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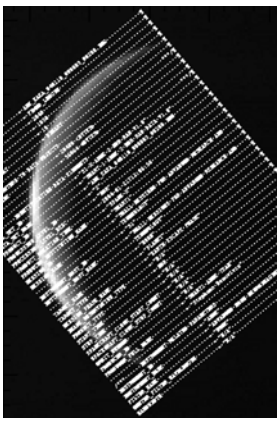
SMART-1

AMIE

*A*dvanced *M*oon micro-*I*mager *E*xperiment



Document Title: **AMIE to Planetary Science Archive Interface Control Document (EAICD)**
Document Number: **S1-AMIE-RSSD-IF-001**
Issue: **1 g**
Date: **31 Jul 2008**

	Function	Name	Date	Signature
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IAS	Langevin	x	Helsinki Obs.	Muinonen	x

Change Log

Date	Sections Changed	Reasons for Change
25 Sep 2003	Added description of tbds Did some formatting to increase readability Updated Figure 1, filter names now show in drawing Expand description in 5.3.1.9.1 – 3., description of SC_EFRF_VECTOR… Section 4.4.3.4, index directory: geo index file expected from PSA team Added description of master index file.	
21 Oct 2003	All	Minor changes recommended by PSA team
11 Dec 2003	Editorials, added directory structure in section 4.4.3, changed browse image from 16 bit to 8 bit, …	
30 Mar 2004	All	Updates and minor corrections
06 Apr 2004	All	More updates and corrections
06 May 2004	Appendix G – page 43	Minor error correction
09 May 2007	Updated text in Section 5.3.1.9, description of SC_EFRF_VECTOR…	
	Update the description of DATA_QUALITY_ID and .._DESC to make it inline with the real label	Updated according to Minutes of the AMIE PDS Label clarification meeting, S1-AMI-RSSD-MN-002/1-, 18 Jan 2007, AI 71
	Update the Section 4.1.3, directory names, to what is actually in use	
30 May 2007	Update some editorials Add a section on “Caveats”	

	Plenty of editorials in section 4, mostly changing the wording from future tense to past tense.	
31 May/03 Jun 2007: Updated according to Minutes of the AMIE PDS Label clarification meeting, S1-AMI-RSSD-MN-002/1-, 18 Jan 2007, see detailed comments in the following.		
p. 17	Change directory name MOON to LUNAR_PHASE	
	Updated the sample label according to the minutes	AI 1 - 26
Label example	Updated ^IMAGE to `36865 and LSB_... to MSB...`. This was wrong in the old label and caused the vertical lines when calling AMIE_COMBINE	See S1-AMI-RSSD-RP-007
p. 15	Updated the table describing AMIE routines, mainly reducing it to the four currently available routines.	AI 28
p. 16	Updated the data set naming convention, letter X to 'L_X' and replaced text 'multiple targets' with 'no specific targets'	AI 29
p. 16	Changed MOON to LUNAR_PHASE	AI 30
	Updated the file naming convention, AMIE_MAE1_etc. was replaced with AMIE_LE1_etc. *i.e.* the mission phase was reduced to one letter only	AI 31
p. 18	Updated Figure 5 with directory structure	AI 32
p. 21	Delete Fig 6 in section 5.1. Added some text to explain the directory structure of 'data'	AI 33
p. 21	Deleted the reference to LABEL_REVISION_NOTE in Section 5.3.1.1. This is only used in the Catalog file.	AI 34
p. 22	Updated the mission phase in the file name to M (rather than MP)	AI 35
p. 24	Release_ID – changed text to say "There will be one release of the complete dataset with a RELEASE_ID = 0001."	AI 36
p. 24	In DATA_SET_ID, updated 'X' to 'L/X'	AI 37
p. 25	Section 5.3.1.4, updated label as in appendix	
p. 25	Updated ^IMAGE to 36865 <BYTES>	See S1-AMI-RSSD-RP-007
p. 25	Delete the underscore in GROUND CALIBRATION, RAW DATA and CAL DATA	AI 38/39/40
p. 25	To PRODUCT_ID, added "… without extension"	AI 42
p. 25	Still open	AI 43
p. 26	Section TARGET_NAME – change the description, it will come from a list now	AI 44
p. 26	Section TARGET_TYPE – as previous	AI 45

p. 27	Section MISSION_PHASE_NAME, updated according to email from D. Heather, 02 Jan 2006, 15h37m	AI 46
p. 27	IMAGE_OBSERVATION_TYPE – delete 'underscore' in OFF TRACK	AI 47
p. 27	ORBIT_NUMBER – make it four digits	AI 48
p. 28	PRODUCER_ID – delete the tbd.	AI 49
p. 28	PRODUCER_FULL_NAME will always be Stephane Beauvivre.	AI 50
p. 29	FOCAL_PLANE_TEMPERATURE – refer to the section "Culprits and things to know" describing how the value for this keyword is generated.	AI 51
p. 30	Updated the DATA_QUALITY_ID with a text proposed by Virgile, email from him on 04 Jun 2007, 16h13m.	AI 52
p. 31	Deleted reference to pitch, roll, and yaw in section SC_ATTITUDE_VECTOR_AMIE	AI 71
p. 32	Inserted the word "image" after "browse"	AI 53
p. 32	Deleted the values (0..360) for the rate in SC_ROT_RATE_VECTOR	AI 56
21-31 July 2008	All	Final updates for PSA release

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1 Introduction

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is twofold. First it provides users of the AMIE instrument with a detailed description of the product and a description of how it was generated, including data sources and destinations. As such, it is also a requirements document to the software of the Ground Support Equipment, which has to generate the data files in the format described herein. Secondly, it is the official interface the AMIE instrument team and the Smart-1 archiving authority, the Planetary Science Archive (PSA).

1.2 Contents

This document describes the data flow of the AMIE instrument on Smart-1 from the s/c until insertion into the Planetary Science Data Archive (PSA). It includes information on how data was processed, formatted, labelled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained. Software that may be used to access the product is explained.

The design of the data set structure and the data product is given. Examples of these are given in the appendix.

An important point for data users is the Section 'Caveats and things to know' which explain a few points which are important when looking at the data. Don't overlook it!

1.3 Intended Readership

The staff of archiving authority (Planetary Science Archive for ESA), the design team and any potential user of the AMIE data.

1.4 Applicable Documents

	Name	Reference
AD1	Planetary Data System Preparation Workbook Part 1	JPL-D-7669/3.1, 01 Feb 1995
AD2	Planetary Data System Standards Reference	JPL-D-7669/3.5, 30 Oct 2002
AD3	Smart-1 Archive Generation, Validation and Transfer Plan	

1.5 Reference documents

	Name	Reference
RD 1	Calibration report for the AMIE PFM	SOP-RSSD-RP-001/1a, 20 Feb 2003
RD 2	Buie IDL Library	http://www.lowell.edu/users/buie/idl/idl.html
RD 3	GSFC IDL Library "astrolib"	http://www.gsfc.nasa.gov/
RD 4	GSE software description	This Dataset document directory. UNPACKING.TXT
RD 5	The Calibration of AMIE images	This Dataset document directory. CALIBRATION. PDF
RD 6	AMIE Detector orientation in spacecraft coordinates	This Dataset document directory. DETECTOR_ORIENTATION.DOC
RD 7	AMIE Target List	This Dataset Extras directory. TARGET_LIST.TXT
RD 8	Clementine offset report	This Dataset document directory. CLEMENTINE_OFFSET.TXT

RD 9	Cruise logbook	This Dataset document directory. CRUISE_LOGBOOK.DOC
RD 10	AMIE SPICE Kernel test report	This Dataset document directory. KERNEL_TEST.DOC
RD 11	Pointing Analysis report	This dataset document directory. KERNEL_TEST.PDF
RD 12	Science objectives and first results from the SMART-1/AMIE multicolour micro-camera	Advances in Space Research 37, 2006, pag 14-20, and this dataset document directory SCIENCE_OBJECTIVES.PDF
RD 13	Spectral response report	This Dataset document directory. SPECTRAL_RESPONSE.PDF
RD 14	Estimation of focal plane temperature report	This Dataset document directory. TEMPERATURE.PDF
RD 15	SMART-1 time correlation	This Dataset document directory. TIME_CORRELATION.PDF
RD 16	AMIE user manual	This Dataset document directory. USER_MANUAL.PDF
RD 17	"Phase names and orbit numbers for Smart-1 archiving"	This dataset Mission Catalog. MISSION.CAT

1.6 Relationships to other interfaces

Changes in this EAICD would affect:

- The software module in the GSE software which writes the image data into PDS-labelled files. This software was written by the AMIE test engineer at CSEM. The document describing the software is RD4.
- The software written especially for AMIE by Miguel Almeida.

1.7 Acronyms and abbreviations

AMIE	Advanced Moon Imaging Experiment
CCD	Charge-Coupled Device
Co-I	Co-Investigator
CTE	Charge Transfer Efficiency
DN	Digital Number (a value from 0 to 1023 (= 2^{10} – 1) for AMIE) – occasionally, the abbreviation DU (Digital Unit) is used. It is exactly the same.
DU	Digital Unit
EFRF	Earth-fixed reference frame (a coordinate system)
EM	Engineering Model
ESA	European Space Agency
FM	Flight Model
FoV	Field of View
GSE	Ground Support Equipment
IDL	Interactive Data Language (a computer language)
PDS	Planetary Data System (a standard to archive data)
PFM	Proto-Flight Model
PSA	Planetary Science data Archive
RSSD	Research and Scientific Support Department

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2 Caveats and things to know

This section reports a few points which are important for the data user. If you plan to use the AMIE data or if you look at the data and want to judge its quality, read this section first. If you need an understanding of AMIE first, skip to Section 3.

2.1 Filter images and number of images files

The AMIE data is stored as one file per filter. Since AMIE has eight different filter regions fixed on the sensor, whenever the complete sensor is read out, 8 separate files are generated. The NONE filter area does not contain any filter, whereas the rest of the sensor is covered with band-pass filters.

Thus, it is normally not possible to select an exposure time where the complete sensor is exposed correctly. Whenever the exposure time was set such that the NONE filter area is exposed correctly, the filtered areas will be underexposed. Whenever the exposure time was selected to properly expose the filter areas, the NONE filter should be expected to be overexposed.

In principle it would have been possible to only read out the filter areas which were of interested in a selected exposure. However, since it turned out that the data volume was not really restricted, normally the complete sensor was read out. This means, that normally all 8 files for each filter area are available. However, normally only *either* the NONE filter area *or* the filtered areas will be exposed correctly. I.e. when judging the quality of the images, don't just count the number of correctly exposed images!

The DATA_QUALITY_ID indicates the percentage of saturated pixels in an image.

2.2 Temperature of AMIE images

See RD 14.

3 Description of AMIE

The AMIE Imaging System is composed of 2 units: the AMIE Micro-Imager or Unit 1 (OPTH) and the AMIE Electronics or Unit 2 (RMEL). The Unit 1 is placed on the –X panel of the S/C on the external side and the Unit 2 is on the same panel but on the internal side. The main functions of the system are:

- To take images with spectral information.

- To keep image data in a memory buffer.
- To achieve images processing (data compression, sub-image extraction).
- To allow the downloading of the images by the On Board Computer (OBC).

The AMIE Imaging System has three electrical interfaces. The functions of these interfaces are described below and shown in Figure 1:

- The serial and power interface connects the two units together. It is composed of one cable
- supporting the serial full duplex digital link at 10 Mbit/s and the power supply from the Unit 2 to the Unit 1.
- The CAN Bus interface handles the data between the On Board Computer and the AMIE Imaging System.
- The Power Bus Interface is used to power the AMIE Imaging System with a Regulated 50 VDC.

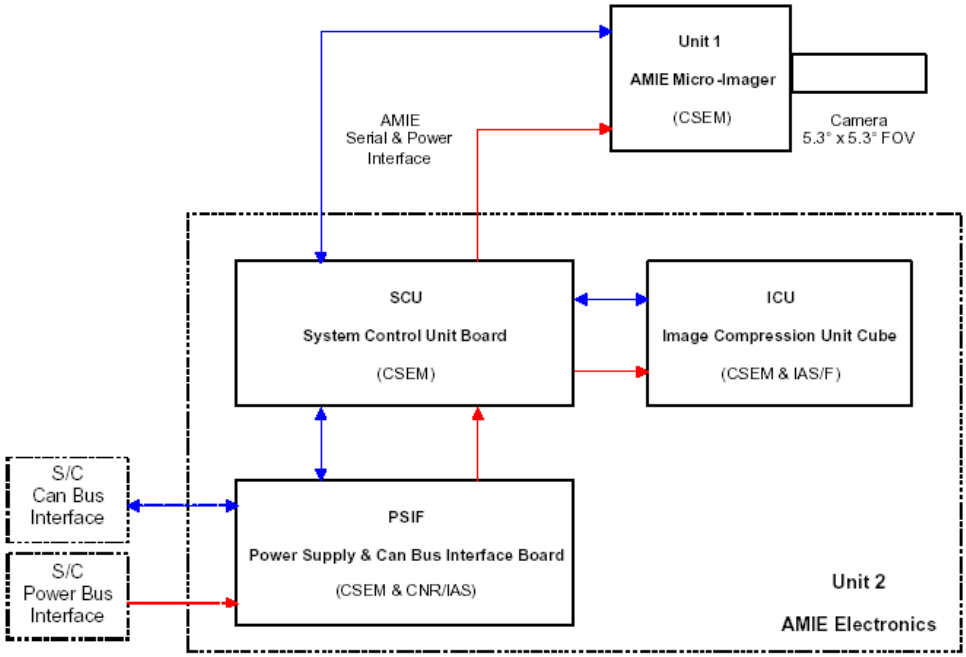

Figure 1: Main hardware functions of AMIE.

AMIE Unit 1 is a micro-camera equipped with a tele-objective, as shown in Figure 2. It comprises a micro-camera head with an opto-mechanical interface to attach the objective. The micro-camera head is radiation-protected by a 4 mm thick anodised black aluminium shielding all around it with a 7 mm top cover (for the side facing the S/C, the thickness is reduced to 1 mm). It is screwed directly to the aluminium holding bracket and has neither mechanical nor electrical interaction with the camera.

Figure 2: Photograph of the AMIE camera head (Unit 1).

A set of filters is fixed-mounted in front of the CCD; their specifications are given in Figure 4. The orientation of the filter within the camera head is given in Figure 3. A detailed description on how to convert the s/c coordinate system to the AMIE detector coordinate system is given in RD 6.

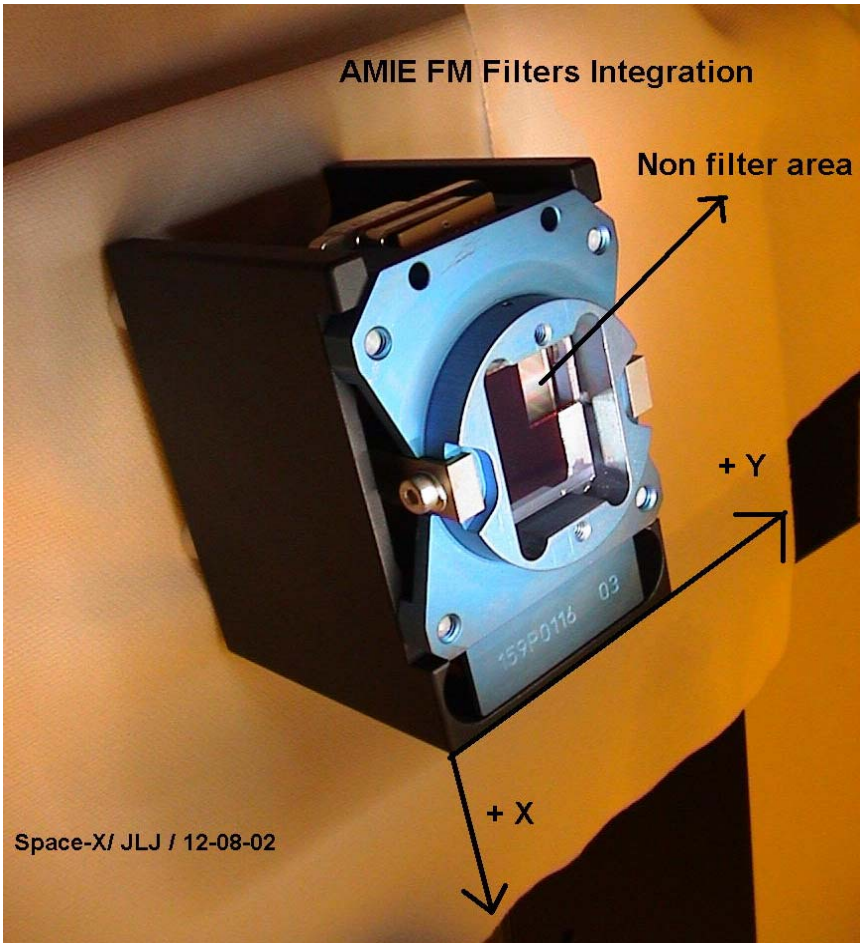

Figure 3: Photograph of AMIE sensor head without optics.

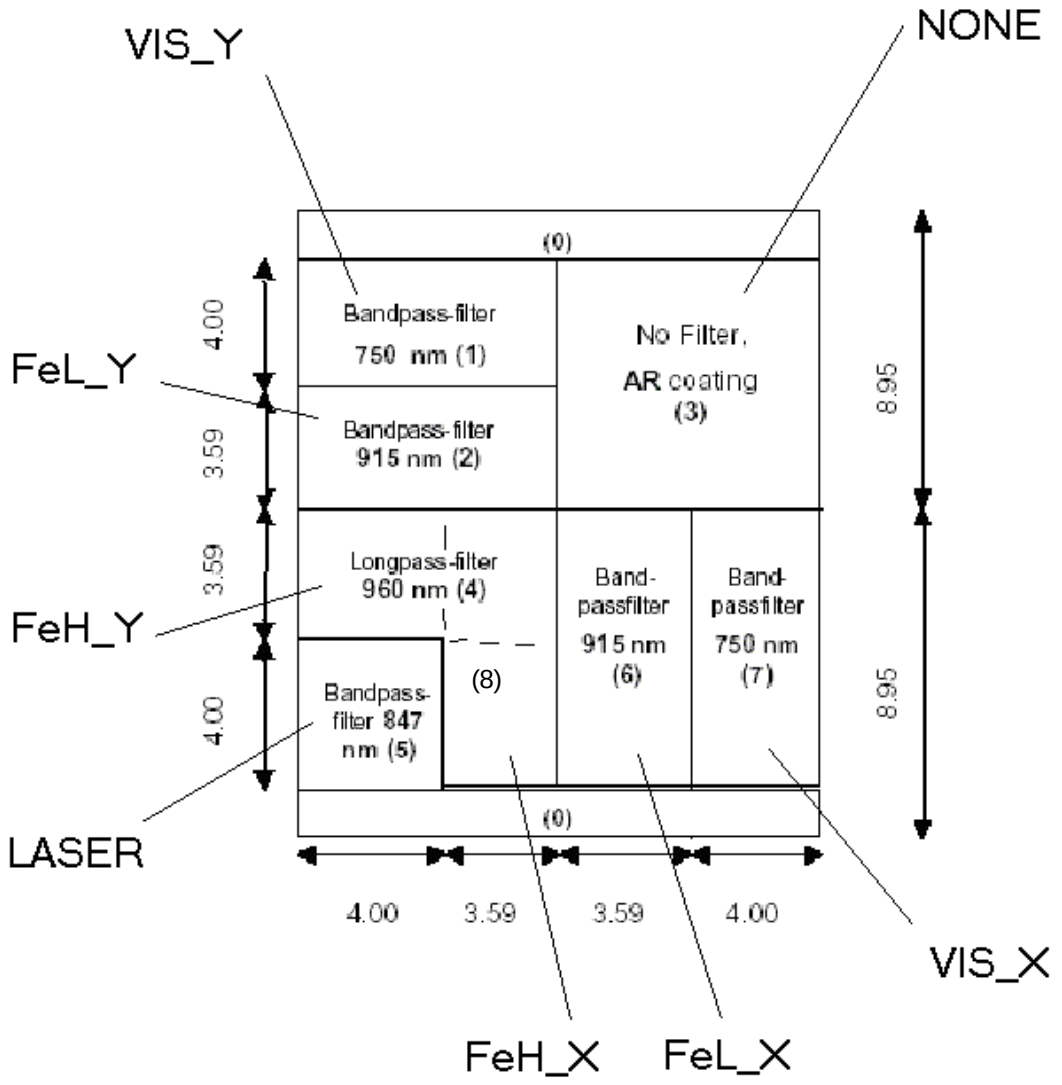

Figure 4: Filter layout in front of the detector. '0' denotes that the filter area is outside the detector. The following filter names are used: '1' = VIS_Y, '2' = FeL_Y, '3' = NONE, '4' = FeH_Y' (horizontal area) and FeH_X (vertical area), '5' = LASER, '6' = FeL_X, '7' =VIS_X.

The camera can in theory be commanded in two different ways.

(a) No compression – windows can be commanded by passing the x/y coordinates of the lower left corner and the x/y coordinates of the upper right corner to the camera. Only the window will be read out.

(b) With compression – a bit mask can be set to flag a 4 x 4 matrix overlaying the detector with 0 or 1. Those parts of the complete detector flagged with 1 will be compressed and downlinked, those with '0' will not. Note that in theory it is possible to downlink *e.g.* the upper left 1/16th of the detector and the lower right 1/16th of the detector at the same time.

The AMIE team has decided to reduce these theoretically possible windowing methods to those that are scientifically useful. These are:

(a) Read out the complete detector (INSTRUMENT_MODE_ID = ALL)

(b) Read out only one filter area (*e.g.* INSTRUMENT_MODE_ID = LASER)

(c) Read out certain restricted combinations of filters. Currently, the following two are defined:

   a. COLOR_X: A combination of VIS_X, FeL_X, and FeH_X;

   b. COLOR_Y: A combination of VIS_Y, FeL_Y, and FeH_Y.

Telecommand sequences have been defined to command only these modes. The commanded mode will be stored in the label keyword 'INSTRUMENT_MODE_ID'.

4 Overview of Process and Product Generation

On ground, the data coming from the camera is read out with the Ground Support Equipment, consisting of an interface box, a laptop or other PC running the Windows operating system, and a software written by Microcameras to control the camera and read out the data. Images can be stored in a binary format without header (called *.mmi) or in a format that attempts to be compatible to PDS. The responsible person for the GSE software is the AMIE test engineer.

The main part of the optical calibration was performed at ESA/ESTEC, in the laboratories of TOS/OMM (now TEC). The optical calibration was done under the responsibility of the calibration Co-I Detlef Koschny, in collaboration with TOS optical engineers and the Technical Co-I. The data analysis was done by Miguel Almeida and D. Koschny.

Additional data was taken during the environmental test campaigns at ESTEC by the test engineer.

Characterisation of the filters and analysis of the calibration data with respect to the filter homogeneity is performed at TOS/OMM under the responsibility of Z. Sodnik.

In flight, the data was distributed by ESOC to the GSE either in the Smart-1 PISA at ESOC or, later in the mission, to the GSE at Microcameras, (former SPACE-X), Neuchatel. There, the data has been made available to the Co-Is on an ftp server secured by a password.

A 'calibration pipeline' was set up using the IDL routines developed at ESA/RSSD and made available via a web interface (RD5). This pipeline will perform standard calibration, *e.g.* read the temperature from the PDS header and subtract the proper dark current matrix from the image and perform flat fielding.

The data was retrieved from the DDS at ESOC using a GSE computer and software physically located at Microcameras. It produced Level 2 data and write it to disk. The calibration pipeline setup by ESA/RSSD is installed on the same computer at Neuchatel to generate Level 3 data, *i.e.* corrected for dark current and flat fielded. However, the pipeline was not run during the mission (as initially intended), but is used only off-line to process the data in one batch.

Both the Level 2 and the Level 3 data will be available to the science Co-Is via an ftp server at Space-X. After the proprietary period, it will be given to the Planetary Science Data Archive (PSA) group at ESA for ingestion into the PSA.

4.1 Pre-Flight Data products

AMIE plans to deliver the calibration data, as described in Section 4.3.

4.2 Sub-System Tests

No subsystem tests were performed.

4.3 Instrument Calibrations

A number of calibrations have been performed so far, a description can be found in RD1.

4.4 Other Files written during Calibration

No 'other files' are available.

4.5 In-Flight Data Products

The data products all are images. A full image corresponds to reading out the complete detector (1024 pixel x 1024 pixel). The detector is covered by a number of fixed filters. It is also possible to only download images from one filter area only or from a combination of filters. Each individual PDS file will contain only one filter, *i.e.* when a complete image was read out, 8 files were generated. Even in the few occasions where only a part of the image was read out, eight files (partly containing dummy values) have been created.

4.6 Software

ESA/RSSD has prepared IDL routines to read and calibrate the AMIE images. The routines are based on the PDS routines as provided on the PDS web site for scientists: http://pdssbn.astro.umd.edu/nodehtml/software.shtml#IDL. The IDL routines are distributed in the DOCUMENT/IDL directory of the PSA data product. They can also be found at the RSSD AMIE LIvelink server at http://www.rssd.esa.int/livelink (go to Smart-1/Payload/AMIE/Software).

For image analysis we are using routines based on IDL libraries from GSFC and M. Buie, see RD2, RD3.

The IDL software available enables to:

- read and search AMIE images,
- Image calibration processing.

Most of them work together in the calibration pipeline, but they can be used separately. The Table 1 and Table 3 describe the existent software.

Table 1 - IDL software available for AMIE images produced by RSSD

READ_AMIE.PRO	The basic reading routine for AMIE images. Calls READPDS but adds handling old data files and shifting the bits properly. For a more detailed description, see the file header.
READ_AMIEW.PRO	A wrapper to interactively use READ_AMIE
AMIE_COMBINE.PRO	Allows to select one AMIE filter file, finds the files which were taken with the same exposure (if any) and combines them to one large image
AMIE_FINDGEOMETRY.PRO	Computes the viewpoint of an AMIE image on the Lunar surface

Table 2 – Calibration pipeline IDL routines

AMIE_GETFILTER.PRO	retrieves the filter from the PDS label
AMIE_GETMASTER.PRO	selects the MASTER file
AMIE_GETTEMPERATUREFACTOR.PRO	gets the temperature facture for dark current calculation
AMIE_GETTEMPERATURE	retrieves the temperarure from the PDS label
AMIE_PIPELINE.PRO	main program of the AMIE calibration pipeline
CALIBRATE_AMIE.PRO	routine that does the actual calibration
CREATE_LOG_ENTRY.PRO	calibration logging routine
CREATE_NEW_LABEL.PRO	produces the new label for the calibrated image
DARK_FRAME.PRO	calculates the dark current image for a given raw image

DO_BROWSE_IMAGE	produces the new browse image for the calibrated image
INITIALIZE_LOG.PRO	calibration logging routine
PDSUPDATEKEYWORD.PRO	update keyword values in the label
READ_AMIE_PIPELINE_CFG.PRO	reads the pipeline configuration file
REPLACESTRING.PRO	replaces strings in the label to produce the new calibrated image label
WRITE_AMIE.PRO	writes to file the new calibrated image

Table 3 – List of PDS IDL routines distributed by the PDS Small Bodies Node

ADDEOBJ.PRO	APPLY_BITMASK.PRO
ARRCOLPDS.PRO	ARRCOL_STRUCT.PRO
ARR_STRUCT.PRO	BTABVECT2.PRO
CLEANARR.PRO	CLEAN.PRO
COLL_STRUCT.PRO	ELEM_STRUCT.PRO
EXTRACT_KEYWORD.PRO	GET_IDL_TYPE.PRO
GET_INDEX.PRO	HEADPDS.PRO
IMAGEPDS.PRO	OBJPDS.PRO
PDSPAR.PRO	POINTPDS.PRO
QUBEPDS.PRO	***READPDS.PRO***
READSPREADSHEET.PRO	REMOVE.PRO
STR2NUM.PRO	TASCPDS.PRO
TBINPDS.PRO	TIMEPDS.PRO

4.7 Documentation

The document directory contains all the documents necessary to understand the AMIE dataset. Specific information can be found in 5.4.3.6.

4.8 Derived and other data products

This Section is supposed to answer the following questions:

- Will we provide any other derived data (even outside of the official archiving efforts)?
- Will we provide data products that result from co-operation with other instrument teams?

This needs to be discussed within the team. It could be envisaged that we generate maps or combined data sets with AMIE and SIR, but currently this is all open.

5 Archive Format and Content

This chapter contains general rules and constraints for the AMIE data sets. The scheme or convention we will use for naming our directories and file names will be specified below. It might be, that the information given here is short in nature or in some cases not available. We then simply keep it short or write “n/a”, if applicable.
Specific and detailed information can be found on chapter 6.

5.1 Format and Conventions

5.1.1 Deliveries and Archive Volume Format

The data will be delivered to the Smart-1 Archiving Team by FTP.

One data volume will contain three datasets for the three mission phases.

5.1.2 Data Set ID Formation

This is the identification (ID) for a data set. The following data sets are currently envisaged:

- In-flight raw data from the FM during Earth escape and lunar phase
- In-flight calibrated data from the FM during Earth escape and lunar phase

The naming convention will follow the rule:

`S1-?-AMIE-N-TTT-XXX-Vn.n`

Where

`?` Image target.
- `C` `Laboratory Calibration`
- `L/X` no specific targets

`N` is the data processing level number. This is redundant to the following entry, but required by PDS.
- `2` Raw data – Edited data in the PDS dictionary
- `3` Derived data – Calibrated data in the PDS dictionary

`TTT` the type of the data, can be one of the following:

- `EDR` denotes an Experiment Data Record (EDR) as defined in the PDS standard (AD2). It will be used for raw data coming from the instrument;
- `MDR` denotes a Master Data Record (MDR) as defined in the PDS standard (AD2). It will be used for master dark images and master flat images (an output of the calibration and used in the calibration pipeline).
- `RDR` stands for Reduced Data Record (RDR) as defined in the PDS standard (AD2). It will be used for derived data products, like image mosaics, maps, *etc*.

`XXX or XX` is a description of the data set.

- `EEP` Earth Escape Phase dataset
- `LP` Lunar phase dataset
- `EP` Extended phase dataset

`Vn.n` Version number of the dataset

All items are separated by hyphens ('-').

An example would be: `"S1-L/X-AMIE-2-EDR-LP-V1.0"`

This example would denote all raw data from the Lunar phase data.

5.1.3 Data Directory Naming Convention

The 'data' directory will contain subdirectories that structure the data in a logical way.
There will be two levels of directories in all three datasets. In the Earth Escape phase dataset there will be a top level containing a three mont period description:

EARTH_ESCAPE_yyyy_mm_TO_mm+3 , yyyy is the year and mm the month

That will have as subdirectories the day at wich the data was acquired:

EARTH_ESCAPE_yymmdd , yy is the year, mm the month and dd the day

For the lunar and extended mission phases the top level folder is a range of orbits:

`ORBIT_XXXXX_TO_YYYYY` where `XXXXX and YYYYY` are the orbit number range, with preceeding zeros.

That will have as subdirectories the individual orbits:

ORBIT_nnnnnn, nnnnn is the orbit number.

5.1.4 File naming Convention

The goal of the file naming convention is to provide a unique name for each data file, which also gives some indication of the type of image and at what time it was acquired. It will follow the following convention:

`AMI_PTF_XXXXXX_NNNNN_TTTTT.IMG`

Where

`AMI` denotes the experiment name 'AMIE';

`P` denotes the mission phase; it can be one of the following:

- C for calibration,
- E Earth escape and cruise phase;
- L Lunar phase and extended mission

`T` stands for the data type. It can be one of the following:

- E denotes an Experiment Data Record (EDR) as defined in the PDS standard (AD2). It will be used for raw data coming from the instrument;
- M denotes a Master Data Record (MDR) as defined in the PDS standard (AD2). It will be used for master dark images and master flat images.
- R stands for Reduced Data Record (RDR) as defined in the PDS standard (AD2). It will be used for calibrated images.

`F` is a number from 1 to 7 or A and indicates the used filter. The following relation between the number and the filter name as defined later is valid: '1' = VIS_Y, '2' = FeL_Y, '3' = NONE, '4' = FeH_Y' (horizontal area) and FeH_X (vertical area), '5' = LASER, '6' = FeH_X, '7' = FeL_X, A for full frame.

`XXXXXX` depends on the mission phase. Before reaching the Moon, it shall follow the convention YYMMDD, which stands for the year, month, and day of the image acquisition; when we are in regular orbit around the moon, it shall follow the convention Rnnnnn, where R is mandatory and stands for 'revolution', nnnnn is the consecutive orbit number. The number will be padded by leading zeros if required, *e.g.* 'R00329'.

`NNNNN` is a consecutive number of the image on that day or within that orbit;

`TTTTT` is the exposure time in milliseconds of the image;

`.IMG` is the standard extension for images.

All underscore characters '_' are mandatory and separate the different fields.

5.2 Standards Used in Data Product Generation

5.2.1 PDS Standards

All keywords in the header follow the PDS 3.6 standards. The format of the header and the image data follows the PDS standards; in particular, AD2 is used.

5.2.2 Time Standards

The CCSDS time standards as described in the PDS standards are used.

5.2.3 Reference Systems

The lunar equatorial coordinate system (IAU Moon) with Lunar Longitude and Lunar Latitude, in the *Earth Mean Equatorial J2000* reference system is used.

5.2.4 Other Applicable Standards

N/a

5.3 Data Validation

For the data validation the Dataset verification tool (PVV) will be used. The PSA will set up a peer review of the data.

5.4 Content

5.4.1 Volume Set

One data volume is three datasets, for each of the mission phases.

5.4.2 Data Set

There are three datasets envisaged that are described in Table 4.. The size of the datasets in Table 4 refers to the sum of the size of all files, depending on the operating system the size reported will be different.

Table 4 - AMIE Datasets

Dataset id	Delivery date	Size
S1-L/X-AMIE-2-EDR-EEP-V1.0	July 2008	16148744216 bytes
S1-L/X-AMIE-2-EDR-LP-V1.0	July 2008	37702643061 bytes
S1-L/X-AMIE-2-EDR-EP-V1.0	July 2008	52556571005 bytes

5.4.3 Directories

There are three datasets envisaged for the AMIE experiment. These datasets will have the same directory structure, except for the Data directory. Figure 5 will shows how the directories are structured for both raw images volume and calibrated images volume.

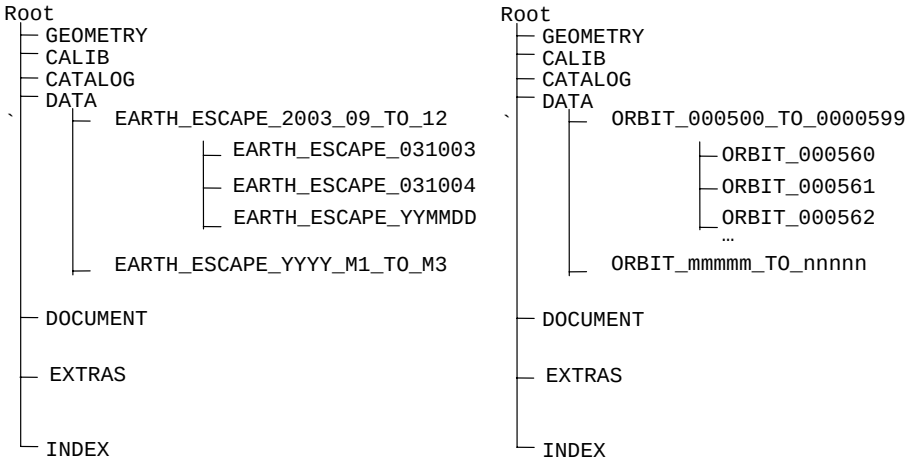

Figure 5: Directory structure for the AMIE Datasets (Left Earth Escape Phase, Right Lunar and Extended Phases)

The following chapters will describe in detail each of the directories.

5.4.3.1 Root Directory

Will contain two files. A readme text file explaining briefly the AMIE dataset and the voldesc.cat catalog, which lists all the catalogs in the volume.

5.4.3.2 Calib Directory

This directory will contain the so-called “master dark images” and “master flat images” that were generated from the ground-based calibration or were derived from space data and are needed for the calibration of data coming from the instrument. These files will be used to generate the calibrated images dataset.

5.4.3.3 Catalog Directory

This directory will contain catalog files with brief descriptions of the experiment, the dataset, and other relevant informative facts for the archive team and the end user. The files included will be:

- INST.CAT – Describes the instrument
- DATASET.CAT – Describes the dataset
- INSTHOST.CAT – Describes the SMART-1 Spacecraft
- MISSION.CAT – Describes the SMART-1 mission
- PERSON.CAT – List of people involved with the instrument
- REF.CAT – List of reference articles related to the instrument
- SOFT.CAT – List and description of the software distributed in the dataset

5.4.3.4 Index Directory

5.4.3.4.1 Dataset Index File, index.lbl and index.tab

The Dataset index file will contain a list with all files in a given Data Set.

5.4.3.4.2 Geometric Index File, geo_moon.lbl and geo_moon.tab

The index directory will contain the geometrical information about each image, Replicating some information from the image labels but also providing additional information.

5.4.3.4.3 Missing Images Index File, missing_imgs.lbl, missing_imgs.tab

This file has the list of missing images, that were commanded and never received on the ground.

5.4.3.4.4 Temperatures Index file, temperature.lbl and temperature.tab

This file contains the focal plane temperature at image acquisition time estimated with different methods and the associated errors.

5.4.3.5 Geometry Directory

The geometry directory will include spice files provided by the PSA.

5.4.3.6 Document Directory

This directory will contain (RD4 to RD 16) the:

- EAICD (this document)
- The Calibration of AMIE images
- Clementine offset report
- Cruise logbook describing all the operations during cruise
- AMIE SPICE Kernel test report
- Pointing Analysis report
- Detector Orientation report
- Science objectives paper
- Spectral response report
- Estimation of focal plane temperature report
- SMART-1 time correlation
- Description of the unpacking software
- AMIE user manual

With corresponding labels and accompanying images in encapsulated post script format.

5.4.3.7 Extras Directory

The extras directory will contain additional documents that might be of interest as well as the data collected in the lab before the mission launch for calibration purposes. This folder will also contain master images derived from the lab data, that were in the meantime superseded with the data present in the CALIB folder.
The documents present in this folder are:

- AMIE_CMDS edf containing all the AMIE commands extracted from the SMART-1 command database.
- AMIE_CMDS_MERGED, containing all AMIE planned commands and execution times
- AMIE temperature list with temperatures from the unit 1 sensor
- SMART1_AMIE_T570T with temperatures at reference point
- AMIE Target list

5.4.3.8 Data directory

5.4.3.8.1 Raw and Calibrated Images Volume

Both Raw and Calibrated Images Volume will have the same structure.. Figure 5**Error! Reference source not found.** shows this structure. As stated before the data will be grouped according to the period of acquisition. For the Earth Escape phase a data is grouped in 3-month periods. For the Lunar phase this grouping is related to the orbit number, and each contains 100 orbits.

6 Detailed Interface Specifications

6.1 Structure and Organization Overview

In Figure 5 it is possible to see the ***/*data** directory structure organization. The Earth escape phase is divided on top level in five phases of 3 months each containing individual days. The lunar phase is divided in one subdirectory per 100 orbits. When no images were taken during a complete orbit, the directory is not existent.

6.2 Data Product Design

In this Section, we give the details of

- the label files – see Section 6.3.1.
- what kind of software algorithms might be necessary to access the data products – the image files will be accessible using standard PDS reading routines, *e.g.* in IDL (Interactive Data Language) use

```
image = readpds ('<filename.img>')
```

Note that this call will currently not handle the required bitwise shift of the data properly, thus the routine `READ_AMIE` has to be used.

6.3 Sample Labels

6.3.1 Data Product Design

The data product simply is the image file produced by the GSE, containing a header, an 'image' object and a 'browse image' object, which contains the same information as the image, but reduced to 128 x 128 pixels and stored with 8 bits. All the information is in one file, *i.e.* we do not use detached labels.

6.3.1.1 PDS version

The following keywords are described in this section:

```
PDS_VERSION_ID                = PDS3
```

6.3.1.1.1 Description of the keyword PDS_VERSION_ID

This keyword describes the pds version in use by the AMIE team.

6.3.1.2 File Characteristics Data Elements

The following keywords are defined for this section:

```
FILE_NAME                    = "AMI_LE2_R00629_00037_00013.IMG"
RECORD_TYPE                  = FIXED_LENGTH
RECORD_BYTES                 = 1024
FILE_RECORDS                 = 292
LABEL_RECORDS                = 20
INTERCHANGE_FORMAT           = BINARY
```

6.3.1.2.1 Description of the keyword FILE_NAME

See 5.1.4.

6.3.1.2.2 Description of the keyword RECORD_TYPE

The RECORD_TYPE is always FIXED_LENGTH.

6.3.1.2.3 Description of the keyword RECORD_BYTES

This keyword denotes the number of bytes in one record. After discussing with the ESA PSA team it was decided that one record is defined to correspond to one line in the main image. As one pixel is stored in 2 bytes, the value of this keyword is twice the number of pixels per row. Depending on the filter, this number can vary, as described in Table 5.

6.3.1.2.4 Description of the keyword FILE_RECORDS

This keyword gives the number of records in the complete file. The header is defined such that its length will always be 20480 bytes (10 records for the maximum size image). The browse image will always be 128 pixels by 128 pixels, *i.e.* 128 * 128 bytes. The total number of records in a file is the sum of the label records (see 6.3.1.2.5), the browse image records and the image records (number of image lines), and is described in Table 5.

6.3.1.2.5 Description of the keyword LABEL_RECORDS

This keyword is required by PDS for attached labels and denotes the number of records in the label. The label has the fixed length of 20480 bytes. The bytes per record are determined by the filter name, thus the number of records for the label is a function of the filter, as can be seen in Table 5.

Table 5: Value for records as a function of filter name.

Filter number	Filter name	Browse image records	Image Records	RECORD_BYTES	FILE_RECORDS	LABEL_RECORDS
N/a	ALL	8	1024	2048	1042	10
1	VIS_Y	16	256	1024	292	20
2	FeL_Y	16	256	1024	292	20
3	NONE	16	512	1024	548	20
4	FeH_Y	16	256	1024	292	20
5	LASER	32	256	512	328	40
6	FeL_X	32	512	512	584	40
7	VIS_X	32	512	512	584	40
8	FeH_X	32	512	512	584	40

6.3.1.2.6 Description of the keyword INTERCHANGE_FORMAT

The AMIE data is stored in binary format; therefore the value for this keyword will always be BINARY.

6.3.1.3 Data Object Pointers

The following keywords are defined for this section:

```
^BROWSE_IMAGE                  = 20481 <BYTES>
^IMAGE                         = 36865 <BYTES>
```

6.3.1.3.1 Description of the keyword ^BROWSE_IMAGE

The first pointer points to a browse image, which is the first object in the data file. Its size is always 128 pixels by 128 pixels. Thus the values of both pointers will always be constant.

6.3.1.3.2 Description of the keyword ^IMAGE

As mentioned before, the value is constant and will always be 36865 bytes.

6.3.1.4 Identification Data Elements

The following keywords are defined for this section:

```
RELEASE_ID                     = 0001
REVISION_ID                    = 0000
DATA_SET_ID                    = "S1-L/X-AMIE-2-EDR-RAW-V1.0"
DATA_SET_NAME                   = "SMART-1 LUNAR/OTHER AMIE 2 EDR RAW DATA
                                   V1.0"
PRODUCT_ID                     = AMI_LE1_002821_00001_00015.IMG
PROCESSING_LEVEL_ID            = 2
PROCESSING_LEVEL_DESC          = "EDITED DATA CORRECTED FOR TELEMETRY ERRORS,
                                  SOMETIMES CALLED EXPERIMENTAL DATA RECORD
                                  (EDR)"
PRODUCT_CREATION_TIME          = 2006-08-21T15:36:08
PRODUCER_INSTITUTION_NAME      = "SPACE-X"
MISSION_ID                     = "SMART1"
MISSION_NAME                   = "SMALL MISSIONS FOR ADVANCED RESEARCH
                                   AND TECHNOLOGY"
INSTRUMENT_HOST_ID             = "S1"
INSTRUMENT_HOST_NAME           = "SMALL MISSIONS FOR ADVANCED RESEARCH AND
                                   TECHNOLOGY"
TARGET_NAME                    = "MOON"
TARGET_TYPE                    = "SATELLITE"
MISSION_PHASE_NAME             = "LUNAR PHASE"
IMAGE_OBSERVATION_TYPE         = "NADIR"
PRODUCT_TYPE                   = EDR
UNCORRECTED_START_TIME         = 2005-08-19T12:35:17.563
START_TIME                     = 2006-08-19T12:35:19.000
STOP_TIME                      = 2006-08-19T12:35:19.015
SPACECRAFT_CLOCK_START_COUNT   = 8/78275639.134
SPACECRAFT_CLOCK_STOP_COUNT    = 8/78275639.149
ORBIT_NUMBER                   = 2821
PRODUCER_ID                    = "SMART1_AMIE_TEAM"
PRODUCER_FULL_NAME             = "Stephane Beauvivre"
```

6.3.1.4.1 Description of the keyword RELEASE_ID

There will be one release of the complete dataset with a RELEASE_ID = 0001.

6.3.1.4.2 Description of the keyword REVISION_ID

This keyword is intended to allow the possibility to correct for mistakes found on the dataset releases. The revision values range from 000 to 999.

6.3.1.4.3 Description of the keyword DATA_SET_ID

See 5.1.2.

6.3.1.4.4 Description of the keyword DATA_SET_NAME

Here the name of the data set will be given, e.g. `SMART-1 LUNAR/OTHER AMIE 2 EDR RAW DATA LUNAR PHASE V1.0"`

6.3.1.4.5 Description of the keyword PRODUCT_ID

This constitutes a unique ID for the data product. The value for this keyword will be the file name without the extension.

6.3.1.4.6 Description of the keyword PROCESSING_LEVEL_ID

This keyword is an ID for the processing level of the image. The values will be:

`2` for raw data
`3` for calibrated data

6.3.1.4.7 Description of the keyword PROCESSING_LEVEL_DESC

This keyword provides the description for the processing level. The values will be:

“EDITED DATA CORRECTED FOR TELEMETRY ERRORS, SOMETIMES CALLED EXPERIMENTAL DATA RECORD (EDR)” for raw data.

“CALIBRATED DATA., SOMETIMES CALLED REDUCED DATA RECORD (RDR)" for calibrated data. For AMIE, two calibration steps are foreseen, a first one which will subtract master dark images and divide by master flat images, a second one which also produces geometrically processed data.

6.3.1.4.8 Description of the keyword PRODUCT_CREATION_TIME

The creation time of the product will be given in UTC, following the format

`YYYY-MM-DDTHH:MM:SS`

Where

`YYYY` is the year,
`MM` the month,
`DD` the day of the cration;
`T` always is T,
`HH` is the hour,
`MM` the minute,
`SS` the second of the creation time.

6.3.1.4.9 Description of the keyword PRODUCER_INSTITUTION_NAME

This will be ‘`SPACE-X`’.

6.3.1.4.10 Description of the keyword MISSION_ID

The value of this keyword will always be `SMART1`.

6.3.1.4.11 Description of the keyword MISSION_NAME

The value of this keyword will always be `"SMALL MISSIONS FOR ADVANCED RESEARCH AND TECHNOLOGY"`.

6.3.1.4.12 Description of the keyword INSTRUMENT_HOST _ID

The value of this keyword will always be `S1`.

6.3.1.4.13 Description of the keyword INSTRUMENT_HOST_NAME

The value of this keyword will always be "SMALL MISSIONS FOR ADVANCED RESEARCH AND TECHNOLOGY".

6.3.1.4.14 Description of the keyword TARGET_NAME

This keyword can have the following values. Note that a 'AMIE target list' was produced and is available as AMIE list (RD 7) giving the value for this keyword as a function of time.

CALIMG	for calibration in the lab,
MOON	for the Moon,
EARTH	for the Earth,
STAR	for stars,
SUN	for sun-pointing (or pointing away from the Sun, *e.g.* during the straylight test,
JUPITER	during the AMIE-SIR alignment campaign.
PLEIADES	for the observation of the Plejades
DARK SKY	when looking at a point in the sky which does not contain an object, normally used for dark images

6.3.1.4.15 Description of the keyword TARGET_TYPE

This keyword will point out the category of the target. The following values are foreseen for this keyword. The same list as for TARGET_NAME will give the value for TARGET_TYPE as a function of time.

PLANET	for the EARTH or JUPITER
STAR	for star imaging
SUN	when TARGET_NAME is SUN
SATELLITE	when the TARGET_NAME is MOON
STAR CLUSTER	for the PLEIADES
N/A	for DARK SKY

6.3.1.4.16 Description of the keyword MISSION_PHASE_NAME

The following values can be assigned to this keyword:

"EARTH ESCAPE PHASE"	for the phase between launch and Moon capture, from 2003-09-28T15:33:06 to 2005-03-13T00:52:34 as described in RD 17.
"LUNAR PHASE"	for the Lunar phase, from 2005-03-13T00:52:35 to 2005-08-01T01:36:03 ().
"EXTENDED MISSION"	for the extended mission phase, starting 2005-08-01T01:46:04, ending at the Smart-1 impact, 2007-09-03.

6.3.1.4.17 Description of the keyword IMAGE_OBSERVATION_TYPE

The image_observation_type element identifies the type or purpose of an observation that may be associated with an image. Image observation types include limb, black sky, spacecraft calibration, or other image attribute that may be used for identification.

The values that can be found here are:

LAB
DARK_CURRENT
FLAT_FIELD
STRAY_LIGHT
LIMB
NADIR
OFF_TRACK
TARGET
OBAN
RSIS
LASER_LINK

PUSH_BROOM
REGULAR

6.3.1.4.18 Description of the keyword PRODUCT_TYPE

This keyword will describe the product type. The product type will be a derived from the processing level, therefore having the same values.
The values will be:

"EDR" for raw data
"RDR" for reduced data
"MDR" for master data

6.3.1.4.19 Description of the keyword UNCORRECTED_START_TIME

This keyword describes is the time of the command acknowledgement. The AMIE data was only time stamped after arriving at the mass memory, so the actual time of acquisition had to be derived.

6.3.1.4.20 Description of the keyword START_TIME

This keyword describes the start of the exposure and will be given in UTC, following the format

YYYY-MM-DDTHH:MM:SS.SSS

Where

YYYY is the year,
MM the month,
DD the day of the creation;
T always is T,
HH is the hour,
MM the minute,
SS the second of the start time,
.SSS the milliseconds.

6.3.1.4.21 Description of the keyword STOP_TIME

As above, but for the end of the exposure, *i.e.* the START_TIME + EXPOSURE_DURATION.

6.3.1.4.22 Description of the keyword SPACECRAFT_CLOCK_START_COUNT

The counter value of the s/c clock at START_TIME.

6.3.1.4.23 Description of the keyword SPACECRAFT_CLOCK_STOP_COUNT

As above, but for the STOP_TIME.

6.3.1.4.24 Description of the keyword ORBIT_NUMBER

'N/A' before reaching regular lunar orbit. When in lunar orbit, this number will denote the orbit number around the Moon, starting with '0001'. The number will be padded with leading zeros.

6.3.1.4.25 Description of the keyword PRODUCER_ID

The producer ID will always have the value:

SMART1_AMIE_TEAM

6.3.1.4.26 Description of the keyword PRODUCER_FULL_NAME

This keyword will always have the value:

"STEPHANE BEAUVIVRE"

6.3.1.5 Instrument and Detector Descriptive Data Elements

The following keywords are foreseen for this section:

```
INSTRUMENT_ID                  = "AMIE"
INSTRUMENT_NAME                = "ADVANCED MOON MICROIMAGING EXPERIMENT"
INST_CMPRS_NAME                = "WAVELET"
INST_CMPRS_RATE                = 1 <BIT/PIXEL>
FILTER_NAME                    = "FeL_Y"
CENTER_FILTER_WAVELENGTH       = 915 <NM>
BANDWIDTH                      = 30 <NM>
EXPOSURE_DURATION              = 13 <MS>
FOCAL_PLANE_TEMPERATURE        = 291.47 <K>
GAIN_NUMBER                    = 280 <e/DN>
DATA_QUALITY_ID                = 3
DATA_QUALITY_DESC              = ""THE DATA QUALITY IS EVALUATED ACCORDING
                                  TO THE RATIO OF SATURATED TO NON-
                                  SATURATED PIXELS IN THE IMAGE.
                                  4 IS HIGHEST QUALILTY, RATIO IS [0, 0.02]
                                  3 IS HIGH QUALITY, RATIO IS ]0.02,0.34]
                                  2 IS MEDIUM QUALITY, RATIO IS ]0.34,0.66]
                                  1 IS LOW QUALITY, RATIO IS ]0.66,0.98]
                                  0 IS LOWEST QUALITY, RATIO IS ]0.98,1]
                                  -1 IS NON EXISTENT"
INSTRUMENT_MODE_ID             = "ALL"
INSTRUMENT_MODE_DESC           = "ALL - Read out complete detector
                                  filter name - read out only one filter
                                  COLOR_X - Read out VIS_X, FeL_X, FeH_X
                                  COLOR_Y - Read out VIS_Y, FeL_Y, FeH_Y"
INSTRUMENT_TYPE                = "IMAGING CAMERA"
```

6.3.1.5.1 Description of the keyword INSTRUMENT_ID

This keyword can have the values of AMIE or AMIE_EM, depending on the model.

6.3.1.5.2 Description of the keyword INSTRUMENT_NAME

The extended name of the instrument will always be ‘ADVANCED MOON MICROIMAGING EXPERIMENT’.

6.3.1.5.3 Description of the keyword INST_CMPRS_NAME

This keyword describes the compression method used. The values it can have are:

"WAVELET"	For wavelet compression
"REVERSIBLE"	For reversible compression
"NO COMPR"	For no compression

6.3.1.5.4 Description of the keyword INST_CMPRS_RATE

This keyword describes the compression rate applied to the images. The values for this keyword will be of the form, *n.m,* where n and m are integer numbers. The unit of the compression rate is bits per pixel (bits/pixel).

6.3.1.5.5 Description of the keyword FILTER_NAME

Table 6 defines all possible values for this keyword.

Table 6: Definition of the filter name, center wavelength, and bandwidth.

Filter number	FILTER_NAME	CENTER_WAVELENGTH	BANDWIDTH
N/a	ALL	N/a	N/a
1	VIS_Y	750 nm	10 nm
2	FeL_Y	915 nm	30 nm
3	NONE	800 nm	700 nm
4	FeH_Y	960 nm	Long-pass
5	LASER	847 nm	10 nm
6	FeL_X	915 nm	30 nm
7	VIS_X	750 nm	10 nm
8	FeH_X	960 nm	Long-pass

6.3.1.5.6 Description of the keyword CENTER_FILTER_WAVELENGTH

Table 6 defines all possible values for this keyword.

6.3.1.5.7 Description of the keyword BANDWIDTH

Table 6 defines all possible values for this keyword.

6.3.1.5.8 Description of the keyword EXPOSURE_DURATION

This is the exposure time in milliseconds.

6.3.1.5.9 Description of the keyword FOCAL_PLANE_TEMPERATURE

See RD 14.

6.3.1.5.10 Description of the keyword GAIN_NUMBER

The gain of the Analog to Digital Converter (ADC) in electrons per Digital Number (e-/DN). This is a fixed number defined by the electronics. For the AMIE FM, this value is

```
GAIN_NUMBER = 280 <e/DN>
```

6.3.1.5.11 Description of the keyword DATA_QUALITY_ID

This keyword allows indicating whether the data is useful or not. It will be a number from 0 to 4 indicating the amount of saturated pixels in the image.

6.3.1.5.12 Description of the keyword DATA_QUALITY_DESC

This keyword will give the description for the data quality identified in the previous keyword. The value will be:

```
"THE DATA QUALITY IS EVALUATED ACCORDING TO THE RATIO OF SATURATED TO
NON-SATURATED PIXELS IN THE IMAGE.
4 IS HIGHEST QUALILTY, RATIO IS [0, 0.02]
3 IS HIGH QUALITY, RATIO IS ]0.02,0.34]
2 IS MEDIUM QUALITY, RATIO IS ]0.34,0.66]
1 IS LOW QUALITY, RATIO IS ]0.66,0.98]
0 IS LOWEST QUALITY, RATIO IS ]0.98,1]
-1 IS NON EXISTENT"

Data with the value -1 is not present in the dataset. A list of
planed images where no data was present on ground is provided in the
index folder. See 5.4.3.4.3.
```

6.3.1.5.13 Description of the keyword INSTRUMENT_MODE_ID

This keyword is related to the commanding of the instrument. Depending on the science objectives of a given observation, it is possible that only a part of the image will be valuable,

and therefore downloaded to the ground, thus representing the possible modes of operation. Foreseen so far are the following values for this keyword:

ALL - Read out complete detector
VIS_Y - read out only the VIS_Y filter
FeL_Y - read out only the FeL_Y filter
NONE - read out only the NONE filter
FeH_Y - read out only the FeH_Y filter
LASER - read out only the LASER filter
FeL_X - read out only the FeL_X filter
VIS_X - read out only the VIS_X filter
FeH_X - read out only the FeH_X filter
COLOR_X - Read out VIS_X, FeL_X, FeH_X
COLOR_Y - Read out VIS_Y, FeL_Y, FeH_Y"

6.3.1.5.14 Description of the keyword INSTRUMENT_MODE_DESC

This keyword describes the previous ID. The value will always be:

```
"ALL - Read out complete detector
 filter name - read out only one filter
 COLOR_X - Read out VIS_X, FeL_X, FeH_X
 COLOR_Y - Read out VIS_Y, FeL_Y, FeH_Y"
```

6.3.1.5.15 Description of the keyword INSTRUMENT_TYPE

This keyword describes the category of the instrument. AMIE will have as value for this keyword, "IMAGING CAMERA"

6.3.1.6 Structure Definition of Instrument Parameter Objects

N/A

6.3.1.7 Image calibration related parameters

The following keywords are foreseen for this section:

```
DARK_CURRENT_CORRECTION_FLAG    = "FALSE"
DARK_CURRENT_FILE_NAME          = "N/A"
FLAT_FIELD_CORRECTION_FLAG      = "FALSE"
FLAT_FIELD_FILE_NAME            = "N/A"
```

6.3.1.7.1 Description of the keyword DARK_CURRENT_CORRECTION_FLAG

This keyword describes if the image is dark current corrected. It can have the values:

"FALSE"	Not corrected
"TRUE"	Corrected

6.3.1.7.2 Description of the keyword DARK_CURRENT_FILE_NAME

This keyword will have has value the index dark current file list with the dark current files used for calibration.

6.3.1.7.3 Description of the keyword FLAT_FIELD_CORRECTION_FLAG

This keyword describes if the image is flat field corrected. It can have the values:

"FALSE"	Not corrected
"TRUE"	Corrected

6.3.1.7.4 Description of the keyword FLAT_FIELD_FILE_NAME

This keyword will have as value the name of the flat file used for flat field division.

6.3.1.8 Positional information

This section contains geometric information at the time of the image acquisition. The keywords are self explanatory, and are used as described in the PSA dictionary.

6.3.1.9 Description of Instrument

N/A

6.3.1.10 Parameters Index File Definition

N/A

6.3.1.11 Mission Specific Keywords

The following keywords are foreseen for this section:

```
SMART1:AMIE_SC_ATTITUDE_VECTOR = "N/A"
SMART1:AMIE_SC_EFRF_VECTOR     = "N/A"
SMART1:AMIE_SC_ROT_RATE_VECTOR = "N/A"
```

6.3.1.11.1 Description of the AMIE_SC_EFRF_VECTOR keyword

This keyword stands for Spacecraft Earth Fixed Reference Frame Vector. It describes the (x,y,z) coordinates in km of the spacecraft in the so-called Earth Fixed Reference Frame (EFRF). The origin of this coordinate system is in the centre of the Earth. The x-axis of the EFRF is in the equatorial plane of the Earth, going through the Greenwich meridian (*i.e.* longitude = 0 deg). The z-axis points to the North pole of the Earth. The y-axis concludes the right-handed coordinate system. See Figure 6 for an illustration.

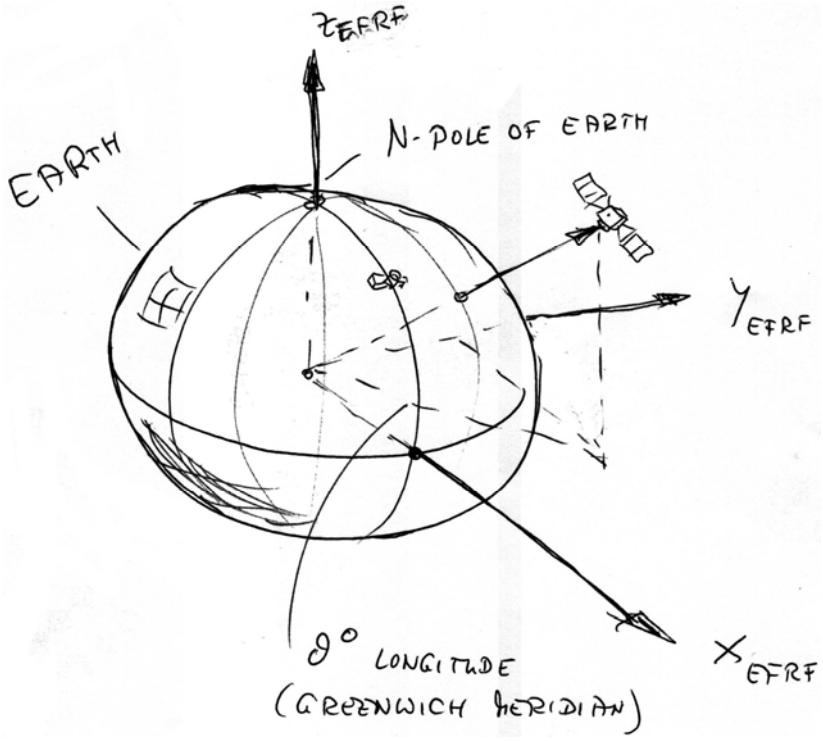

Figure 6: Definition of the Earth-fixed reference frame (EFRF).

6.3.1.11.2 Description of the AMIE_SC_ATTITUDE_VECTOR keyword

This keyword will hold a vector that will reflect the spacecraft attitude from nadir. This vector will have as coordinates the rotation about the x_sc, y_sc, and z_sc-axis, respectively, in this sequence. The rotation will count as positive following the right-hand rule.. These values will be in decimal degrees from 0 ° to 360 °. The reference attitude from which these rotations are measured will be defined as follows: the z_{sc} axis is pointing towards nadir (*i.e.* towards the mass center of the Earth), the x_sc axis is pointing North. The y_{sc} axis is pointing East and completes the right-handed coordinate system.NOTE 1: To understand the relation between the spacecraft coordinate system and the field of view of AMIE, refer to RD 6.

-NOTE 2: This keyword was defined mainly for useage by the Laser Link experiment, thus it refers to the Earth even when orbiting the Moon. This should be taken into account when using the values of this keyword.

6.3.1.11.3 Description of the AMIE_SC_ROT_RATE_VECTOR keyword

This keyword describes the angular velocity of the spacecraft in the coordinates described in the above keyword, *i.e.* rotation around the spacecraft x_sc, y_sc, and z_sc axes, in decimal degrees per second where right-handed rotation is positive.

6.3.1.12 Data Object Definition

The AMIE products will contain two objects, a “browse image” and the full resolution image. The keywords to describe these objects are described in this section.

Note that it was decide that even when the full sensor is read out, one image file will contain only one filter, *i.e.* if the complete sensor is read out, 8 individual files will be generated. The browse image always shows a 128 px x 128 px version of the full frame, with only the current filter filled in. This means that from the browse image the user can immediately see which filter is contained in this file. An example is given below.

```
OBJECT                          = BROWSE_IMAGE
   LINES                        = 128
   LINE_SAMPLES                 = 128
   SAMPLE_TYPE                  = MSB_UNSIGNED_INTEGER
   SAMPLE_BITS                  = 8
   SAMPLE_BIT_MASK              = 2#11111111#
END_OBJECT                      = BROWSE_IMAGE

OBJECT                          = IMAGE
   DERIVED_MINIMUM              = 0
   DERIVED_MAXIMUM              = 1023
   FIRST_LINE                   = 1
   LINE_PREFIX_BYTES            = 0
   LINE_SUFFIX_BYTES            = 0
   LINES                        = 256
   LINE_SAMPLES                 = 512
   SAMPLE_TYPE                  = LSB_UNSIGNED_INTEGER
   SAMPLE_BITS                  = 16
   SAMPLE_BIT_MASK              = 2#1111111111000000#
END_OBJECT                      = IMAGE
```

6.3.1.12.1 Description of the keyword OBJECT and END_OBJECT

These keywords mark the start and the end of the objects.

6.3.1.12.2 Description of the keyword DERIVED_MINIMUM

The DERIVED_MINIMUM data element represents the minimum value that is valid for the image. For the AMIE raw images the value is 0.

6.3.1.12.3 Description of the keyword DERIVED_MAXIMUM

The DERIVED_MAXIMUM data element represents the maximum value that is valid for the image. For the AMIE raw images the value is 1023.

6.3.1.12.4 Description of the keyword FIRST_LINE

The FIRST_LINE element indicates the line within a source image that corresponds to the first line in a sub-image. The value is always 1

6.3.1.12.5 Description of the keyword LINE_PREFIX_BYTES

The LINE_PREFIX_BYTES element indicates the number of non-image bytes at the beginning of each line. The value must represent an integral number of bytes. This value is 0.

6.3.1.12.6 Description of the keyword LINE_SUFFIX_BYTES

The LINE_SUFFIX_BYTES element indicates the number of non-image bytes at the end of each line. This value must be an integral number of bytes. This value is 0.

6.3.1.12.7 Description of the keyword LINES

The LINES element indicates the total number of data instances along the vertical axis of an image. For AMIE the values permitted for this keyword depend on the object:

IMAGE listed in Table 7
BROWSE_IMAGE object, this value is 128.

6.3.1.12.8 Description of the keyword LINE_SAMPLES

The LINE_SAMPLES element indicates the total number of data instances along the horizontal axis of an image. For AMIE the values permitted for this keyword depend on the object:

IMAGE listed in Table 7
BROWSE_IMAGE object, this value is 128.

Table 7: Values for LINES and LINE_SAMPLES function of the filter

Filter number	Filter name	LINES	LINE_SAMPLES
N/a	ALL	1023	1023
1	VIS_Y	256	512
2	FeL_Y	256	512
3	NONE	512	512
4	FeH_Y	256	512
5	LASER	256	256
6	FeL_X	512	256
7	VIS_X	512	256
8	FeH_X	512	256

6.3.1.12.9 Description of the keyword SAMPLE_TYPE

The SAMPLE_TYPE element indicates the data storage representation of sample value. The value for this keyword will always be LSB_UNSIGNED_INTEGER.

6.3.1.12.10 Description of the keyword SAMPLE_BITS

The SAMPLE_BITS element indicates the stored number of bits, or units of binary information, contained in a line sample value. For the AMIE data products this value will be dependent on the object:

BROWSE_IMAGE: 8
IMAGE: 16

6.3.1.12.11 Description of the keyword SAMPLE_BIT_MASK

The SAMPLE_BIT_MASK element identifies the active bits in a sample. The browse image has all the bits active. As for the images as they are stored in the upper 10 bits of 2 bytes, the value is also always the same:

BROWSE_IMAGE: 2#11111111#
IMAGE: 2#1111111111000000#

7 Appendix A: Complete data label

```
PDS_VERSION_ID                = PDS3

/***      FILE CHARACTERISTICS
***/
FILE_NAME                     = "AMI_LE2_R00629_00037_00013.IMG"
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 1024
FILE_RECORDS                  = 292
LABEL_RECORDS                 = 20
INTERCHANGE_FORMAT            = BINARY

/***      POINTERS TO DATA OBJECTS
***/
^BROWSE_IMAGE                 = 20481 <BYTES>
^IMAGE                        = 36865 <BYTES>

/***      IDENTIFICATION DATA ELEMENTS
***/
RELEASE_ID                    = 0001
REVISION_ID                   = 0000
DATA_SET_ID                   = "S1-L/X-AMIE-2-EDR-LP-V1.0"
DATA_SET_NAME                 = "
                    SMART-1 LUNAR/OTHER AMIE 2 EDR RAW DATA LUNAR PHASE
V1.0"
PRODUCT_ID                    = AMI_LE2_R00629_00037_00013
PROCESSING_LEVEL_ID           = 2
PROCESSING_LEVEL_DESC         = "EDITED DATA CORRECTED FOR TELEMETRY
ERRORS.
                             SOMETIMES CALLED EXPERIMENTAL DATA RECORD
(EDR)"
PRODUCT_CREATION_TIME         = 2007-08-10T14:23:05
PRODUCER_INSTITUTION_NAME     = "SPACE-X"
MISSION_ID                    = "SMART1"
MISSION_NAME                  = "
                         SMALL MISSIONS FOR ADVANCED RESEARCH AND
TECHNOLOGY"
INSTRUMENT_HOST_ID            = "S1"
INSTRUMENT_HOST_NAME          = "
                         SMALL MISSIONS FOR ADVANCED RESEARCH AND
TECHNOLOGY"
TARGET_NAME                   = "MOON"
TARGET_TYPE                   = "SATELLITE"
MISSION_PHASE_NAME            = "LUNAR PHASE"
IMAGE_OBSERVATION_TYPE        = "REGULAR"
PRODUCT_TYPE                  = EDR
UNCORRECTED_START_TIME        = 2005-05-21T05:10:07.953
START_TIME                    = 2005-05-21T05:10:09.089
STOP_TIME                     = 2005-05-21T05:10:09.102
SPACECRAFT_CLOCK_START_COUNT  = "8/0038936927.05084"
SPACECRAFT_CLOCK_STOP_COUNT   = "8/0038936927.05936"
ORBIT_NUMBER                  = 0629
PRODUCER_ID                   = SMART1_AMIE_TEAM
PRODUCER_FULL_NAME            = "STEPHANE BEAUVIVRE"

/***      INSTRUMENT RELATED PARAMETERS
***/
INSTRUMENT_ID                 = AMIE
INSTRUMENT_NAME               = "ADVANCED MOON MICROIMAGING EXPERIMENT"
INST_CMPRS_NAME               = "WAVELET"
INST_CMPRS_RATE               = 1 <BIT/PIXEL>
FILTER_NAME                   = "FeL_Y"
```

```
CENTER_FILTER_WAVELENGTH       = 915 <NM>
BANDWIDTH                      = 30 <NM>
EXPOSURE_DURATION              = 13 <MS>
FOCAL_PLANE_TEMPERATURE        = 291.47 <K>
GAIN_NUMBER                    = 280 <E/DN>
DATA_QUALITY_ID                = 3
DATA_QUALITY_DESC              = "THE DATA QUALITY IS EVALUATED ACCORDING TO
                                  THE RATIO OF SATURATED TO NON-SATURATED
                                  PIXELS IN THE IMAGE.
                                  4 IS HIGHEST QUALILTY, RATIO IS [0, 0.02]
                                  3 IS HIGH QUALITY, RATIO IS ]0.02,0.34]
                                  2 IS MEDIUM QUALITY, RATIO IS ]0.34,0.66]
                                  1 IS LOW QUALITY, RATIO IS ]0.66,0.98]
                                  0 IS LOWEST QUALITY, RATIO IS ]0.98,1]
                                  -1 IS NON EXISTENT"
INSTRUMENT_MODE_ID             = "ALL"
INSTRUMENT_MODE_DESC           = "ALL - Read out complete detector
                                  filter name - read out only one filter
                                  COLOR_X - Read out VIS_X, FeL_X, FeH_X
                                  COLOR_Y - Read out VIS_Y, FeL_Y, FeH_Y"
INSTRUMENT_TYPE                = "IMAGING CAMERA"

/***      IMAGE CALIBRATION RELATED PARAMETERS
***/
DARK_CURRENT_CORRECTION_FLAG   = "FALSE"
DARK_CURRENT_FILE_NAME         = "N/A"
FLAT_FIELD_CORRECTION_FLAG     = "FALSE"
FLAT_FIELD_FILE_NAME           = "N/A"

/***      POSITIONAL INFORMATION
***/

  /*** TARGET PARAMETERS: POSITION <KM>, VELOCITY <KM/S> ***/
SC_TARGET_POSITION_VECTOR      = (-1023.0, -1981.6, 974.4) <KM>
SC_TARGET_VELOCITY_VECTOR      = (0.7086, 0.6111, 1.3089) <KM/SEC>
TARGET_CENTER_DISTANCE         = 2433.7 <KM>
SOLAR_DISTANCE                 = 151727949.6 <KM>
CENTER_LONGITUDE               =   24.17 <DEG>
WESTERNMOST_LONGITUDE          =   23.40 <DEG>
EASTERNMOST_LONGITUDE          =   24.92 <DEG>
RETICLE_POINT_LONGITUDE        = (  24.86,  23.40,  23.48,  24.92) <DEG>
CENTER_LATITUDE                =  -42.98 <DEG>
MINIMUM_LATITUDE               =  -43.29 <DEG>
MAXIMUM_LATITUDE               =  -42.66 <DEG>
RETICLE_POINT_LATITUDE         = ( -43.29, -43.19, -42.66, -42.76) <DEG>

  /*** SPACECRAFT POSITION             ***/
SPACECRAFT_ALTITUDE            = 696.3 <KM>

/***      GEOMETRICAL INFORMATION
***/

  /*** TARGET WITHIN SENSOR FOV: ANGLES IN <DEG> ***/
SLANT_DISTANCE                 =    696.8 <KM>
RIGHT_ASCENSION                = 240.67 <DEG>
RETICLE_POINT_RA               = (239.16, 242.03, 242.19, 239.29) <DEG>
DECLINATION                    = 23.77 <DEG>
RETICLE_POINT_DECLINATION      = (23.24, 22.98, 24.29, 24.56) <DEG>
HORIZONTAL_PIXEL_SCALE         = 63 <M/PIXEL>
VERTICAL_PIXEL_SCALE           = 63 <M/PIXEL>

  /*** VIEWING AND LIGHTING GEOMETRY (SUN ON TARGET) ***/
INCIDENCE_ANGLE                =   44.04 <DEG>
PHASE_ANGLE                    =   44.03 <DEG>
EMISSION_ANGLE                 =    2.61 <DEG>
```

```
LOCAL_HOUR_ANGLE                =  176.57 <DEG>
SUB_SOLAR_LATITUDE              = 0.95 <DEG>
SUB_SOLAR_LONGITUDE             = 27.59 <DEG>
SOLAR_ELONGATION                =  135.97 <DEG>

/***      SMART-1 SPECIFIC DICTIONARY
***/
SMART1:AMIE_SC_EFRF_VECTOR      = (
                                  -142376.5031, -344624.2564, -70276.3307)
<KM>
SMART1:AMIE_SC_ATTITUDE_VECTOR = (222.29, 31.70, 345.78) <DEG>
SMART1:AMIE_SC_ROT_RATE_VECTOR = (0.00, 0.04, -0.00) <DEG/SEC>

/***      OBJECT DESCRIPTION
***/
OBJECT                          = BROWSE_IMAGE
   LINES                        = 128
   LINE_SAMPLES                 = 128
   SAMPLE_TYPE                  = MSB_UNSIGNED_INTEGER
   SAMPLE_BITS                  = 8
   SAMPLE_BIT_MASK              = "2#11111111#"
END_OBJECT                      = BROWSE_IMAGE

OBJECT                          = IMAGE
   DERIVED_MINIMUM              = 0
   DERIVED_MAXIMUM              = 1023
   FIRST_LINE                   = 1
   LINE_PREFIX_BYTES            = 0
   LINE_SUFFIX_BYTES            = 0
   LINES                        = 256
   LINE_SAMPLES                 = 512
   SAMPLE_TYPE                  = LSB_UNSIGNED_INTEGER
   SAMPLE_BITS                  = 16
   SAMPLE_BIT_MASK              = "2#1111111111000000#"
END_OBJECT                      = IMAGE
```

8 Appendix B: Values for label keywords function of filter

Table 8: Values for label keywords function of filter

Filter number	FILTER_NAME	Browse image records	Image Records	RECORD_BYTES	FILE_RECORDS	LABEL_RECORDS	CENTER_WAVELENGTH	BANDWIDTH	LINES	LINE_SAMPLES
N/a	**ALL**	8	1024	2048	1042	10	N/a	N/a	1024	1024
1	**VIS_Y**	16	256	1024	292	20	750 nm	10 nm	256	512
2	**FeL_Y**	16	256	1024	292	20	915 nm	30 nm	256	512
3	**NONE**	16	512	1024	548	20	800 nm	700 nm	512	512
4	**FeH_Y**	16	256	1024	292	20	960 nm	Long-pass	256	512
5	**LASER**	32	256	512	328	40	847 nm	10 nm	256	256
6	**FeL_X**	32	512	512	584	40	915 nm	30 nm	512	256
7	**VIS_X**	32	512	512	584	40	750 nm	10 nm	512	256
8	**FeH_X**	32	512	512	584	40	960 nm	Long-pass	512	256