Remarks	Longitude increases towards the East. The plane defined by the instrument position and the start and end points of the line may differ from the plane defined by the center of the planet and the same two end points. Therefore, the center of the line from the instrument perspective may differ from the geometrical center as seen from the center of the planet, and may also differ from the mathematical center of a straight line connecting both end points.				

Keyword	PHASE_ANGLE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	180.000	**Min. Value**	0.000		
Description	The PHASE_ANGLE element provides a measure of the relationship between the instrument viewing position and incident illumination (such as solar light). Phase angle is measured at the target; it is the angle between a vector to the illumination source and a vector to the instrument.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	INCIDENCE_ANGLE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	90.000	**Min. Value**	0.000		

Description	The INCIDENCE_ANGLE element provides a measure of the lighting condition at the intercept point. Incidence angle is the angle between the local vertical at the intercept point (surface) and a vector from the intercept point to the sun. The incidence angle varies from 0 degrees when the intercept point coincides with the sub-solar point to 90 degrees when the intercept point is at the terminator (i.e., in the shadowed or dark portion of the target body).
Formation Rule	*none*
Remarks	*none*

Keyword	EMISSION_ANGLE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	90.000	**Min. Value**	0.000		
Description	The EMISSION_ANGLE element provides the value of the angle between the surface normal vector at the intercept point and a vector from the intercept point to the spacecraft. This angle varies from 0 degrees when the spacecraft is viewing the sub-spacecraft point (nadir viewing) to 90 degrees when the intercept is tangent to the surface of the target body.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	SLANT_DISTANCE			**Max. Length**	
Data Type	ASCII_REAL	**Units**	KM	**N/A Value**	-999.999
Max. Value	*none*	**Min. Value**	0.000		
Description	The SLANT_DISTANCE element provides a measure of the distance from the spacecraft to the center of the observation on the target.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	NORTH_POLE_AZIMUTH_ANGLE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	359.999	**Min. Value**	0.000		
Description	The NORTH_POLE_AZIMUTH_ANGLE element provides the value of the angle between a line from the image center to the north pole and a reference line in the image plane. The reference line is a horizontal line from the image center to the middle right edge of the image. This angle increases in a clockwise direction.				
Formation Rule	*none*				
Remarks	The NORTH_POLE_AZIMUTH_ANGLE is defined as the angle between a vector from the “line center” to the north pole, and a vector from the “line center” to the right-hand end point of the line.				

Keyword	SUB_SC_AZIMUTH_ANGLE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	359.999	**Min. Value**	0.000		
Description	The SUB_SC_AZIMUTH_ANGLE element provides the value of the angle between the line from the center of an image to the sub-spacecraft point and a horizontal reference line (in the image plane) extending from the image center to the middle right edge of the image. The values of this angle increase in a clockwise direction.				
Formation Rule	*none*				

Remarks	The SUB_SC_AZIMUTH_ANGLE is defined as the angle between a vector from the "line center" to the sub-spacecraft point, and a vector from the "line center" to the right-hand end point of the line.

Keyword	SUB_SOLAR_AZIMUTH_ANGLE			**Max. Length**	7
Data Type	ASCII_REAL	**Units**	DEGREES	**N/A Value**	999.999
Max. Value	359.999	**Min. Value**	0.000		
Description	The SUB_SOLAR_AZIMUTH_ANGLE element provides the value of the angle between the line from the center of an image to the sub-solar point and a horizontal reference line (in the image plane) extending from the image center to the middle right edge of the image. The values of this angle increase in a clockwise direction.				
Formation Rule	*None*				
Remarks	The SUB_SOLAR_AZIMUTH_ANGLE is defined as the angle between a vector from the "line center" to the sub-solar point, and a vector from the "line center" to the right-hand end point of the line.				

Keyword	HORIZONTAL_PIXEL_SCALE			**Max. Length**	
Data Type	ASCII_REAL	**Units**	METER	**N/A Value**	-999.999
Max. Value	*none*	**Min. Value**	0.000		
Description	The HORIZONTAL_PIXEL_SCALE provides the number of meters per horizontal resolution unit at the center of the observation.				
Formation Rule	*none*				
Remarks	*none*				

Keyword	VERTICAL_PIXEL_SCALE			**Max. Length**	
Data Type	ASCII_REAL	**Units**	METER	**N/A Value**	-999.999
Max. Value	*none*	**Min. Value**	0.000		
Description	The VERTICAL_PIXEL_SCALE provides the number of meters per horizontal resolution unit at the center of the observation.				
Formation Rule	*none*				
Remarks	*none*				