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Institut für Planetenforschung

VMC on VenusExpress

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VEX-VMC To Planetary Science Archive Interface Control Document (EAICD)

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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 two fold. First it provides users of the VMC instrument with detailed description of the product and a description of how it was generated, including data sources and destinations. Secondly, it is the official interface between the VMC team and the Planetary Science Archive.

1.2 Archiving Authorities

The ESA Planetary Science Archive is the official archive authority of the Venus Express Mission.

1.3 Contents

This document describes the data flow of the VMC instrument on VenusExpress from the s/c until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled 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 furtheron.

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

1.4 Intended Readership

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

1.5 Applicable Documents

1. Planetary Data System Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part1
2. Planetary Data System Standards Reference, August 1, 2003, Version 3.6, JPL, D-7669, Part 2
3. VenusExpress Archive Generation, Validation and Transfer Plan, J. Zender, , ESA-VEX-PL-001, Version 1.1, 7. June 2004.
4. Venus Monitoring Camera Flight User Manual, Issue 1,VMC-IDA-MA-SF000-001_1, 26.05.2004, Prepared by Björn Fiethe
5. Venus Express VMC Data Products Naming Convention, T. Roatsch, VMC-DLR-TN-001, Issue 001, 20-February-2006.
6. PDS Standards Reference , http://pds.jpl.nasa.gov/documents/sr/index.html
7. Planetary Science Data Archive Technical Note – Geometry and Position Information, Issue 3, Revision 4, J. Diaz del Rio, ESA RSSD Planetary Missions Division, SOP-RSSD-TN-010, 09-November-2004.

8. VenusExpress - VMC Level-1 Product Description, T. Roatsch, VMC-DLR-TN-002, Issue 001, 20-February-2006.
9. VenusExpress - VMC Level-2 Product Description, T. Roatsch, VMC-DLR-TN-003, Issue 001, 20-February-2006.
11. The VICAR Image Processing System, http://www-mipl.jpl.nasa.gov/external/vicar.html
12. Navigation and Ancillary Information Facility (NAIF), http://pds-naif.jpl.nasa.gov/
13. Planetary Science Archive PVV User Manual, D. Heather, A. Venet, J, Vazquez, SOP-RSSD-UM-004, Issue 2.6, 21-October-2004
14. Planetary Science Archive Experiment Data Release Concept Technical Proposal, J. Zender, SOP-RSSD-TN-015 Issue 1.14 22 October 2004

1.6 Relationships to Other Interfaces

This document is in close relationship to

- VenusExpress - VMC Data Products Naming Convention [5]
- VenusExpress - VMC Level-1 Product Description [8]
- VenusExpress - VMC Level-2 Product Description [9]

The contents of these documents is summarized in this document for easier use.

1.7 Acronyms and Abbreviations

CoI	Co-Investigator
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
ESOC	European Space Operation Center
ESTEC	European Space Research and Technology Center
IDA	Institute of Computer and Communication Network Engineering, Braunschweig, Germany
JPL	NASA Jet Propulsion Laboratory
MPS	Max-Planck-Institute for Solar System Exploration, Lindau
PI	Principal Investigator
PSA	Planetary Science Archive
PVV	PSA Volume Verifier
VICAR	Video Image Communication and Retrieval
VMC	Venus Monitoring Camera

1.8 Contact Names and Addresses

Archive generation software	Klaus-Dieter Matz, DLR
Archive distribution	Thomas Roatsch, DLR
Levels 1 generation software cognizant engineer	Thomas Roatsch, DLR
Calibration software and procedures	Klaus-Dieter Matz, DLR
VICAR software cognizant Engineer	Robert G. Deen, JPL

2 Overview of Instrument Design, Data Handling Process and Product Generation

2.1 Instrument Design Overview

The VMC camera consists of one unit that houses the optics, CCD and readout electronics (CRE), digital processing unit (DPU), and power converter (POC). Figure.1 shows the sketch of the VMC camera.
The experiment consists of one unit with optics and focal plane mounted to the upper cover and a stack of electronic boards occupying the rest of the box. The size of PCBs is 80x80 mm. The walls of the camera are 3 mm thick to provide sufficient stiffness and radiation protection. Additional radiation shielding will be provided in the vicinity of the CCD.

The current baseline is to mount the camera on the +Y wall inside the spacecraft. Red dots on the +Y wall in the VMC sketch mark the mounting points of the camera. A Peltier cooler is attached to the CCD bottom. A thermal strap will take heat from the CCD to the spacecraft wall. The red star shows the thermal reference point (TRP), specified for the CCD and the electronics. In order to avoid moving parts (filter wheel) the camera is designed so that four objectives (channels) share a single CCD. The stray light protection is provided by external and internal baffles. The latter are also used to prevent optical cross-talk between the channels.

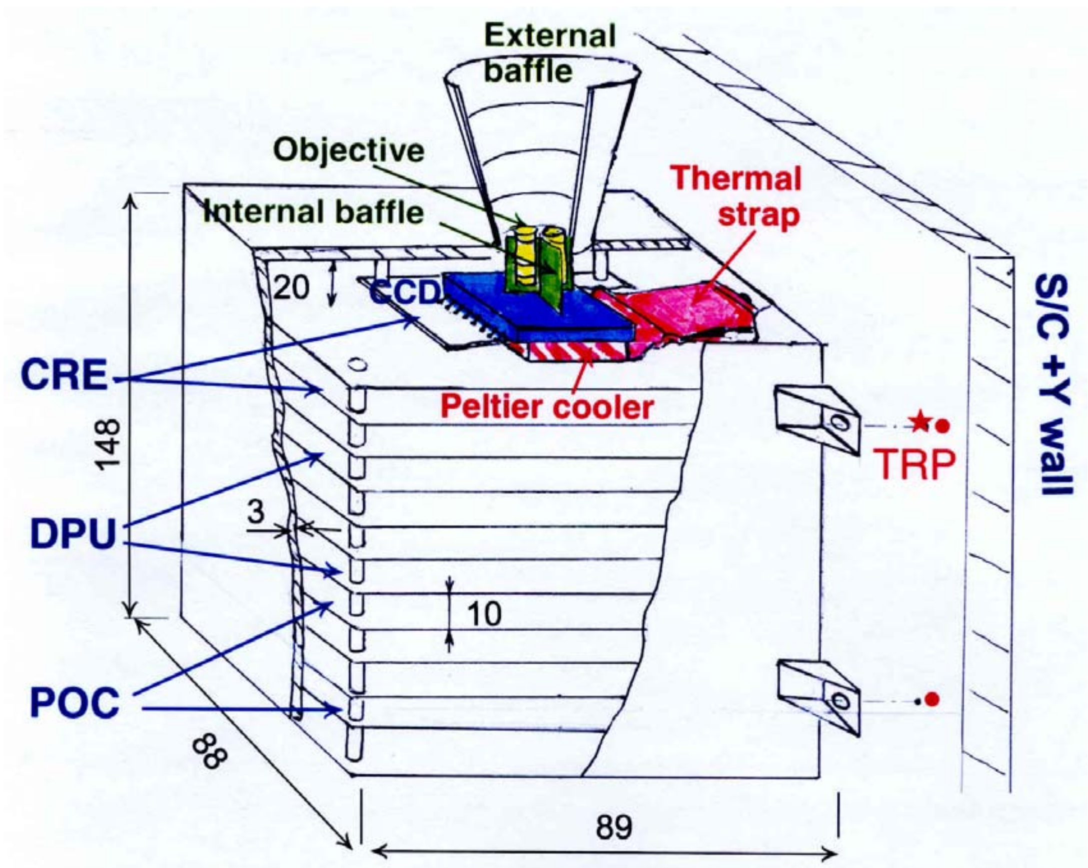

Figure.1: VMC sketch

Further information about the insturment and its operation can be found in [4].

2.2 Data Handling Process

All VMC data are processed at IDA, Braunschweig and DLR in Berlin, Germany.

The data processing consists of the following steps:

- transfer of data from ESOC to IDA
- remove all transmission headers to get the original camera data
- decompress the data
- transfer data to DLR
- convert data into VICAR file format

- split data from different sensors to generate Level-1 files
- radiometric calibration of the data
- calculate footprints of every image file and get Level-2 files

The formats of the data levels 1 and 2 are described in [8] and [9], respectively.

All data processing steps at DLR are performed in the VICAR environment [11], a software package developed and maintained by JPL and used for the data processing of many planetary missions.

DLR developed specific VICAR modules for every processing step.

The cognizitant persons for the specific task are listed in chapter 1.8. Please, adress all questions and comments through the Data Processing Manager (thomas.roatsch@dlr.de).

2.3 Product Generation

The VMC data are processed at IDA and DLR when they become available at ESOC. Both level-1 and level-2 data are sent to the PI and distributed to the CoI team. The data will be checked by the team and improved versions of the data will be calculated if necessary. Another reason for new image version are improved SPICE kernels..

The final step of the product generation is the conversion from the VICAR format to PDS format and the generation of the complete data sets. This step is also performed at DLR in Berlin about a month before the final delivery to PSA.

The final products will be sent to the PI and the CoIs who are in charge for the data validation. The data will be send from DLR to PSA after succesful validation and PI approval.

3 Archive Format and Content

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

The VMC data will be delivered to PSA every 6 months. Every delivery contains the data taken during a time period of 6 months. The delivery will be performed only via file transfer, no storage media like CD or DVD will be used. The Planetary Science Archive of ESA implemented the “Release” concept [14]: data is delivered as units (releases), which can be updated (revision). Two specific data elements are included to handle the release concept:
RELEASE_ID
REVISION_ID

RELEASE_ID defines the release number and REVISION_ID defines the revision number.

The data will be split in a couple of different releases to avoid file transfer problems with very huge files. The releases will also be compressed (using bzip2) to minimize the file transfer time.

Every release will be packed to one single file (only for the file transfer from DLR to PSA) using the UNIX tar command with the following options: tar cfv. The following file naming scheme (including release and revision number) will be used for the file transfer ot the releases:

VMC_rel001rev000.tar.bz2

The VMC team delivers only radiometrically calibrated data since raw data are useless for the general public due to a couple of camera problems.

The uncalibrated (raw) data will be delivered to ESTEC in VICAR format six months after the end of the nominal mission together with the radiometric calibration software. No special documentation will be written for these data and the software.

3.1.2 Data Set ID Formation

The data from the nominal mission belong to this dataset:

VEX-V-VMC-3-RDR-V2.0

The data from the first mission extension (starting with orbit 550) belong to this dataset:

VEX-V-VMC-3-RDR-EXT1-V2.0

The data from the second mission extension (starting with orbit 550) belong to this dataset:

VEX-V-VMC-3-RDR-EXT2-V2.0

The data from the third mission extension (starting with orbit 550) belong to this dataset:

VEX-V-VMC-3-RDR-EXT3-V2.0

The data from the fourth mission extension (starting with orbit 550) belong to this dataset:

VEX-V-VMC-3-RDR-EXT4-V2.0

This name follows the standard PDS rules and contains the mission name, the instrument name, describes the level of processing (REDR) and the version number. It is currently not planned to deliver different versions. The DATA_SET_ID must be changed whenever it will become necessary to deliver different versions.

3.1.3 Data Directory Naming Convention

The VMC data are sorted by orbit in the DATA directory, each sub-directory will have the name
oooo
where oooo is the number of the orbit in which the data were taken.

3.1.4 Filenaming Convention

The file naming convention is described in detail in [5]. The image files in the DATA directories follow this convention:
VOOOO_MMM_DD2.IMG

where
OOOO 4 digit orbit number
MMM number of the image in this orbit
DD sensor name (can be N1, N2, VI, UV)
The '2' indicates the level of processing which is archived in PSA/PDS.

Please, note that all sensor data which were taken together will get the same image number.

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

All data apply to version 3.6 of the PDS Standards Reference, please see [1], [6] for details.

3.2.2 Time Standards

All time information in the data follows the SPICE time standards. Please, see [12] for details.
Within the data products themselves, the time standard used is ET (Ephemeris Time), which is a double precision number of seconds. The starting point for this time is the J2000 epoch. This epoch is Greenwich noon on January 1, 2000 Barycentric Dynamical Time. This ephemeris time is calculated from the Spacecraft Onboard Time using the appropriate SPICE routines and the time correlation packages which are provided by ESTEC as a SPICE Clock Kernel. Outside of the products themselves, there are a few instances in the VMC data sets where time flags are provided. The main time values are provided in the data product labels, which provide a start and stop time for the measurement, and a corresponding clock count from the spacecraft. Below, the standards used to define these values are described.

3.2.2.1 START_TIME and STOP_TIME Formation

The PDS formation rule for dates and time in UTC is:

YYYY-MM-DDThh:mm:ss.fff

YYYY year (0000-9999)
MM month (01-12)
DD day of month (01-31)

T	date/time separator
hh	hour (00-23)
mm	minute (00-59)
ss	second (00-59)
fff	fractions of second (000-999) (restricted to 3 digits)

This standard is followed for all START_TIME and STOP_TIME values in the products included in the VMC data sets.

3.2.2.2 SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT

The SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT values represent the on-board time counters (OBT) of the spacecraft and instrument computers. This OBT counter is given in the headers of the experiment telemetry source packets. It contains the data acquisition start time as 32-bit of unit seconds followed by 16-bit of fractional seconds. The time resolution of the fractional part is 2^-16 = 1.52×10^-5 seconds. Thus, the OBT is represented as a decimal real number in floating-point notation with 5 digits after the decimal point.
A reset of the spacecraft clock is represented by an integer number
followed by a slash, e.g. "1/" or "2/".

Example:
SPACECRAFT_CLOCK_START_COUNT = "1/21983325.39258"

3.2.3 Reference Systems

The reference systems used for orbit, attitude, and target body follow the SPICE standards and are defined in the different SPICE kernels. Please, see [3], and [12] for details.

All latitudes and longitudes are given in degrees, latitudes are planetocentric.

3.2.4 Other Applicable Standards

No other standards are used.

3.3 Data Validation

The validation of these volumes is divided into two processes:

The first process is to check that the volumes are technically correct:
- Insure that the volume is complete, and has correct structure as defined in this document.
- Insure that dynamically generated file, such as index and catalog files are correct and complete.
- Insure that structure of each generated volume is PDS compliant

These steps will be performed using PVV, the PSA Validation and Verification Tool developed by ESTEC [13].

The second process is to check that the image data contained in the data volumes are correct. This will be done by visual inspection by the PI and the CoIs (tbd). Specific tools for automated checks may be developed by the teams in charge for this step.

3.4 Content

3.4.1 Volume Set

There are no volume sets since the data will be delivered electronically. It is not planned to generate archives on any medium (like CD-ROM or DVD).

3.4.2 Data Set

There are five datasets, one contains the data from the nominal mission, the second one (starting at orbit 550) contains the data from the first mission extension, the third one contains the data from the second mission extension, the fourth one contains the data from the third mission extension, and te fivth one contains the data from the fourth mission extension.

3.4.3 Directories

3.4.3.1 Root Directory

The Root Directory contains the following standard PDS files:
AAREADME.TXT
ERRATA.TXT
VOLDESC.CAT

3.4.3.2 Calibration Directory

There is no calibration directory for the data set VEX-V-VMC-3-RDR-V1.0, the data are already radiometrically calibrated.

Information about the geometric calibration can be found in the SPICE instrument kernel which is distributed seperately by PSA.

3.4.3.3 Catalog Directory

The Catalog Directory contains the following standard PDS files:
CATINFO.TXT
DATASET.CAT
INST.CAT
INSTHOST.CAT

MISSION.CAT
PERSON.CAT
REF.CAT
This directory also contains the file RELEASE.CAT as described in [14]. This file is necessary to use the release concept developed by PSA.

3.4.3.4 Index Directory

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

The Index Directory contains the required PDS index files which are generated by PVV [13].

3.4.3.4.2 Geometric Index File, geoindex.lbl and geoindex.tab

The Index Directory also contains the Geometric Index File as defined in [7].
The geometry index files contains the information for 100 points in the VMC image when at least a part of Venus is visible in the image. These 100 points are the same as in the label entries FOOTPRINT_POINT_LATITUDE and FOOTPRINT_POINT_LONGITUDE which describe the footprint of the image.

3.4.3.4.3 Other Index Files

The data set also contains browse index files which are generated using PVV [13].
Browse images are still tbd, please see 3.4.3.5

3.4.3.5 Browse Directory and Browse Files

It is still tbd if browse image are necssary. The original images data are already very small (512x512).
This will be decided when a sufficient set of Venus data will be available.

3.4.3.6 Geometry Directory

This directory has the same structure as the DATA directory, the files are sorted by orbit number.
The geometry files have the same filename as the image files, only the extension is changed to GEO.
Each geometry file has five bands:
INCIDENCE ANGLE, EMISSION ANGLE, PHASE ANGLE, LATITUDE, and LONGITUDE
The unit for all five bands is DEGREE.

All external geometry information (orbit data, attitude data, etc.) can be found in the Venus Express SPICE data set. The SPICE data are released as seperate data sets and are necessary for the generation of higher data levels, SPICE kernels will not be available as separate release at the time of the first VMC data release, unfortunately.
The user of the VMC data has to get the SPICE kernels from the ftp server at ESTEC
ftp:// ssols01.esac.esa.int/pub/projects/vex/data/spice/kernels/
or from the ftp mirror at NAIF
ftp://naif.jpl.nasa.gov/pub/naif/VEX/kernels/

3.4.3.7 Software Directory

No software will be delivered.

Software to read the images and the geometry files is available at different locations, e.g.:

- IDL PDS Reader Library
http://pds-smallbodies.astro.umd.edu/tools/tools_readPDS.shtml

- PDS Image Readers
http://www.planetary.org/explore/space-topics/space-imaging/data.html
http://www.mmedia.is/bjj/utils/img2png/

- GIMP and Plug-in to load PDS images into GIMP
http://www.gimp.org/
http://registry.gimp.org/node/1627

3.4.3.8 Gazetter Directory

There is no Gazetter Directory.

3.4.3.9 Label Directory

There is no Label directory.

3.4.3.10 Document Directory

This directory contains the documentation for the VMC data sets.
The content is:

- DOCINFO.TXT	the standard PDS info file.
- VMC_EAICD.LBL	the label for the Experimenter to Archive ICD
- VMC_EAICD.PDF	the Adobe PDF file of the Experimenter to Archive ICD
- VMC_EAICD.TXT	the Text file of the Experimenter to Archive ICD
- VMC_ESA_SP.LBL	the label for the VMC Instrument Description published in the ESA SP-13
- VMC_ESA_SP.PDF	the Adobe PDF file of the ESA SP-1325
- VMC_LABEL.LBL	the label for VMC_LABEL.PDF
- VMC_LABEL.PDF	a table summarizing the PDS label
- VMC_NATURE.LBL	the label for VMC_NATURE.PDF
- VMC_NATURE.PDF	an article from Nature summarizing the first scientific results from VMC
- VICAR2.LBL	the Label for the description of the VICAR labels
- VICAR2.TXT	Text file describing the VICAR label.

3.4.3.11 Extras Directory

There is no Extras Directory.

3.4.3.12 Data Directory

The Data Directory contains sub-directories for every orbit which is part of the data set, the directory names are the four digits orbit number. The contents of these sub-directories is described in 3.4.8.

3.4.4 Other Data Products

No Pre-Flight Data Products, Sub-System test data, and instrument calibration data will be delivered to PSA/PDS.

3.4.5 In-Flight Data Products

The VMC data archive contains all data which were taken in Venus orbit.

3.4.6 Software

The VMC processing software was developed in the VICAR environment [11]. VICAR was developed by NASA/JPL and was used for the processing of camera data from many planetary missions (e.g. Viking, Galeileo). The data processing team at DLR in Berlin developed specific modules to process the VMC data.

These modules perform the following steps:

- remove all telemetry headers from the data
- sort the data by sensor and combine the image data with the housekeeping data
- decompression of the data
- radiometric calibration of the data
- apply additonal orbit dependent calibration files to reduce the data artefacts
- calculation of the footprints for every image

3.4.7 Documentation

The contents of the documentation directory is described in 3.4.3.10.

3.4.8 Derived and other Data Products

There are currently no plans to deliver derived and other data products. Also, no data based on the cooperation with other Venus Express teams will be delivered.

4. DETAILED INTERFACE SPECIFICATIONS

4.1. Data Product Structure

The data structure consists of an ASCII PDS label, followed by an embedded ASCII VICAR label, followed by a block of binary image data. Inherent to the VICAR label is the possibility of an ASCII EOL label being appended after the binary data in order to handle label modifications. This EOL label is simply a continuation field for the main VICAR label, when there is no more space for expansion before the image data.

4.2 Label and Header Descriptions

4.2.1 PDS Label

VMC data have an attached PDS label. A PDS label is object-oriented and describes the objects in the data file. The PDS label contains keywords for product identification. The label also contains descriptive information needed to interpret or process the data in the file.

PDS labels are written in Object Description Language (ODL [1]. PDS label statements have the form of "keyword = value". Each label statement is terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects in the file:

^object = location

where the carat character (^, also called a pointer) is followed by the name of the specific data object. The location is the 1-based starting record number for the data object within the file.

4.2.2 PDS Image Object

An IMAGE object is a two-dimensional array of values, all of the same type, each of which is referred to as a *sample*. IMAGE objects are normally processed with special display tools to produce a visual representation of the samples by assigning brightness levels or display colors to the values. An IMAGE consists of a series of lines, each containing the same number of samples.

The required IMAGE keywords define the parameters for simple IMAGE objects:

- LINES is the number of lines in the image.
- LINE_SAMPLES is the number of samples in each line.
- SAMPLE_BITS is the number of bits in each individual sample.
- SAMPLE_TYPE defines the sample data type.

The IMAGE object has a number of keywords relating to image statistics. These keywords will be present in all data, the statistics keywords are:

- MEAN
- MEDIAN
- MAXIMUM
- MINIMUM
- STANDARD_DEVIATION

Many variations on the basic IMAGE object are possible with the addition of optional keywords and/or objects. The "^IMAGE" keyword identifies the start of the image data and will skip over the VICAR label.

4.2.3 Keyword Length Limits

All PDS keywords are limited to 30 characters in length (Section 12.7.3 in PDS Standards Reference). Therefore, software that reads VMC PDS labels must be able to ingest keywords up to 30 characters in length.

4.2.4 Data Type Restrictions

In order to accomodate VICAR dual-labeled files, 16-bit data must be stored as signed data. Unsigned 16-bit data is not supported.

4.2.5 Interpretation of N/A, UNK, and NULL

During the completion of data product labels or catalog files, one or more values may not be available for some set of required data elements. In this case PDS provides the symbolic literals "N/A", "UNK", and "NULL", each of which is appropriate under different circumstances.

- "N/A" ("Not Applicable") indicates that the values within the domain of this data element are not applicable in this instance.

- "UNK" ("Unknown") indicates that the value for the data element is not known and never will be.

- "NULL" is used to flag values that are *temporarily* unknown. It indicates that the data preparer recognizes that a specific value should be applied, but that the true value was not readily available. "NULL" is a placeholder

The following values are used for N/A and UNK in the image labels (as described in chapter 17 of the PDS standards reference [6]):

	Signed Integer (4 byte)	Real
N/A	-2147483648	-1.E32
UNK	2147483647	1.E332

4.2.6 VICAR Label

For all data products, an embedded VICAR label follows the PDS label and is pointed to by the PDS pointer "^IMAGE_HEADER". The VICAR label is also organized in an ASCII, "keyword = value" format, although there are only spaces between keywords (no carriage return/line feeds as in PDS). The information in the VICAR label is an exact copy of the information in the PDS label as defined in the next section. The VICAR label is not intended for the data user, it is only used DLR internal during the processing pipeline.

4.2.7 VICAR Format

The reader is referred to the VICAR File Format document for details of the format, which is available at the URL "http://www-mipl.jpl.nasa.gov/vicar/vic_file_fmt.html". The following text is an excerpt which describes the basic structure:

> A VICAR file consists of two major parts: the labels, which describe what the file is, and the image area, which contains the actual image. The labels are potentially split into two parts, one at the beginning of the file, and one at the end. Normally, only the labels at the front of the file will be present. However, of the EOL keyword in the system label (described below) is equal to 1, then the EOL labels (End Of file Labels) are present. This happens if the labels expand beyond the space allocated for them. The VICAR file is treated as a series of fixed-length records, of size RECSIZE (see below). The image area always starts at a record boundary, so there may be unused space at the end of the label, before the actual image data starts.
>
> The label consists of a sequence of "keyword=value" pairs that describe the image, and is made up entirely of ASCII characters. Each keyword-value pair is separated by spaces. Keywords are strings, up to 32 characters in length, and consist of uppercase characters, underscores ("_"), and numbers (but should start with a letter). Values may be integer, real, or strings, and may be multiple (e.g. an array of 5 integers, but types cannot be mixed in a single value). Spaces may appear on either side of the equals character (=), but are not normally present. The first keyword is always LBLSIZE, which specifies the size of the label area in bytes. LBLSIZE is always a multiple of RECSIZE, even if the labels don't fill up the record. If the labels end before LBLSIZE is reached (the normal case), then a 0 byte terminates the label string. If the labels are exactly LBLSIZE bytes long, a null terminator is not necessarily present. The size of the label string is determined by the occurrence of the first 0 byte, or LBLSIZE bytes, whichever is smaller. If the system keyword EOL has the value 1, then End-Of-file Labels exist at the end of the image area (see above). The EOL labels, if present, start with another LBLSIZE keyword, which is treated exactly the same as the main LBLSIZE keyword. The length of the EOL labels is the smaller of the length to the first 0 byte or the EOL's LBLSIZE. Note that the main LBLSIZE does not include the size of the EOL labels. In order to read in the full label string, simply read in the EOL labels, strip off the LBLSIZE keyword, and append the rest to the end of the main label string.

4.3 Binary Data Storage Conventions

VMC data are stored as binary data. The data are stored in signed 16-bit integers. The PDS and VICAR labels are stored as ASCII text.
The ordering of bits and bytes is only significant for pixel data; all other labeling information is in ASCII.
All data are stored as Most Significant Byte first ("big-endian", as used by e.g. Sun computers and Java)

4.4 PDS keyword table

The same keywords are used for all data. These keywords are described in the following table.
Please, note that more keywords could become necessary if advanced onboard processing will be used.
The decision about advanced onboard processing is delayed until arrival at Venus.
Aditional geometry keywords, e.g. SPACECRAFT_ALTITUDE, can be calculated by the user using the SPICE kernels from the PSA web page ftp://ssols01.esac.esa.int/pub//data/SPICE/VEX/kernels/. The SPICE tutorials from the NAIF web page ftp://naif.jpl.nasa.gov/pub/naif/toolkit_docs/Tutorials/ contain detailed examples in different programming languages how to calculate these values.

FILE_NAME	usual default name of the output file; this entry allows the user to check for accidental renaming of files, filename without path		string	
DATA_SET_ID	The data_set_id element is a unique alphanumeric identifier for a data set or a data product.		string	VEX-V-VMC-2-EDR-V1.0 VEX-V-VMC-3-RDR-V1.0
DATA_SET_NAME	The data_set_name element provides the full name given to a data set or a data product.		string	
PRODUCER_ID	The producer_id element provides a short name or acronym for the producer or producing team/group of a dataset.		string	
PRODUCER_FULL_NAME	The producer_full_name element provides the full_name of the individual mainly responsible for the production of a data set.		string	
PRODUCER_INSTITUTION _NAME	The producer_institution_name element identifies a university, research center, NASA center or other institution associated with the production of a data set.		string	
DETECTOR_ID	identifies which of the ten CCD detectors was used for this particular image.		string	VEX_VMC_NIR-1, VEX_VMC_NIR-2, VEX_VMC_VIS, VEX_VMC_UV
INSTRUMENT_HOST_ID	The instrument_host_id element provides a unique identifier for the host where an instrument is located.		string	VEX
INSTRUMENT_HOST_ NAME	full name of the spacecraft		string	VENUS_EXPRESS
INSTRUMENT_ID	The instrument_id element provides an abbreviated name or acronym which identifies an instrument.		string	VMC

INSTRUMENT_NAME	full name of an instrument		string	VENUS MONITORING CAMERA
INSTRUMENT_TYPE	The instrument_type element identifies the type of an instrument.		string	FRAMING CAMERA
MISSION_NAME	full name of mission		string	VENUS_EXPRESS
MISSION_ID	The mission_id element provides a synonym or mnemonic for the mission_name element.		string	VEX
MISSION_PHASE_NAME	The mission_phase_name element provides the commonly-used identifier of a mission phase.		string	
PROCESSING_LEVEL_ID	identifies the processing level of a data set; parameter must be updated after each processing step according to the program specification , DLR-Levels		int	1 or 2
PRODUCT_CREATION_ TIME	The product_creation_time element defines the UTC system format time when a product was created.		string	
PRODUCT_ID	The product_id data element represents a permanent, unique identifier assigned to a data product by its producer.		string	
PRODUCT_TYPE	The PRODUCT_TYPE data element identifies the type or category of a product within a data set.		string	
RELEASE_ID	Number of the data release		int	
REVISION_ID	Number of the revision in a release		int	
VEX:SCIENCE_CASE_ID	Tbd		int	{1, 2, …, 9, 10}
OBSERVATION_TYPE	Type of the observation this image belongs to.		string	{ tbd }
SPACECRAFT_CLOCK_ START_COUNT	Provides the value of the spacecraft clock at the beginning of a time period of interest.		String	
SPACECRAFT_CLOCK_ STOP_COUNT	Provides the value of the spacecraft clock at the end of a time period of interest.		string	
IMAGE_TIME	Date and time of the middle of the image acquisition in UTC format "YYYY-MM-DDTHH:MM:SS.MMMZ"			
START_TIME	Date and time of the start of the image acquisition in UTC format "YYYY-MM-DDTHH:MM:SS.MMMZ"		string	
STOP_TIME	Date and time of the end of the image acquisition in UTC format "YYYY-MM-		string	

	DDTHH:MM:SS.MMMZ"			
ASCENDING_NODE_ LONGITUDE	value of the angle of the xy-plane of the J2000 coordinate system to the ascending node computed from the spacecraft's position- and velocity vector at periapsis (not to be used during test and cruise)	deg	real	
MAXIMUM_RESOLUTION	highest resolution in an image	m/pixel	real	
FOOTPRINT_POINT_ LATITUDE	The footprint_point_latitude element provides the latitude of a point within an array of points along the border of a footprint, described as a polygon, outlining an imaged area on the planet's surface. Latitude values are planetocentric.	deg	real (100)	
FOOTPRINT_POINT_ LONGITUDE	The footprint_point_longitude element provides the longitude of a point within an array of points along the border of a footprint, described as a polygon, outlining an imaged area on the planet's surface. Longitude values are planetocentric.	deg	real (100)	
ORBIT_NUMBER	number of the orbital revolution of the s/c around the target body (not to be used during test and cruise)		int	
ORBITAL_ECCENTRICITY	value of orbit eccentricity computed from the spacecraft's position- and velocity vector at periapsis (not to be used during test and cruise)		real	
ORBITAL_INCLINATION	value of the angle of inclination with respect to the xy-plane computed from the spacecraft's position- and velocity vector at periapsis		real	
ORBITAL_SEMIMAJOR_ AXIS	value of orbit semi-major axis computed from spacecraft's position- and velocity vector at periapsis (not to be used during test and cruise)	km	real	
PERIAPSIS_ALTITUDE	The PERIAPSIS_ALTITUDE element provides the distance between the spacecraft and the target body at periapsis. Periapsis is the closest approach point of the spacecraft to the target body in its orbit around the target body.	km	real	
PERIAPSIS_ARGUMENT_ ANGLE	angle in the xy-plane of the J2000 coordinate system from the ascending node to periapsis (not to be used during test and cruise)	deg	real	
PERIAPSIS_TIME	The PERIAPSIS_TIME element is the time, in UTC format "YYYY-MM-DDThh:mm:ss[.fff]Z", when the spacecraft passes through periapsis. Periapsis is the closest approach point of the spacecraft to the target body in its orbit around the target body. (not to be	time	string	

SPACECRAFT_ ORIENTATION	The spacecraft orientation element provides the orientation of a spacecraft in orbit or cruise in respect to a given frame. E.g. a non-spinning spacecraft might be flown in +Y or -Y direction in respect to the spacecraft mechanical build frame. This element shall be used in combination with the keyword spacecraft_orientation_desc that describes the convention used to describe the spacecraft orientation. The spacecraft orientation shall be given as a 3-tuple, one value for the x,y and z axes		real	
SPACECRAFT_POINTING_ MODE	The spacecraft pointing element provides information on the pointing mode of the spacecraft. The definition of the modes and the standard values are given in the s/c pointing mode description element, that shall always accompany the keyword		string	{"NADIR", "ALONGTRACK", "ACROSSTRACK", “INERT”}
RIGHT_ASCENSION	The right_ascension element provides the right ascension value. Right_ascension is defined as the arc of the celestial equator between the vernal equinox and the point where the hour circle through the given body intersects the Earth's mean equator (reckoned eastward).	degree	real	
DECLINATION	The declination element provides the value of an angle, corresponding to latitude, used to fix position on the celestial sphere. Declination is measured positive north and negative south of the celestial equator, and is defined relative to a specified reference period or epoch.	degree	real	
SPACECRAFT_SOLAR_ DISTANCE	the spacecraft's distance to the Sun measured from its position vector at periapsis (not to be used during test and cruise)	km	real	
TARGET_NAME	name of the target body		string	VENUS, SKY
TARGET_TYPE	The target_type element identifies the type of a named target.		string	PLANET, STAR, SUN, COMET
DETECTOR_ TEMPERATURE	Detector temperature	Celsius	real	
INST_CMPRS_NAME	flag indicating whether spacecraft on-board compression has been bypassed, in which case, the received data were uncompressed		string	NONE, tbd
INST_CMPRS_QUALITY	The compression index. A higher value means more compression		int	
INST_CMPRS_RATIO	mean compression rate for the entire image data represented in the file, this number is =1 for data collected in the bypass mode.		real	

BANDWIDTH	The bandwidth element provides a measure of the spectral width of a filter or channel. For a root-mean-square detector this is the effective bandwidth of the filter i.e., the full width having a flat response over the bandwidth and zero response elsewhere. For VMC this value is for the whole sensor (CCD+Optics).	nm	real	
CENTER_FILTER_ WAVELENGTH	The center_filter_wavelength element provides the mid_point wavelength value between the minimum and maximum instrument filter wavelength values. For VMC this value is for the whole sensor (CCD+Optics).	nm	real	
EXPOSURE_DURATION	Integration time of the instruments CCD.	ms	real	
MACROPIXEL_SIZE	The MACROPIXEL_SIZE element provides the sampling array size (e.g., 2x2, 4x4, 8x8), in pixels, that is used to reduce the amount of data an image contains by summing the values of the pixels, along the lines of the image.		int	
LINE_FIRST_PIXEL	The line_first_pixel element provides the line index for the first pixel that was physically recorded at the beginning of the image array.		int	
SAMPLE_FIRST_PIXEL	The sample_first_pixel element provides the sample index for the first pixel that was physically recorded at the beginning of the image array.		int	
RADIANCE_OFFSET	The radiance_offset element provides the constant value by which a stored radiance is added. Note: Expressed as an equation: true_radiance_value = radiance_offset + radiance_scaling_factor * stored_DN_value.	W/m3/steradian	real	
RADIANCE_ SCALING_FACTOR	The radiance_scaling_factor element provides the constant value by which a stored radiance is multiplied. Note: Expressed as an equation: true_radiance_value = radiance_offset + radiance_scaling_factor * stored_DN_value	W/m3/steradian	real	

4.5. Example PDS Product Label

```
  PDS_VERSION_ID                    = PDS3

/* FILE DATA ELEMENTS */

RECORD_TYPE                              = FIXED_LENGTH
RECORD_BYTES                       = 1024
```

```
FILE_RECORDS                        = 528
LABEL_RECORDS                       = 9

/* POINTERS TO DATA OBJECTS */

^IMAGE_HEADER                       = 10
^IMAGE                              = 17

/* PRODUCER IDENTIFICATION */

PRODUCT_CREATION_TIME               = 2006-11-01T12:42:09.000Z
PRODUCER_FULL_NAME                  = "THOMAS ROATSCH"
PRODUCER_ID                         = DLR
PRODUCER_INSTITUTION_NAME           = "DEUTSCHES ZENTRUM FUER LUFT- UND
                                       RAUMFAHRT"

/* DATA DESCRIPTION AND IDENTIFICATION */

DATA_SET_ID                         = "VEX-V-VMC-3-RDR-V1.0"
DATA_SET_NAME                       = "VENUS EXPRESS VENUS VMC 3 V1.0"
DETECTOR_ID                         = "VEX_VMC_NIR-1"
FILE_NAME                           = "V0025_0000_N12.IMG"
INSTRUMENT_HOST_ID                  = VEX
INSTRUMENT_HOST_NAME                = "VENUS EXPRESS"
INSTRUMENT_ID                       = VMC
INSTRUMENT_NAME                     = "VENUS MONITORING CAMERA"
INSTRUMENT_TYPE                     = "FRAMING CAMERA"
^INSTRUMENT_DESC                    = "INSTRUMENT_DESC.TXT"
MISSION_ID                          = VEX
MISSION_NAME                        = "VENUS EXPRESS"
MISSION_PHASE_NAME                  = PHASE_0
PROCESSING_LEVEL_ID                 = 2
PRODUCT_ID                          = "V0025_0000_N12.IMG"
PRODUCT_TYPE                        = RDR
RELEASE_ID                          = 0001
REVISION_ID                         = 0000

/* TIME RELATED INFORMATION */

SPACECRAFT_CLOCK_START_COUNT        = "1/0038065833.64010"
SPACECRAFT_CLOCK_STOP_COUNT         = "1/0038065833.64207"
IMAGE_TIME                          = 2006-05-15T13:50:34.000Z
START_TIME                          = 2006-05-15T13:50:33.998Z
STOP_TIME                           = 2006-05-15T13:50:34.001Z

/* ORBITAL INFORMATION */

ASCENDING_NODE_LONGITUDE            = 107.3
ORBIT_NUMBER                        = 25
ORBITAL_ECCENTRICITY                = 0.84
ORBITAL_INCLINATION                 = 89.94
ORBITAL_SEMIMAJOR_AXIS              = 39468.3
PERIAPSIS_ALTITUDE                  = 269.17
PERIAPSIS_ARGUMENT_ANGLE            = 101.25
PERIAPSIS_TIME                      = 2006-05-16T01:34:46.000Z
```

```
MAXIMUM_RESOLUTION                    = 46063.6 <m/pixel>
FOOTPRINT_POINT_LATITUDE            = (-11.8599,-12.397,-12.8521,-13.242,
                                                    -13.5773,-13.8648,-
14.1092,-14.4806,
                                                    -14.7057,-14.7646,-
14.7869,-14.7714,
                                                    -14.7159,-14.617,-
14.4702,-13.6511,
                                                    -11.5284,-18.7065,-
18.0101,-17.4004,
                                                    -22.4778,-21.6752,-
23.0756,-23.2093,
                                                    -17.2483,-23.646,-
22.0455,-23.5859,
                                                    -17.0539,-22.5451,-
19.6774,-21.3421,
                                                    -21.6056,-20.8355,-
18.4799,-21.8812,
                                                    -20.7332,-18.4333,-
19.8844,-16.3322,
                                                    -17.3995,-14.1295,-
15.0577,-13.4548,
                                                    -14.3536,-12.5112,-
11.9466,-11.673,
                                                    -4.48951,-6.52847,-
6.90381,-7.43973,
                                                    -7.76693,-7.86837,-
7.93341,-7.96459,
                                                    -7.87035,-7.50725,-
7.32558,-7.11188,
                                                    -6.86434,-6.25669,-
5.8883,-4.42895,
                                                    -3.76713,-2.94906,-
1.83265,-0.525568,
                                                    -
1.46103,4.4672,0.757054,1.83794,
      1.49245,4.26984,0.564325,4.19422,
      4.66562,1.01102,4.67885,3.89761,5.66783
                                                    ,-
0.081147,5.52245,0.597961,3.24192,
      0.851394,1.33399,3.52298,-1.2659,
                                                    -0.721338,1.27833,-
1.6656,1.16806,
                                                    -1.16743,-1.3162,-
4.28845,-1.15241,
                                                    -5.16394,-0.740856,-
11.8599)
FOOTPRINT_POINT_LONGITUDE     = (256.244,256.856,258.482,260.324,
      262.348,264.077,285.237,289.763,302.474
      ,305.836,309.461,312.541,315.801,
```

```
      318.568,321.472,324.429,327.06,329.763,
      332.482,335.173,337.754,340.289,342.782,
      345.456,347.873,350.468,353.01,355.484
      ,357.849,359.915,2.6989,5.2615,7.66938,
9.69767,12.8128,15.5552,18.1162,20.4181
      ,23.5341,26.3797,28.9658,32.2748,
      35.2849,37.9259,41.2141,45.1023,48.381,
      53.0852,56.714,78.584,80.3664,82.3779,
84.2168,85.898,86.6523,87.2512,101.076,
      107.129,112.31,124.06,127.438,130.541,
      133.596,136.433,139.285,141.989,144.629
      ,147.178,149.673,152.157,154.65,156.975
      ,159.308,161.66,164.047,166.526,168.712
      ,170.976,173.303,175.726,177.84,180.49,
      182.759,185.221,187.243,189.942,192.263
      ,194.786,197.679,199.874,202.486,
      205.377,207.992,210.947,214.316,217.572
      ,220.82,224.851,228.694,256.244)
SPACECRAFT_ORIENTATION              = (0.945199,-0.324269,0.0380489)
^SPACECRAFT_ORIENTATION_DESC       = "SPACECRAFT_ORIENTATION_DESC.TXT"
SPACECRAFT_POINTING_MODE            = "NULL"
^SPACECRAFT_POINTING_MODE_DESC     = "SPACECRAFT_POINTING_MODE_DESC.TXT"

/* TARGET IDENTIFICATION */

TARGET_TYPE                               = PLANET
TARGET_NAME                               = VENUS
RIGHT_ASCENSION                     = -1e+32
DECLINATION                               = -1e+32
SPACECRAFT_SOLAR_DISTANCE     = 1.0894e+08

/* SCIENCE OPERATIONS INFORMATION */

VEX:SCIENCE_CASE_ID                 = -2147483647
VEX:^SCIENCE_CASE_ID_DESC         = "VEX_SCIENCE_CASE_ID_DESC.TXT"
OBSERVATION_TYPE                    = "NULL"
^OBSERVATION_TYPE_DESC              = "OBSERVATION_TYPE_DESC.TXT"
```

```
/* INSTRUMENT INFORMATION */

EXPOSURE_DURATION                    = 3.0 <ms>
INST_CMPRS_NAME                      = NONE
INST_CMPRS_RATIO                     = 1.0
INST_CMPRS_QUALITY                   = 0
MACROPIXEL_SIZE                      = 1
LINE_FIRST_PIXEL                           = 1
SAMPLE_FIRST_PIXEL                   = 1
DETECTOR_TEMPERATURE               = 3.4 <degC>

/* RADIOMETRIC DATA INFORMATION */

RADIANCE_OFFSET                      = 0.0 <W*m**-3*sr**-1>
RADIANCE_SCALING_FACTOR              = 378966.0 <W*m**-3*sr**-1>

/* DATA OBJECT DEFINITIONS */

OBJECT                                     = IMAGE
  INTERCHANGE_FORMAT                 = BINARY
  LINES                                    = 512
  LINE_SAMPLES                             = 512
  SAMPLE_TYPE                              = MSB_INTEGER
  SAMPLE_BITS                              = 16
  BANDS                                    = 1
  BAND_STORAGE_TYPE                  = BAND_SEQUENTIAL
  MAXIMUM                                  = 662
  MEAN                                     = 32.1774
  MINIMUM                                  = 0
  STANDARD_DEVIATION                 = 101.901
END_OBJECT                                 = IMAGE
```