EXPERIMENTER TO PLANETARY SCIENCE ARCHIVE INTERFACE CONTROL DOCUMENT (EAICD)

FOR THE

MEX-MARSIS SUBSURFACE (SS) MODE: TOTAL ELECTRON CONTENT (TEC) OF THE IONOSPHERE LEVEL 5 DERIVED DATA

Issue 1.3

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Distribution list

Recipient	Organisation

Change Log

Date	Sections Changed	Reasons for Change
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1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to Archive Interface Control Document) is to provide users of the MEX-MARSIS Level 5 Total Electron Content (TEC) derived data, and also the project archiving authority, with a detailed description of the product. It will also provide a detailed description of the entire data set, the pipeline used to produce the data, and the way in which data should be used.

1.2 Archiving Authorities

The Planetary Data System (PDS) Standard is used as the archiving standard by NASA for U.S. planetary missions, and has, in large part, been adopted by the ESA Planetary Data Archive (PSA). Mars Express data are archived to the PSA by individual Principal Investigator groups, and archived data volumes must comply with PSA standards.

1.3 Contents

This document describes how derived TEC data from the MARSIS instrument are prepared for archiving at the ESA PSA in PDS-compliant form. It includes information on how data were 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 and further explanatory material are given in the appendices.

1.4 Intended Readership

The staff of archiving authority (Planetary Data system for NASA and Planetary Science Archive for ESA) designs team and any potential user of the MARSIS data. Typically, these individuals would be software engineers, data analysts, or planetary scientists.

1.5 Applicable Documents

[AD01] MARSIS Flight User Manual, Issue 3, INFOCOM ID-MAR-0008-INF, 18 December 2003
[AD02] MARSIS DES Operation Sequence Table, Issue 1, LABEN TL 19392, 29 January 2003
[AD03] MARSIS DES Parameters Table, Issue 3, LABEN TL 18546
[AD04] MARSIS Packet Structure Definition, Issue 6, LABEN TL 16927, 3 February 2003
[AD05] Mars Exploration Rover Project Planetary Constants and Models, Version 2, JPL IOM 312.F-02-003, 4 October 2002
[AD06] Mars Express Archive Generation, Validation and Transfer Plan, Revision 1.0, ESA-MEX-TN-4009, 21 June 2001
[AD07] Mars Express Auxiliary Data Conversion into SPICE Kernels and Distribution, Issue 1.0, MEX-EST-PL-10210, 20 September 2002
[AD08] Mars Express Master Science Plan, Draft 1.0, MEX-EST-PL-11912, 12 May 2003
[AD09] Planetary Data System Data Preparation Workbook, Version 3.1, JPL D-7669, Part 1, 17 February 1995
[AD10] Planetary Data System Standards Reference, Version 3.7, JPL D-7669, Part 2, 20 March 2006

[AD11] Planetary Science Data Dictionary, Revision D, JPL D-7116, 15 July 1996
[AD12] Planetary Science Archive - Experiment Data Release Concept, Issue 1.16, SOP-RSSD-TN-015, 12 May 2005
[AD13] Planetary Science Archive - Non-PDS compliant keyword Usage, Draft 2, SOP-RSSD-PL-XXXX, 2 April 2002
[AD14] Planetary Science Archive - Required Keywords, Issue 1.4, SOP-RSSD-LI-004, 27 January 2004
[AD15] Planetary Science Data Archive Technical Note - Geometry and Position Information, Issue 3, Revision 4, SOP-RSSD-TN-010, 9 November 2004
[AD16] Ionospheric impact on MARSIS radar signal. *ESA study contract report* No 21646/08/NL/NR, volume 1.
[AD17] Correcting the ionospheric impact on MARSIS radar signal. *ESA study contract report* No 21646/08/NL/NR, volume 2.
[AD18] Data processed to correct the ionospheric impact on MARSIS radar signal. *ESA study contract report* No 21646/08/NL/NR, volume 3.

The following example list of references directs the data user to additional information regarding the derivation and interpretation of the TEC parameters derived from the MARSIS data (SS mode).

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Melnik, O., and Parrot, M.. 1999. **Propagation of electromagnetic waves through the Martian ionosphere**. *J. Geophys. Res. 104,* 12705.

Mouginot, J., Kofman, W., Safaeinili, A., and Herique, A. 2008. **Correction of the Ionospheric distortion on the MARSIS surface sounding echoes**. *Planet. Space Sci. 56*, 917-926.

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Picardi, G., Plaut, J.J., Biccari, D., Bombaci, O., et al. 2005. **Radar soundings of the subsurface of Mars**. *Science 310*, 1925-1928.

Safaeinili, A., Kofman, W., Nouvel, J-F, Herique, A., and Jordan, R.L. 2003. **Impact of Mars ionosphere on orbital radar sounder operation and data processing**. *Planet. Space Sci. 51*, 505-515.

Safaeinili, A., et al. 2007. **Estimation of the total electron content of the Martian ionosphere using radar sounder surface echoes**. *Geophys. Res. Lett. 34*, L23204.

Schunk, R.W., and Nagy, A.F. 1980. Ionospheres of terrestrial planets. *Rev. Geophys. Space Phys. 18*, 813.

Smith, D.E., et al. 2001. **Mars Orbiter Laser Altimeter : Experiment summary after the first year of global mapping of Mars**. *J. Geophys. Res. 106*, 23689-23722.

1.6 Relationships to Other Interfaces

Other interfaces that have an impact on MARSIS data set generation, packaging, distribution, and documentation include:

- MARSIS calibration data/software: reprocessing of calibration data or a change to the software may have a direct impact on the generation of the data sets.
- Release Concept: Changes would directly impact data set generation, packaging, distribution, and documentation.
- PSA Archive Delivery Requirements: Any delivery requirement changes will directly impact the MARSIS datasets.
- SPICE Data: Changes to these data will affect any geometry files delivered

- PVV Software: Changes to this validation software could force changes to labels or data sets.

1.7 Acronyms and Abbreviations

ACQ	Acquisition phase
AIS	Active Ionosphere Sounding mode
ASDC ASI	Science Data Centre
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
CAL	Calibration mode
CD-ROM	Compact Disk - Read Only Memory
CMP	Compressed data
DCG	Digital Chirp Generator
DVD	Digital Versatile Disk
EAICD	Experimenter to Planetary Science Archive Interface Control Document
ESA	European Space Agency
ESOC	European Space Operation Centre
ESTEC	European Space Technology Centre
FFT	Fast Fourier Transform
IND	Individual Echoes
LOL	Loss of Lock
MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MEX	Mars Express
NPM	Noise Power Measurement
OST	Operation Sequence Table
PSA	Planetary Science Archive
PT	Parameter Table
RAW	Raw data
RXO	Receive Only mode
S/C	Spacecraft
SCET	Spacecraft Elapsed Time
SS1-SS5	Subsurface Sounding modes 1-5
SAZ	Sun Zenith Angle
TEC	Total Electron content

TC	Telecommand
TM	Telemetry
TRK	Tracking phase
UNC	Uncompressed data

1.8 Contact Names and Addresses

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2 OVERVIEW OF INSTRUMENT DESIGN, DATA HANDLING PROCESS AND PRODUCT GENERATION

2.1 Scientific Objectives

The primary objective of MARSIS is to map the distribution of water, both liquid and solid, in the upper portions of the crust of Mars. Detection of such reservoirs of water will address key issues in the hydrologic, geologic, climatic and possible biologic evolution of Mars.

The scope of this document addresses only the secondary objective of using MARSIS as an ionosphere sounder to characterize the interactions of the solar wind with the ionosphere and upper atmosphere of Mars. Radar studies of the ionosphere will allow:

- Global measurements of the ionosphere electron density,
- Investigation of the influence of the Sun and the solar wind on the electron density.

Note: Ionospheric parameters may also be investigated from the Active Ionospheric Sounding MARSIS mode. An example reference is Gurnett et al. [2005].

2.2 Instrument Description

MARSIS is a multi-frequency nadir-looking pulse-limited radar sounder and altimeter, which uses synthetic aperture techniques. MARSIS also has the capability to operate as a topside ionospheric sounder. MARSIS can be effectively operated at any altitude lower than 800 km in subsurface sounding mode, and below ~1200 km in ionosphere sounding mode. The instrument consists of two antenna assemblies and an electronics assembly. Maximum penetration depths are achieved at the lowest frequencies, and penetration will be in the order of a few kilometres, depending on the nature of the material being sounded. On the dayside of Mars, the solar wind-induced ionosphere does not allow subsurface sounding at frequencies below approximately 3.5 MHz, as the signal would be reflected back at the radar without reaching the surface. To achieve greater subsurface probing depths, operations on the night side of Mars are thus strongly preferred.

For subsurface sounding, a “chirp” signal will be generated and transmitted at each operating frequency for a period of about 250 microseconds. The instrument then switches to a receive mode and records the echoes from the surface and subsurface. The total transmit-receive cycle lasts a few milliseconds, depending on altitude. The received signals are passed to a digital-to-analogue converter and compressed in range and azimuth. The azimuth integration accumulates a few seconds of data and results in an along-track footprint size of 10 km. The cross-track footprint size is on the order of 20 km. Digital on-board processing greatly reduces the output data rate to 75 kilobits per second or less. For each along-track footprint, echo profiles will show the received power as a function of time delay, with a depth resolution of 50-100 m, depending on the wave propagation speed in the crust.

Active ionosphere sounding consists of transmitting a pulse from MARSIS at a frequency f, and then measuring the intensity of the reflected radar echo as a function of time delay. For a radar signal incident on a horizontally stratified ionosphere, a strong specular reflection occurs from the level where the wave frequency is equal to the electron plasma frequency. By measuring the time delay for the reflected signal (controlled by the group delay), the plasma frequency, and therefore the electron density can be derived as a function of height. The frequency of the transmitted pulse is systematically stepped to yield time delay as a function of frequency.

2.2.1 Antennas

MARSIS antenna assembly consists of two antennas, a dipole and a monopole. The primary dipole antenna, parallel to the surface and to the direction of spacecraft motion, is used for transmission of pulses and for reception of pulse echoes reflected by the Martian surface, subsurface and ionosphere. The secondary monopole antenna, oriented along the nadir direction, is designed to reduce clutter when MARSIS operates in subsurface sounding mode.

2.2.2 Frequencies

MARSIS is an ultra-wideband radar sounder capable of transmitting at frequencies ranging from approximately 10 kHz to 5.5 MHz. For subsurface sounding, the transmitted signal has a 1 MHz bandwidth, centred at either 1.8 MHz, 3 MHz, 4 MHz or 5 MHz. For ionosphere sounding, transmission frequencies will range from about 10 kHz to 5.5 MHz, with a transmitted bandwidth of 10.937 kHz and an identical frequency granularity.

2.2.3 Transmitted Waveforms

For subsurface sounding, the transmitted waveform is a chirp, a long pulse that is linearly modulated in frequency. Chirps are used when the length of the pulse for the desired range resolution is so short that to achieve good signal-to-noise ratio the pulse would require a peak power exceeding the limits imposed by the mission design. The chirp allows a resolution that depends on the bandwidth of the pulse rather than on its duration, but requires processing of the received signal: with a bandwidth B, the approximate time resolution of the output pulse, after processing is $1/B$.

MARSIS is capable of transmitting two chirps having different frequencies in close succession, thus allowing effective simultaneous subsurface sounding at two different bands.

2.3 *On-board Processing*

Due to limits in permitted data rate for data transmission between the instrument and the solid state mass memory of the spacecraft, and constraints on the data volume that can be down-linked to Earth, most data processing will be performed within the instrument itself. Major tasks performed by MARSIS digital processing unit are Doppler processing, range processing, surface echo acquisition and tracking, and multi-looking. Different operative modes will require all, some or none of these capabilities: this section aims at providing a general description of the working of on-board processing from a subsurface sounding perspective, but differences with other operative modes will be noted as well.

2.3.1 Analogue-to-Digital Conversion

Any signal received from the antennas is converted to digital numbers by means of an analogue-to-digital converter, sampling the waveform at a frequency of 2.8 MHz. To adequately represent the characteristics of a signal containing frequencies higher than the sampling frequency, as for example in the case of subsurface echoes at bands centred at 3 MHz, 4 MHz or 5 MHz, the signal is lowered to a carrier frequency of 0.7 MHz through a mixer before sampling takes place.

2.3.2 I/Q Synthesis

Digital numbers produced by the signal sampling process are represented as 1-byte signed integers, which, aside from a scaling factor, are actual voltages from the real signal. For a more convenient numerical treatment of the signal during digital processing, such samples are converted to single-precision complex numbers (four bytes for both the real and imaginary part) by means of a numerical interpolation scheme called I/Q synthesis, which exploits the fact that real functions have symmetric Fourier transforms to represent signal properties by means of a complex function with only half of the samples of the original real function.

2.3.3 Doppler Processing

Conceptually, Doppler processing of pulse echoes consists in artificially adding a delay, corresponding to a phase shift of the complex signal spectrum, to the samples of each pulse, and then in summing the samples so as to allow the constructive sum of the signal component whose delay (phase shift) from one pulse to the next corresponds to a desired direction (usually nadir or close to nadir). This is called also synthetic aperture processing, and is used to improve both horizontal resolution in the along-track direction and signal-to-noise ratio: horizontal resolution becomes that of an equivalent antenna whose length is equal to the segment of the spacecraft trajectory over which pulse echoes are summed coherently, whereas signal-to-noise ratio improves by a factor equal to the number of coherently summed pulses.

In MARSIS subsurface sounding, the same group of echoes undergoing synthetic aperture processing can be used to focus multiple points on the surface, by changing the phase shift from echo to echo so as to produce constructive interference in different directions. The resulting processed echoes are also called Doppler filters.

2.3.4 Range Processing

Range processing consists in computing the correlation between the transmitted pulse and received echoes. If the transmitted amplitude is constant during the pulse, the correlation with an echo identical to the transmitted signal takes the form of a *(sin x)/x* pulse, whose amplitude is $B\tau$ times the amplitude of the input signal (τ is the chirp duration). This process, called also range compression, is performed on ground for most subsurface sounding modes, on the digitally sampled data, to properly compensate ionospheric effects:

accurate coherent pulse compression requires in fact detailed knowledge of the modulation of the returning signals, whose phase structure is distorted in their (two-way) propagation through the ionosphere.

2.3.5 Multi-Look

Multi-look processing is the non-coherent sum of echoes (that is, phase information in the complex signal is ignored), after both Doppler and range processing, performed to increase the signal-to-noise ratio and reduce speckle, this last being the effect of random fluctuations in the return signal observed from an area-extensive target represented by one pixel. Because this process requires that multiple observations of the same area are available for the summing, it spans across several frames in which the same spot on the surface is observed at slightly different angles of incidence in different adjacent synthetic apertures.

2.3.6 Data Compression

After the completion of on-board processing, to conveniently reduce data volume, digitalized radar echoes can be converted from four-byte real numbers to one-byte integer numbers by extracting and storing the exponent of the sample with the largest absolute value, and by normalizing the entire echo by that exponent. Because the mantissa of a four-byte real number is 23 bits long instead of the 8 bits available in a single-byte representation, data compression causes a loss of precision: this, however, is deemed to be negligible, as the available dynamic range for signal representation is estimated to be above the signal-to-noise ratio.

At the end of the processing described in the previous subsection, compression is performed by first calculating the highest exponent in the numerical vector of real numbers containing the echo. Such exponent is reported with 8-bit precision in the auxiliary data accompanying the frame to which the echo belongs. Then, the vector is normalized to the maximum exponent by shifting to the right the bits of the mantissa of each real sample by a number of positions equal to the difference between the sample exponent and the maximum exponent: this causes the loss of the rightmost bits of the sample mantissa, as only the first 8 bits remaining after the shift are stored for download. It is to be noted that the so-called hidden bit in the IEEE 4-byte representation of a real number is accounted for in the right shifting of the mantissa bits.

2.3.7 Individual Echoes Collection

MARSIS can be programmed to skip all on-board processing and down-link raw data as they come out of the analogue-to-digital converter. This option allows the storage of a number of individual echoes in a memory buffer, for subsequent transmission as science telemetry packets.

Because the data production rate of individual echoes is much higher than the data rate possible on the spacecraft data bus, raw data are acquired only for very limited time intervals, and are then transferred over a much longer time span from MARSIS to the spacecraft mass memory.

It is important to remember that individual echoes collection is possible only during subsurface sounding, and that such echoes always come in addition to the processed data, which are transmitted to the ground in any case. Thus, individual echoes are the unprocessed version of data which are also received, after processing, as part of the scientific telemetry of the instrument.

2.3.8 Data Storage in Flash Memory

Another option available in MARSIS for the retrieval of raw data is the use of flash memory chips within the instrument itself. Collection of echoes from the analogue-to-digital converter is similar to that of individual echoes, but data are stored in a different physical device, a long-term memory that can be read and cleared for subsequent overwriting only by means of a specific telecommand, which causes a dump of its entire content to the spacecraft on-board mass memory.

Also, flash memory can be used to store processed data before the final step of data compression is performed: this option is used mainly to check if truncation of data precision is affecting the results.

It is important to remember that storage of data in the flash memory is possible only during subsurface sounding, and that such data always come in addition to the processed data, which are transmitted to the ground in any case. Thus, the flash memory will contain unprocessed data which are also received, after processing, as part of the scientific telemetry of the instrument.

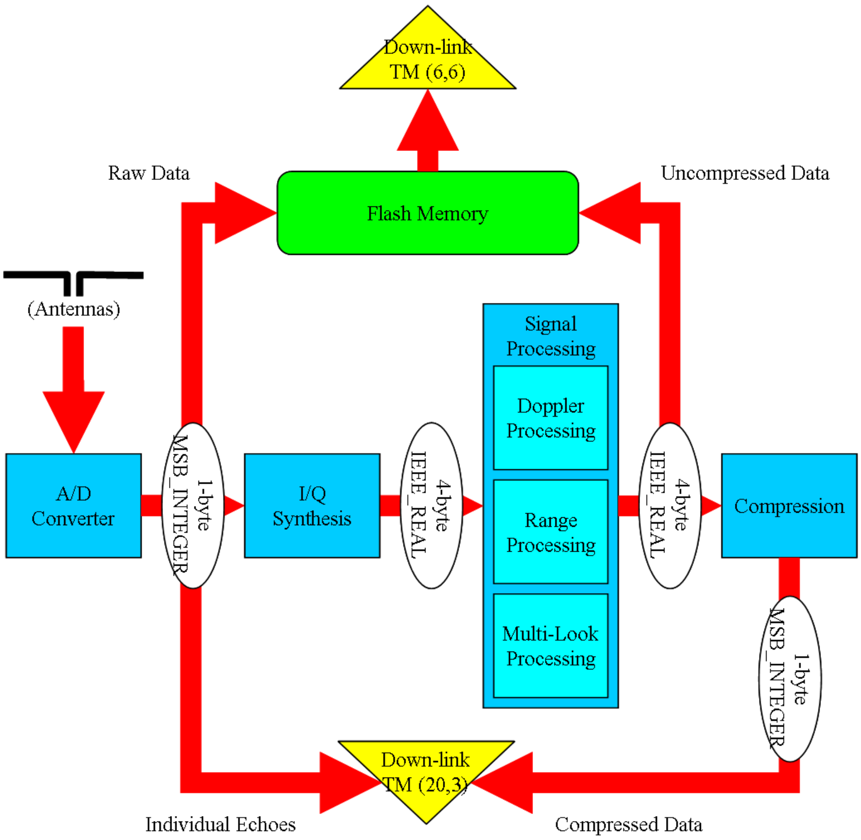

Figure 2.3.8 – 1 Conceptual diagram of MARSIS on-board processing during subsurface sounding. TM (20,3) is the normal scientific telemetry produced by the instrument during operation, while TM (6,6) is the telemetry produced by the instrument following a request to dump the flash memory.

2.3.9 Acquisition Phase

Subsurface sounding is critically dependent on an accurate knowledge of the time delay between transmission and reception to correctly perform the collection and sampling of echoes. Such delay is significantly affected by properties of the Martian ionosphere such as maximum plasma frequency and total electron content, about which very little information is available. MARSIS is thus capable of performing a preliminary determination of the two-way travel time of the transmitted pulse by means of a special way of operating called acquisition phase. Unless programmed to skip acquisition, whenever the instrument enters a new subsurface sounding sub-mode or uses a different frequency band, it starts transmitting a much longer pulse having a much smaller bandwidth (200 kHz), and collecting echoes over a much longer receiving window.

During acquisition, on-board processing of the echoes is aimed at determining the time at which the received power is the greatest, under the assumption that such strong reflection is caused by the surface. Once successfully determined, this time is used to place the receiving window for subsequent sounding in the nominal way of operating, called tracking. During tracking, a check of the received power is continuously performed to determine if changes of the ionosphere have put the echo outside the receiving window: in such instance, the instrument reverts to acquisition until a new time delay between transmission and reception can be determined.

2.3.10 Active Ionospheric Mode

Each active ionosphere sounding observation consists in transmitting and receiving echoes from 160 short, narrow-banded pulses at different frequencies. When a pulse reaches the layer in the ionosphere where the plasma frequency is equal to its frequency, it is reflected back at the radar. Because the detailed variation of the plasma frequency in the ionosphere is unknown, the time delay of each echo cannot be predicted, and it is thus necessary to have an extremely long receiving window to ensure that useful data are collected. To reduce data volume, the receiving window is divided into 80 segments, each of which is as long as the transmitted pulse: power received within each segment is computed, and the result is stored for down-link. Even after this processing, the resulting data rate is still too high for the spacecraft data bus, and it is thus necessary to transfer ionosphere data from MARSIS to the spacecraft mass memory over a time span six times longer than the one used for their acquisition.

2.3.11 Passive Ionosphere Sounding

Passive ionosphere sounding is performed during every subsurface sounding observation, by opening the receiver and collecting the signal produced by the ionosphere plasma around the spacecraft. A weak, thermally excited emission line can often be detected in ionosphere plasmas at the electron plasma frequency: the spectrum of the recorded signal will thus allow the determination of the local electron density, as derived from the plasma frequency.

Passive Ionosphere Sounding consists in acquiring signal samples, converting them to complex numbers through I/Q synthesis, performing an FFT on them and extracting the square modulus of the resulting spectrum.

2.3.12 Operative Modes

In addition to subsurface and ionosphere sounding, MARSIS is capable of two more data collection modes that are not science-related, but are rather used for the testing of the instrument. Hardware calibration mode and receive-only mode are identical in their sequencing of data acquisition, differing only for the fact that in receive-only mode no pulses are actually transmitted. In both modes, 80 echoes are collected from both antennas at one of the frequency bands used in subsurface sounding, stored in a buffer as they come out of the analogue-to-digital converter, and, because the resulting data rate would be too high for the spacecraft data bus, transferred to the spacecraft mass memory over a time span eighty times longer than the one used for data acquisition. Because of the many possible options in programming the instrument, subsurface sounding has been specialized into five different sub-modes, each of which is characterized by a defined set of pulse transmission, echo reception and on-board processing choices. Their different characteristics, as well as those of all remaining operative modes, are summarized in the table below.

Operative Mode	**Acronym**	**Transmitted Waveform**	**Receiving Antennas**	**On-board Processing**
Hardware calibration	CAL	Chirp (One band)	Dipole Monopole	None
Receive only	RXO	None (One band)	Dipole Monopole	None
Active ionosphere sounding	AIS	Monochormatic pulse	Dipole	Echo power evaluation

Susurface souding 1	SS1	Chirp (two bands)	Dipole Monopole	I/Q synthesis Doppler processing (one Doppler filter) Data compression
Subsurface souding 2	SS2	Chirp (two bands)	Dipole	I/Q synthesis Doppler processing (one Doppler filter) Range processing Multi-look processing Data compression
Subsurface souding 3	SS3	Chirp (two bands)	Dipole Monopole	I/Q synthesis Doppler processing (three Doppler filter) Data compression
Subsurface souding 4	SS4	Chirp (one band)	Dipole	I/Q synthesis Doppler processing (five Doppler filter) Data compression
Subsurface souding 5	SS5	Unmodulated pulse train (two bands)	Dipole Monopole	I/Q synthesis Doppler processing (three Doppler filter) Data compression
Passive ionosphere sounding	PIS	None (two bands)	Dipole Monopole	I/Q synthesis Echo power evaluation

Table 2.3.12 – 1 Characteristics of pulse transmission, echo reception and on-board processing for MARSIS operative modes.

2.4 Instrument Operation

MARSIS has been designed to perform subsurface sounding at each orbit when the altitude is below 800 km. A highly eccentric orbit such as the baseline orbit places the spacecraft within 800 km from the surface for a period of about 26 minutes. This would allow mapping of about 100 degrees of arc on the surface of Mars each orbit, allowing extensive coverage at all latitudes within the nominal mission duration. To achieve this global coverage MARSIS has been designed to support both day side and night side operations, although performances are maximized during night time (solar zenith angle >80°), when the ionosphere plasma frequency drops off significantly and the lower frequency bands, which have greater subsurface penetration capability, can be used.

AIS will be also carried out by MARSIS at certain passes when the S/C is below 1200 km of altitude, both during day and night time.

The MARSIS instrument is commanded by means of two tables, the Operations Sequence Table and the Parameters Table, which are up-linked from the ground as part of the instrument programming and commanding, and loaded into instrument memory at switch-on.

2.4.1 Operation Sequence Table

The OST contains commands, which specify selection of operative modes and their duration for the current orbit. Contents of the OST are prepared on the ground, based on the Science Team decisions on which antenna configuration (dipole only or dipole and monopole), frequency and mode duration to use in a particular part of the orbit. In addition, the OST contains necessary parameters to perform Passive Ionosphere Sounding, parameters for SS2 mode, transmission power, ground acquisition presets and flash memory management. The maximum number of rows in an OST is 512. It is possible to execute two tables during the same orbit, but this requires rebooting the instrument to force the upload of another OST.

The following table contains a brief description of fields in the OST. For more information on these fields, refer to [AD02].

OST field	**Number of bits**	**Bit position**	**Description**
Pad	8	1-8	Not significant
Mode duration	24	9-32	Duration of the mode expressed in PRI
Pad	2	33-34	Not significant
Mode selection	4	35-38	Engineering modes : CHECK/INIT(0), STANDBY (1), WARM-UP1(2), WARMUP2(3), IDLE(4) Calibration modes: CALIBR (5), REC. ONLY(6). Science modes: ACT. IONO (7), SS1(8), SS2 (9), SS3 (10), SS4(11), SS5 (12) Flash memory mgmt : data writing in Flash Memory (13) SPARE
DCG configuration	4	39-42	Configuration of the Digital Chirp Generator xxyy: xx refer to the first band transmitted, yy to the second, if two frequencies are used. xx (or yy) = 00 -> B1; xx (or yy) = 01 -> B2 xx (or yy) = 10 -> B3; xx (or yy) = 11 -> B4 In AIS these bits are used as an address to select the requested row in the AIS frequencies table
PI-1 Band selection	3	43-45	band selection for Passive Ionospheric Sounding (PIS) acquisition in the first 5 PRIs of the PIS slot PI-1 = 000 -> B0; PI-1 = 001 -> B1; PI-1 = 010 -> B2 PI-1 = 011 -> B3; PI-1 = 100 -> B4
PI-2 Band selection	3	46-48	band selection for PIS acquisition in the second 5 PRIs of the PIS slot (see PI-1 Band Sel)
PIM_RX	1	49	PIM_RX = 0 -> PIS data from the dipole antenna PIM_RX = 1 -> PIS data from the monopole antenna
Ref_Alg_Sel	2	50-51	Ref_Alg_Sel = 0 -> in TRK use the default reference functions Ref_Alg_Sel = 01 -> in TRK use contrast method to evaluate the reference functions Ref_Alg_Sel = 10 -> in TRK use FSR method to evaluate the reference functions
LOL logic MF	2	52-53	Xy: x refer to the first band transmitted, y to the second one.
Preset tracking	1	54	PT = 0 -> acquisition/tracking operation PT = 1 -> preset tracking operation
F_NPM Address	2	55-56	Band of the Noise Power Measurement during ACQ f_NPM = 00 -> B1 f_NPM = 01 -> B2 f_NPM = 10 -> B3 f_NPM = 11 -> B4
Slope address	4	57-60	binary 4 bit integer addressing among 16 available in PT the value to be assumed by the variable Slope Address
TX Power	4	61-64	The power level of the transmitted signal in count
A2_0 OST Abscissa	12	65-76	12 bit integer,. Values used to initialise the Contrast Method
Ind. Echoes or flash memory	4	77-80	Individual Echoes and Flash Memory Management.

Table 2.4.1 – 1 Parameters and values contained in the Operation Sequence

2.4.2 Parameter Table

The Parameters Table specifies values that apply to all Operational Modes and to the general behaviour of the instrument.

The Parameter Table is a permanent table that is stored in the MARSIS instrument, in contrast to the OST, which is uploaded for every orbit. This tables stores parameters necessary for MARSIS operations and on-board data processing. Values of parameter table are documented in [AD03]. Some values in the PT are physical constants (e.g. speed of light) and some (e.g. coefficients for range to surface, radial and tangential velocity polynomials) are later reported as part of the ancillary data accompanying scientific data. Contents of the PT that are relevant for on-board processing are reported in the ancillary data of the instrument.

A default copy of the PT is maintained in a permanent memory area and it is loaded in the volatile portion of the memory upon instrument boot. During flight, it is possible to change or update the value of one or more parameters stored in the volatile copy of the PT, by means of a dedicated telecommand. It is also possible to update or change the value of parameters stored in the default copy of the PT, in the permanent memory, by means of the standard memory patch services.

2.5 Data Handling Process

In general, data products are generated by the MARSIS team according to the following scheme.

- The PI Institution (INFOCOM) receives the MARSIS instrument data records (Level 1a data) at the MARSIS data processing facility from the Mars Express Project Data Distribution System (DDS).
- From the raw data, INFOCOM generates Level 1b data files (including necessary ancillary data files) in agreed formats, and makes these data files available on the MARSIS ASDC server.
- The Level 1a and Level 1b data files are then automatically transferred to the Iowa MARSIS processing facility on a regular basis via the data mirroring function.
- Once made available on the MARSIS ASDC server, Level 1b data can be retrieved by authorized data users for scientific analysis. Data retrieval is performed by each data user by means of FTP.
- Subsurface data products of Level 2 and higher are generated at the data processing facility located in ThalesAlenia Space (MOC –Marsis Operation Center). Ionospheric data products of Level 2 and higher are generated at Iowa.
- Following internal validation, the Level 2 and higher level subsurface data products are made available on the MARSIS ASDC server, where can be retrieved by authorized data users for scientific analysis. Data retrieval is performed by each data user by means of FTP.
- Following internal validation, the Level 2 and higher level ionospheric data products are made available in the Iowa MARSIS processing facility for access via a Web browser-based display tool (restricted to authorized data users).
- The processed Ionospheric Sounding data products are made PDS-compliant, and, at approximately 6-month intervals, following final internal validation, are delivered to the MARSIS PI (INFOCOM) via the MARSIS ASDC server, as described in [AD01].
- On pre-defined dates, currently foreseen at 6-month intervals (see [AD06]), validated, PDS-compliant data of Level 1b, 2, both subsurface and ionosphere, are delivered to the ESA Planetary Science Archive means of the ESA-provided tool PVV.

2.5.1 Data Handling Process for Level 5 TEC data

However, the Level 5 TEC data are processed by the Grenoble Co-I team, following a slightly different scheme.

- The PI Institution (INFOCOM) receives the MARSIS instrument data records (Level 1a data) at the MARSIS data processing facility from the Mars Express Project Data Distribution System (DDS).
- From the raw data, INFOCOM generates Level 1b data files (including necessary ancillary data files) in agreed formats, and makes these data files available on the MARSIS ASDC server.
- The Level 1a and Level 1b data files are then automatically transferred to the Iowa MARSIS processing facility on a regular basis via the data mirroring function.
- Level 1b data are retrieved by Grenoble Co-I team from the JPL (Jet Propulsion Laboratory, US) server https://elbrus.jpl.nasa.gov, and processed to derived Level 5 TEC data products.
- The Level 5 TEC data products are made PDS-compliant, and, at approximately 6-month intervals, following final internal validation, are delivered to the MARSIS PI (INFOCOM) via the MARSIS ASDC server, as described in [AD01].
- On pre-defined dates, currently foreseen at 6-month intervals (see [AD06]), validated, PDS-compliant Level 5 TEC data, are delivered to the ESA's Planetary Science Archive by means of the ESA-provided tool PVV.

2.6 Product Generation

Level 1b processing starts from the telemetry data, as produced by the C&DH system on the spacecraft and passed to the telemetry subsystem: data are still in the form of transfer frame packets organised by contacts or ground tests data. Processing starts by cleaning, merging and time-ordering the packets. This means that duplicate data have been deleted, missing packets are padded out, and the data are organised by orbits. Data then need to be sorted by instrument data types and instrument modes.

MARSIS Level 1b processing orders data in a useful way for the intended users (i.e. radar scientists) and applications (i.e. quick look to monitor hardware performance and higher-level processing), altering and manipulating them as little as possible to avoid the risk of introducing errors and, at the same time, including all necessary information from all relevant sources. Level 1b data are in scientifically useful form, i.e. individual spectra. These data are still uncalibrated.

MARSIS Level 1b data products consist of the data produced by the instrument reconstructed from the scientific telemetry, sorted by instrument state and data type, and provided with spacecraft position, velocity and attitude information. Any other spacecraft telemetry relevant for calibration and processing (e.g. temperature of the receiver) is also included.

Level 1b processing requires the acquisition of MARSIS scientific telemetry and any relevant spacecraft auxiliary data from the Mars Express Data Disposition System (DDS) in ESOC, and of SPICE kernels describing the spacecraft state and attitude from the Auxiliary Data Conversion System (ADCS) in ESTEC.

Both instrument telemetry and ancillary data are stored at the PI processing facility as they accumulates over the course of the mission, to provide the capability to reprocess data in case of errors or to accommodate new information referring to existing data sets.

Level 1b data distribution to the Co-Is and to the Mars Express mission archive is performed by ASDC. It is required by ESA that data products are delivered in batches of six-month worth of data within six months from the last data take (i.e. one year after the beginning of that particular data collection period), but it is necessary that level 1b processing be completed in a much shorter period, to allow enough time for level 2 data processing and data analysis within the MARSIS team before the expiration of the data proprietary period (which is the same six-month time span).

MARSIS TEC Level 5 data products are routinely produced at the Laboratoire de Planétologie de Grenoble, France, via the following process:

1) MARSIS Level 1b data are regularly retrieved from the JPL (Jet Propulsion Laboratory, US) server https://elbrus.jpl.nasa.gov, and stored at the Laboratoire de Planétologie de Grenoble on a local hard disk.

2) From the level 1b data, MARSIS TEC Level 5 data are generated according to the process described in [AD17], and processed into PSA/PDS-compliant Level 5 formats.

2.7 The ionospheric derivation process

The level 5 TEC data are derived following a method described in details by *Mouginot et al.* [2008], [AD17] and [AD18]. The correction method consists in finding the three parameters *[a1 ; a2 ; a3]* defining the signal distortion phase $\Delta\varphi$ induced by the ionosphere. In the time domain, the ionosphere distortion generates a delay and a spreading of the radar pulse. It is clearly visible on MARSIS radargram without correction. A by-product of the ionospheric correction is the TEC, that can be easily obtained from the *[a1 ; a2 ; a3]* parameters.
[a1 ; a2 ; a3] are investigated in ordrer to get $\Delta\varphi$ with the best SNR As initial conditions for this optimization, we use the parameters fitting with a simplified Gaussian density-profile of the ionosphere. Then the optimization is done by using the following constraints:

- A constraint on the vertical position of the surface echo estimated with the digital elevation model MOLA.
- A constraint on the SNR. The signal amplitude must be maximal after correction.

2.8 Overview of Data products

2.8.1 Pre-Flight Data Products

Because of its 40m long antenna, it was not possible to fully test MARSIS on ground in conditions that can be considered representative of actual operations: thus, the MARSIS team does not plan to release pre-flight data products, as they would be useless for the analysis an interpretation of data acquired at Mars.

2.8.2 Sub-Systems Tests

Sub-system tests performed on MARSIS are useful only for engineering purposes: thus, the MARSIS team does not plan to release sub-system test data products, as they would be useless for the analysis and interpretation of data acquired at Mars.

2.8.3 Instrument calibrations

Calibration runs of the instrument involved mainly the determination of the instrument performance at different temperatures, where it was found that the instrument receiver is indeed sensitive to temperature. Data accumulated during on -ground tests are thus used for the calibration of scientific data, but they are not released as a separate data set. Rather, they have been processed to produce calibration files that are part of standard data product releases.

2.8.4 In-Flights Data Products

Data sets are homogeneous in terms of processing level of the data, and can thus be classified according to the definition of Processing Levels Science Data Sets contained in [AD06]. Currently, three levels of processing are foreseen for MARSIS data:

- Level 1b: telemetry data that have been cleaned and merged , time ordered, sorted by instrument data types and instrument modes. Data are in scientifically useful form, but still uncalibrated.
- Level 2: Level 1b with calibration and corrections applied to yield Data in scientific units.
- Level 5: Total Electron Content of the ionosphere derived from Level 1b.

Level 1b data are also called Experiment Data Records (EDR’s for short), Level 2 data Reduced Data Records (RDR’s), Level 5 are Dervied Data Records (DDR’s).

The resulting list of data sets, together with their official names defined according to the PDS standard used for their archiving [AD10], is provided in the table below (Image. 14).

Data Set	Data Set Name
Level 1b	MARS EXPRESS MARS MARSIS EXPERIMENT DATA RECORD V1.0
Level 2 Subsurface sounding	MARS EXPRESS MARS MARSIS REDUCED DATA RECORD SUBSURFACE V1.0
Level 5 Total Electron Content	MARS EXPRESS MARS MARSIS DERIVED SUBSURFACE TEC DATA RECORD V1.0

Table 2.9.4 – 1 MARSIS Data Sets.

2.8.5 Ancillary Data Usage

Ancillary data used in MARSIS data product generation are needed to correctly reference observations in space and time. Geometric information accompanying instrument data is produced by means of software based on the SPICE library, released by the Navigation and Ancillary Information Facility (NAIF) of JPL. Spacecraft trajectory and attitude data produced by ESOC is thus accessed through the SPICE library in the form of pre-processed data files (called kernels) produced by NAIF according to the standards described in [AD07].

3 ARCHIVE FORMAT AND CONTENT

This section describes the features of the MARSIS Standard Product Archive volumes, including the file names, file contents, and file types, which apply to all MARSIS data sets. Specialization of this information to each single data set is provided in Section 4.

3.1 Format and Conventions

3.1.1 Deliveries and Archieve Volume Formats

Delivery of data from the MARSIS team to the PSA for archiving is done through the Internet, according to the incremental data release concept described in [AD12]. In conformity with guidelines also provided in [AD12], data are organized so that one MARSIS data set coincides with a single logical volume, as defined in the PDS standard [AD10]. For the nominal mission the Data Set ID is showed in Table 3.1.1-1:

Data Set Name	Data Set ID	Volume ID
MARS EXPRESS MARS MARSIS EXPERIMENT DATA RECORD V1.0	MEX-M-MARSIS-2-EDR-V1.0	IT_URM1_DINF_MEXME

MARS EXPRESS MARS MARSIS REDUCED DATA RECORD SUBSURFACE V1.0	MEX-M-MARSIS-3-RDR-SS-V1.0	IT_URM1_DINF_MEXMRS
MARS EXPRESS MARS MARSIS DERIVED SUBSURFACE TEC DATA V1.0	MEX-M-MARSIS-5-DDR-SS-TEC-V1.0	IT_URM1_DINF_MEXMDS

Table 3.1.1 – 1 MARSIS Data Sets, Data Set ID's and corresponding Volume ID's.

For extended phases of the mission beyond its nominal duration, Data Set Names and Data Set ID's are changed to denote that they refer to data from the extended mission:

Data Set Name	**Data Set ID**
MARS EXPRESS MARSIS EDR DATA EXTENSION_$_{Y}$ V1.0	MEX-M-MARSIS-2-EDR-EXT$_{y}$-V1.0
MARS EXPRESS MARSIS RDR SUBSURFACE DATA EXTENSION_$_{Y}$ V1.0	MEX-M-MARSIS-3-RDR-SS-EXT$_{y}$-V1.0
MARS EXPRESS MARSIS DERIVED SUBSURFACE TEC DATA EXTENSION_$_{Y}$ V1.0	MEX-M-MARSIS-5-DDR-SS-TEC-EXT$_{y}$-V1.0

Table 3.1.1 – 2 MARSIS Data Set Names and Data Set ID's for extended mission phases.

Where "y" is an integer number used to identify the extended mission phase.

3.1.2 Data Directory Naming Convention

Because it is expected that a large number of data files is present on a volume, the directory containing them is further divided into a number of subdirectories, each containing data collected over ten orbits. These subdirectory are named so as to make clear which data products they contain and when such data were collected. Their name is in the form pppoooX, where ppp is a group of letter denoting the kind of data product contained in the subdirectory (EDR for Experiment Data Records, RDR for Reduced Data Records, DDR for Derived Data Record), and ooo are the digits common to numbers of the orbits in which data were acquired: for example, the subdirectory named EDR188X contains all files of Level 1b data collected from orbit 1880 to orbit 1889.

3.1.3 File naming convention

All data product files throughout different MARSIS data sets are named using the same file naming convention. File names are built by a concatenation of three-letter components separated by underscore characters ("_"). Each component provides one type of information on the content of the file. Components are concatenated in the following order, although not all of them are necessarily present in any given file name:

<File type>_<Operative mode>_<Instrument state>_<Data form>_<Data product>_<Orbit Number>.<Extension>

File type refers to the type of data file: as it will be detailed in the following sections, MARSIS data products can consist of up to two files each, the first of which contains the data proper, and is called a "frame file" (the corresponding component is FRM), while the second, called a "geometry file" (GEO in short) contains geometric information used to locate observations in space and time.

Operative modes, instrument states, data forms and data product types have been defined in Section 2, while the orbit number is a four-digit number identifying an orbit according to rules defined by the Mars Express mission control.

File extension defines the format of data contained in the file: the extension is usually ".DAT", denoting that the file contains a binary table object (data objects are defined according to [AD10]).

Permitted values for different file name components are listed in the table below.

Type	Mode	State	Form	Product	Orbit	Extension
FRM GEO	CAL RXO AIS TEC SS1 SS2 SS3 SS4 SS5	ACQ TRK	RAW IND UNC CMP	EDR RDR DDR	Four-digit Orbit number	.DAT .TAB

Table 3.1.3 – 1 File name components for MARSIS data product files: refer to Section 1.7 for an explanation of the meaning of acronyms.

As it will be illustrated in section dealing with naming schemes applied to individual Data Sets, the maximum length of data files will never exceed the 27 character limit, as not all name components listed in Table 3.1.3 – 1 are used in each individual file name.

3.2 Standards Used in Data Product Generation

3.2.1 PDS standards

All data released by the MARSIS Team for archiving are required to be compliant with the Planetary Data System (PDS) standard [AD09, AD10, AD11]. This standard imposes requirements on several aspects of the data product generation process, among which there is need for detailed documentation describing the origin, structure and processing undergone by data, for their accurate location in space and time, and in general for all auxiliary and ancillary data which are needed for the scientific use of the data product. Also, such information has to be provided in an Object Description Language (ODL), in the format keyword = value, where keyword is a standard term used to label a parameter (e.g. latitude), and value is any allowed information quantifying that parameter.

3.2.2 Time Standards

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 or YYYY-DDDThh:mm:ss.fff, with

- YYYY year (0000-9999)
- MM month (01-12)
- DD day of month (01-31)
- DDD day of year (001-366)
- 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)

3.2.2.2 SC_CLOCK_START_COUNT and SC_CLOCK_STOP_COUNT

The SC_CLOCK*COUNTS represents 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 two integer numbers separated by a point, the first of which represents the integer part of the clock count, and the second of which represents the fractional second part of the clock count. A reset of the spacecraft clock is represented by an integer number followed by a slash, e.g. “1/” or “2/”.

Example 1: SPACECRAFT_CLOCK_START_COUNT = "1/21983325.39258"

Example 2: SPACECRAFT_CLOCK_START_COUNT = "21983325.39258"

Example 3: SPACECRAFT_CLOCK_START_COUNT = "2/0000325.39008"

Example 1 and Example 2 represent the same time instance.

3.2.2.3 OBT to UTC Time Conversion

Universal Time Coordinate (UTC) is a function of the time correlation packages and the on-board time. The time correlation packages are archived and distributed in the SPICE auxiliary data set and contain linear segments that map the on-board time to UTC time. The linear segment is represented by a time offset and a time gradient. The conversion function is:

Time in UTC = offset + (OBT(seconds) + (OBT(fractional part) * 2-16)) *Gradient

3.2.3 Reference Systems

Locations on the surface of Mars are expressed in planetocentric coordinates. Longitude is comprised in the range 0° – 360°.

3.3 Data Validation

Validation of data is performed at different levels of detail and using different procedures. A dedicated tool, called Monitoring Tool, exists in the MARSIS ground segment software to verify the completeness of data received from the spacecraft. Simple control of the syntax of data product labels and of the correct implementation of the directory structure is performed by means of software tools available from PDS.

Finally, scientific validation of the data takes place during the proprietary period as MARSIS Co-I's perform their scientific analysis and examine in detail the content of each data product.

3.4 Content

This section contains all the information that is data product- and detector-independent but is usually the same for all data sets.

3.4.1 Volume Set

As the concept of a volume as defined in the PDS standard is based on physical media, e.g. CD-Rs, the PSA does not use the name volume. Instead, the concept of deliveries is defined for the PSA and the term delivery is used for the PSA. However, here and in the following sections we will use the word "volume" to refer to a standard PDS directory structure for a data set in which the entire data set consists of a single (virtual) volume. Different MARSIS data sets are organized as separate virtual volumes, and the concept of volume set is not used.

3.4.2 Data Set

MARSIS data sets are organized into one data set on one virtual volume, using the standard PDS volume structure. Such structure is described in Section 19.3 of [AD10], and shown in the Figure 3.4.2 – 1 below.

```
[ROOT] - - |
           |- AAREADME.TXT
           |
           |- ERRATA.TXT
           |
           |- VOLDESC.CAT
           |
           |- [BROWSE]
           |    |
           |    |-[ddrxxxX]
           |          |
           |          |- MARSIS_SS_TEC_xxxX.LBL
           |          |
           |          |- MARSIS_SS_TEC_xxxX.PNG
           |
           |- [DATA]
           |    |
           |    |-[ddrxxxX]
           |          |
           |          |- MARSIS_SS_TEC_xxxX.LBL
           |          |
           |          |- MARSIS_SS_TEC_xxxX.TAB
           |
           |- [CATALOG]
           |    |
           |    |- CATINFO.TXT
           |    |- DATASET.CAT
           |    |- RELEASE.CAT
           |    |- MISSION.CAT
           |    |- INSTHOST.CAT
           |    |- INST.CAT
           |    |- PERSON.CAT
           |    |- REFERENCE.CAT
           |    |- SOFT.CAT
           |
```

```
|- [INDEX]
|    |
|    |- INDXINFO.TXT
|    |- INDEX.TAB
|    |- INDEX.LBL
|
|- [DOCUMENT]
|    |- DOCINFO.TXT
|    |- MARSIS_EAICD_TEC.PDF
|    |- MARSIS_EAICD_TEC.TXT
|    |- MARSIS_EAICD_TEC.LBL
|    |- MARSIS_PSD.PDF
|    |- MARSIS_PSD.LBL
|    |- MARSIS_PT.PDF
|    |- MARSIS_PT.LBL
|    |- MARSIS_OST.PDF
|    |- MARSIS_OST.LBL
|    |- MARSIS_FUM.PDF
|    |- MARSIS_FUM.LBL
|    |- IONOPROCESS_REPORT1.PDF
|    |- IONOPROCESS_REPORT1.LBL
|    |- IONOPROCESS_REPORT2.PDF
|    |- IONOPROCESS_REPORT2.LBL
|    |- IONOPROCESS_REPORT3.PDF
|    |- IONOPROCESS_REPORT3.LBL
|    |- IONOPROCESS_REPORT1_PEER-REVIEW.PDF
|    |- IONOPROCESS_REPORT1_PEER-REVIEW.LBL
|    |- IONOPROCESS_REPORT2_PEER-REVIEW.PDF
|    |- IONOPROCESS_REPORT2_PEER-REVIEW.LBL
|    |- IONOPROCESS_REPORT3_PEER-REVIEW.PDF
|    |- IONOPROCESS_REPORT3_PEER-REVIEW.LBL
```

Figure 3.4.2 – 1 Standard PDS volume set organization: one data set, one volume.

The content of each directory shown in Figure 3.4.2 – 1 is detailed in the following sections.

3.4.3 Directories

3.4.3.1 Root Directory

Files in this directory are provided by the MARSIS science team.

File Name	File Contents
ERRATA.TXT	Describes known deficiencies or caveats in the data of this volume.
VOLDESC.CAT	Description of the contents of the volume in a PDS format readable by both humans and computers

Table 3.4.3.1 – 1 Files located in the root directory of a MARSIS data volume.

3.4.3.2 Index Directory

This directory contains indexes, that are files with information that allows a user to locate data of interest. Within the Planetary Science Archive (PSA), index files fulfil two more purposes. First, some index files are read by database software and allow the ingestion of additional parameters into the database. Secondly, the PSA is using the index files to check for correct deliveries of data set releases and revisions into the PSA.

Indexes are written as INDEX_TABLE objects, that is a specific type of PDS ASCII TABLE objects, and are provided with detached PDS label files.

All index files below the INDEX directory within a data set release are unique and are valid for the actual data set and all previous ones. This means that the content of an index file covers all previous data set releases. The set of index files for MARSIS, as required in [AD12], is:

File Name	File Contents
INDXINFO.TXT	Text description of the directory contents
INDEX.LBL	Detached PDS label to describe INDEX.TAB
INDEX_TAB	PDS stable, listing all files in DATA directory for the corresponding release and revision.

Table 3.4.3.2 – 1 Files located in the INDEX subdirectory of a MARSIS data volume.

All index files are patterned according to the standards defined in [AD10], the only difference being the name of the individual columns forming the INDEX_TABLE.

3.4.3.3 Document Directory

Files in this directory are provided by the MARSIS science team, and will remain the same across different volumes.

File Name	File Contents
DOCINFO.TXT	Text description of the directory contents
MARSIS _EAICD_TEC.LBL	PDS label for MARSIS_EAICD_TEC.TXT and MARSIS_EAICD_TEC.PDF
MARSIS _EAICD_TEC.TXT	MARSIS _EAICD_TEC (this document) in plain ASCII text form
IMAGE***.PNG	PNG files containing figures and tables for MARSIS_EAICD_TEC.TXT. *** is a 3-digit number
MARSIS _EAICD_TEC.PDF	MARSIS_EAICD_TEC (this document) in PDF fomat
MARSIS_FUM.LBL	PDS label for MARSIS_FUM.PDF
MARSIS_FUM.PDF	MARSIS Flight User Manual, Issue 3, INFOCOM ID-MAR-0008-INF, 18 December 2003 [AD01]
MARSIS_OST.LBL	PDS label for MARSIS_OST.PDF
MARSIS_OST.PDF	MARSIS DES Operation Sequence Table, Issue 1, LABEN TL 19392, 29 January 2003 [AD02]
MARSIS_PT.LBL	PDS label for MARSIS_PT.PDF
MARSIS_PT.PDF	MARSIS DES Parameters Table, Issue 3, LABEN TL 18546 [AD03]
MARIS_PSD.LBL	PDS label for MARSIS_PSD.PDF
MARSIS_PSD.PDF	MARSIS Packet Structure Definition, Issue 6, LABEN TL 16927, 3 February 2003 [AD04]
IONOPROCESS_REPORT1.PDF	Ionospheric Impact on MARSIS radar signal
IONOPROCESS_REPORT1.LBL	PDS label for IONOPROCESS_REPORT1.PDF
IONOPROCESS_REPORT2.PDF	Correcting the ionospheric impact on MARSIS radar signal
IONOPROCESS_REPORT1.LBL	PDS label for IONOPROCESS_REPORT2.PDF
IONOPROCESS_REPORT2.PDF	MARSIS derived enhanced ionospheric calibration data
IONOPROCESS_REPORT1.LBL	PDS label for IONOPROCESS_REPORT3.PDF
SAFAEINILI_2007.PDF	Reference paper for the ionospheric correction
MOUGINOT _2008.PDF	Reference paper for the ionospheric correction

Table 3.4.3.3 – 1 Files located in the DOCUMENT subdirectory of a MARSIS data volume.

This directory contains additional documentation provided for a better understanding of the data and their use.

3.4.3.4 Catalogue Directory

Files in this directory are catalogue files, that are files containing PDS catalogue objects. Such objects provide high-level information suitable for loading into a database to facilitate searches across data sets, collections and volumes.

The catalogue objects included on a PDS volume also provide local, high-level documentation. The full set of catalogue objects, listed below, is required in the CATALOG directory of every PDS archive volume.

Such files are provided by the MARSIS science team, with the concurrence of the PSA.

File Name	File Contents
CATINFO.TXT	Text description of the directory contents
MISSION.CAT	PDS catalogue object for the mission
INSHOST.CAT	PDS catalogues object for the spacecraft
INST.CAT	PDS catalogues object for the instrument
DATASET.CAT	PDS catalogues object for the MARSIS dataset
PERSON.CAT	PDS catalogues object for key persons involved in MARSIS
REF.CAT	PDS catalogues object for references appearing in the documentation
SOFT.CAT	PDS catalogues object for the software distributed with the dataset
RELEASE.CAT	PDS catalogues object for current release and revision status of the dataset

Table 3.4.3.5 – 1 Files located in the CATALOG subdirectory of a MARSIS data volume.

3.4.3.5 Data Directory

The DATA directory contains actual data products generated by the MARSIS team. Data files are organised into subdirectories, each containing data collected over ten orbits. Subdirectories in the DATA directory is named according to the scheme described in Section 3.1.3.

An example of the organisation of the DATA directory into subdirectories is provided in section 3.1.

4 Detailed Interface Specifications

4.1 Structure and Organisation Overview

TEC Level 5 data consist of ASCII data files and browse data files, each file associated with a detached PDS label. Since the MARSIS observation intervals are related to orbits and not to time, it was decided to arrange the TEC volume accordingly. Data are therefore separated and sorted by orbit numbers wherever possible.

The organisation of the TEC L5 data volume is as follows:

```
[MEX-M-MARSIS-5-DDR-SS-TEC-V1.0] (Root directory)
          |
          |- AAREADME.TXT          Plain text describing volume contents, organization, and its use (this file).
          |
```

```
|- ERRATA.TXT              Describes known deficiencies or caveats in the data of this volume.
|
|- VOLDESC.CAT             High level description of volume contents.
|
|- [BROWSE]                Contains browse plots depicting the data.
|    |
|    |-[DDRxxxX]           Plots of TEC vs. Sun Zenith Angle for each orbit. A label file is provided
|                          for each plot.
|
|- [CATALOG]               Information about the MEX mission, spacecraft, and Total Electron Content
|                          derived process; lists the cognizant personnel and references revelant
|                          documentation.
|
|- [DATA]                  ASCII archived data
|    |
|    |-[DDRxxxX]           TEC Data for each orbit. A label file is provided for each data file.
|
|- [DOCUMENT]              EAICD (this document), instrument technical documentation, the peer-
|                          reviewed articles related to the TEC, and 3 technical reports describing the
|                          TEC and the derived process.
|
|- [INDEX]                 Volume and cumulative indices of archive products
```

Figure 4.1 – 1 Organisation of the TEC L5 data volume

4.2 Data Sets, Definition and Content

4.2.1 Data Directory

The data from the TEC derived process is calibrated and collected into ASCII files by orbit. The directory structure is given below.

```
[DATA]
    |
    |- [DDRxxxX]
          |
          |- MARSIS_SS_TEC_xxxX.LBL
          |
          |- MARSIS_SS_TEC_xxxX.TAB
```

Figure 4.2.1 – 1 Organisation of the Data directory

The file naming scheme for the data products is MARSIS_SS_TEC_xxxX where xxxX represents a 4-digit orbit number (see section 3.1.3 for details). Product information is given in section 4.3

4.2.2 Browse Directory

The browse directory contains Portable Network Graphics (PNG) files of survey plots of the data. The general subdirectory structure is given below.

```
[BROWSE]
    |
    |- [DDRxxxX]
         |
         |- MARSIS_SS_TEC_xxxX.LBL
         |
         |- MARSIS_SS_TEC_xxxX.PNG
```

Figure 4.2.2 – 1 Organisation of the Browse directory

The file naming scheme for the data products is MARSIS_SS_TEC_xxxX where xxxX represents a 4-digit orbit number (see section 3.1.3 for details). Product information is given in section 4.3

4.3 TEC Data Products

There are two types of data products included in the MARSIS TEC L5 archive volume:

1) Fully calibrated derived Total Electron Content data stored in ASCII format.

2) Browse products in a form of a TEC vs. Sun Zenith Angle (SZA) plot for each orbit (PNG file).

4.3.1 TEC_DDR Data Product Design

TEC_DDR data products will be made by a data file containing an ASCII PDS TABLE object along with the associated detached label file, which describing its structure. The data will contain needed parameters to evaluate the ionosphere distortion on MARSIS data signal, as well as the derived TEC, organised into individual frame. Each frame corresponds to a record in the file which is also a column in the PDS ASCII TABLE. A single calibrated TEC frame is a sequence of 10 parameters in ASCII format.

A Data Product contains all frames acquired using the same instrument mode, in the same instrument state and after the same type of on-board processing during a single orbit. Typically, each TEC frame corresponds to a Level 1b frame

4.3.2 TEC_DDR Browse Product Design

This example below represents data for the MARSIS orbit 2500. the SZA is plotted over the TEC along a given MARSIS radargram. Grey zones on the graph correspond to frames having their keyword “FLAG” equals to zero (see DATA_QUALITY_DESCRIPTION section 4.4). Such a picture will be provided for each orbits, in order to compare the derived Total Electron Content enclosed within the corresponding Data Product versus the Sun Zenith Angle of the subspacecraft point.

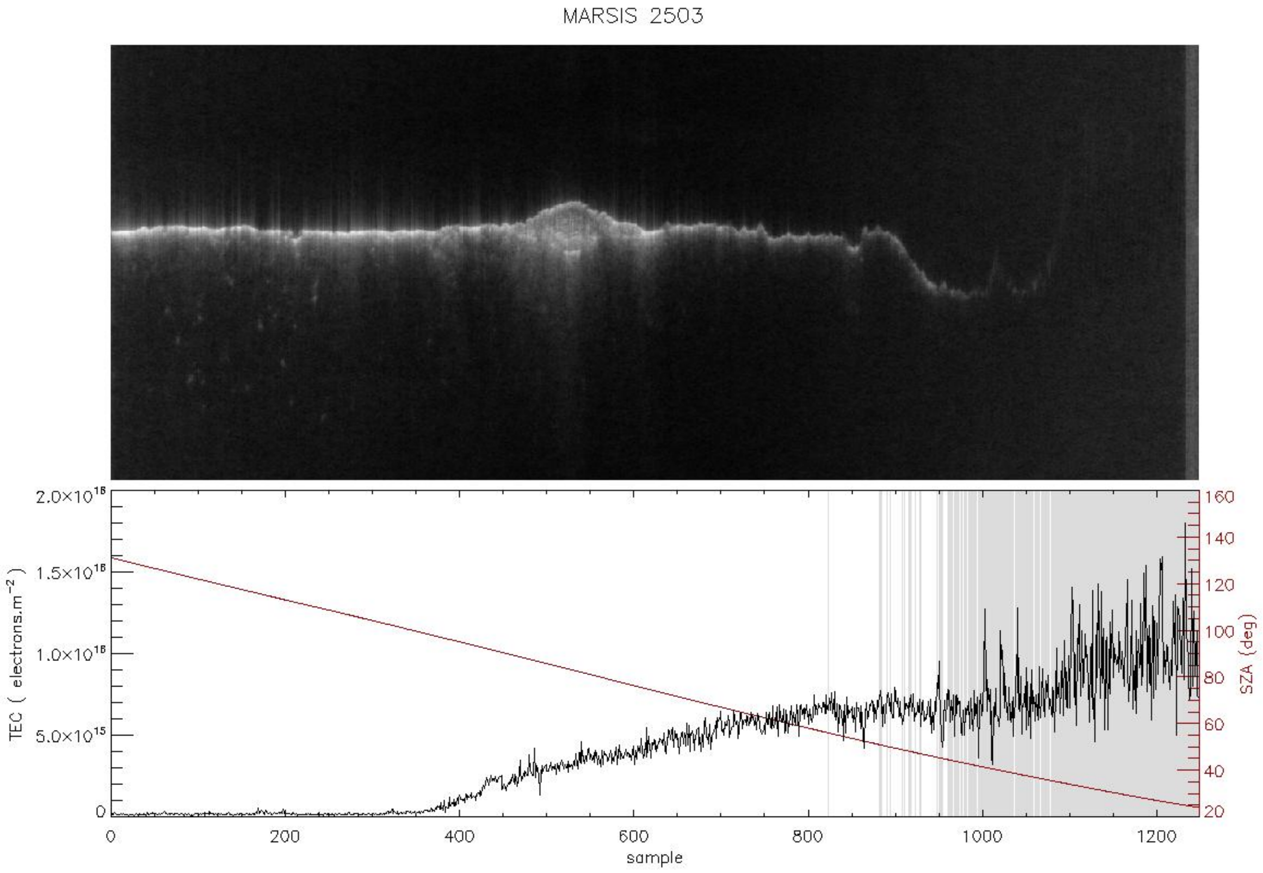

Figure 4.3 – 1 Example of a graphic file available in the browse directory (see text for detail)

4.4 PDS TEC Data Keyword List

The following required list of PDS/PSA keyword-value pairs applies to all MARSIS AIS data. A brief description of each keyword is provided, followed by the value type (i.e. String, Integer), and the actual keyword value used (PDS3, FIXED_LENGTH).

```
PDS_VERSION_ID - This data element represents the version number of the PDS
standards documents that is valid when a data product label is created.
  String
  PDS3

RECORD_TYPE - This element indicates the record format of a file.
  String
  FIXED_LENGTH

RECORD_BYTES - This element indicates the number of bytes in a physical file
record, including record terminators and separators.
  Integer
  400

FILE_RECORDS - This element indicates the number of physical file records,
including both label records and data records.
  Integer
  Equal to the total file length divided by RECORD_BYTES
```

DATA_SET_ID - This element is a unique alphanumeric identifier for a data set or a data product. In most cases it is an abbreviation of the DATA_SET_NAME.
STRING
  MEX-M-MARSIS-5-DDR-SS-TEC-V1.0 (nominal mission, through 31 December 2005)
  MEX-M-MARSIS-5-DDR-SS-TEC-EXT1-V1.0 (mission extension 1)
  MEX-M-MARSIS-5-DDR-SS-TEC-EXT2-V1.0 (mission extension 2)

DATA_SET_NAME - This element provides the full name given to a data set. It typically identifies the instrument that acquired the data, the target of that instrument, and the processing level of the data.
  String
  MARS EXPRESS MARS MARSIS DERIVED SUBSURFACE TEC DATA V1.0
  MARS EXPRESS MARS MARSIS DERIVED SUBSURFACE TEC DATA EXTEND1 V1.0
  MARS EXPRESS MARS MARSIS DERIVED SUBSURFACE TEC DATA EXTEND2 V1.0

PRODUCT_ID - This data element represents a permanent, unique identifier assigned to a data product by its producer.
  String
  For the AIS data set, PRODUCT_ID is the file name including the extension.

PRODUCT_TYPE - This data element identifies the type or category of a data product within a data set.
  String
  RDR

RELEASE_ID - This element defines the unique identifier associated with a specific release of a data set. All initial releases should use a RELEASE_ID value of '0001'. Subsequent releases should use a value that represents the next increment over the previous RELEASE_ID (e.g., the second release should use a RELEASE_ID of '0002'). Releases are done when an existing data set or portion of a data set becomes available for distribution.
  String
  From 0001 to 9999

REVISION_ID - This element is a unique identifier associated with a specific revision of a data set release. A data set revision contains the initial data of a data set release or it might comprise supplementary files that shall be appended to the data set release, or updated files, that shall replace existing files in the data set release, or files existing in the release that shall be deleted from the data set release.
  String
  From 0000 to 9999

PRODUCT_CREATION_TIME - This element defines the local system format time when a product was created.
  Time
  Formation rule is YYYY-MM-DDThh:mm:ss

START_TIME - This element provides the date and time of the beginning of an observation in UTC system format.
  Time
  Formation rule is YYYY-DOYThh:mm:ss.fff

STOP_TIME - This element provides the date and time of the end of an observation in UTC system format.
  Time
  Formation rule is YYYY-DOYThh:mm:ss.fff

SPACECRAFT_CLOCK_START_COUNT - This element provides the value of the spacecraft clock at the beginning of an observation.
  String
  Formation rule is p/cccccccccc.fffff where p is the partition number, c stands for SCET_COARSE, and f for SCET_FINE

SPACECRAFT_CLOCK_STOP_COUNT - This element provides the value of the spacecraft clock at the end of an observation.
  String
  Formation rule is p/cccccccccc.fffff where p is the partition number c stands for SCET_COARSE, and f for SCET_FINE

ORBIT_NUMBER - This element identifies the number of the orbital revolution of the spacecraft around a target body.
  Integer
  Any value used by the Mars Express project

MISSION_PHASE_NAME
  This element provides the commonly-used identifier of a mission phase.
String
  Values (ME Phase 1, for example) are determined by the project, and change according to mission phase.

MISSION_NAME - This element identifies a major planetary mission or project. A given planetary mission may be associated with one or more spacecraft.
  String
  MARS EXPRESS

TARGET_NAME - This element identifies a target.
  String
  MARS

TARGET_TYPE - This element identifies the type of a named target.
  String
  PLANET

INSTRUMENT_HOST_NAME - This element provides the full name of the host on which an instrument is based.
  String
  MARS EXPRESS

INSTRUMENT_HOST_ID - This element provides a unique identifier for the host where an instrument is located.
  String
  MEX

INSTRUMENT_NAME - This element provides the full name of an instrument.
  String
  MARS ADVANCED RADAR FOR SUBSURFACE AND IONOSPHERE SOUNDING

INSTRUMENT_ID - This element provides an abbreviated name or acronym which identifies an instrument.
  String
  MARSIS

INSTRUMENT_TYPE - This element identifies the type of an instrument.
  String
  RADAR

INSTRUMENT_MODE_ID - This element provides an instrument-dependent designation of operating mode. This may be simply a number, letter or code, or a word such as 'normal', 'full resolution', 'near encounter', or 'fixed grating'.
  String
  AIS

INSTRUMENT_MODE_DESC - This element provides an instrument-dependent designation of the INSTRUMENT_MODE_ID in an expanded name format.
  String
  ACTIVE IONOSPHERE SOUNDING

PRODUCER_FULL_NAME - This element provides the full name of the individual mainly responsible for the production of a data set.
  String
  WLODEK KOFMAN, CYRIL GRIMA

PRODUCER_INSTITUTION_NAME - This element identifies a university, research centre, NASA centre or other institution associated with the production of a data set

  String
  LAB DE PLANETOLOGIE DE GRENOBLE UJF/CNRS"

DATA_QUALITY_ID - This element provides a numeric key which identifies the quality of data available for a particular time period.
  String
  -1, 0, 1, 2, 3 or 4

DATA_QUALITY_DESCRIPTION - This element describes the data quality which is associated with a particular DATA_QUALITY_ID value. For TEC Data, the DATA_QUALITY is the percentage of frame having a FLAG equals to 1, meaning the frame has a signal to noise ratio (SNR) greater than 15 dB. SNR is computed by doing the ratio of the brightest echo with the frame noise (more information in [AD 18]). The FLAG is one of the 10 parameters within the Data Products. The various values of DATA_QUALITY_ID and DATA_QUALITY_DESC are instrument dependent.
  String
The DATA_QUALITY_ID is described below.
  -1 = data is of little or no science value
   0 = data has no known deficiencies

   1 = less than 25% low SNR data
   2 = less than 50% low SNR data
   3 = less than 75% low SNR data
   4 = more than 75% low SNR data

4.5 Example PDS TEC Data Product Label

```
PDS_VERSION_ID                 = PDS3
LABEL_REVISION_NOTE            = "2009-01-09 C.GRIMA: DRAFT;
                                  2009-02-19 C.GRIMA: REVISION
                                  2009-04-08 C.GRIMA: REVISION BEFORE RELEASE;"
                                  2009-07-04 C.GRIMA: PARAMETERS ADDED:
                                                      LOCAL_TRUE_SOLAR_TIME
                                                      X_SC_MSO
                                                      Y_SC_MSO
                                                      Z_SC_MSO"

RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 94
FILE_RECORDS                   = 508
FILE_NAME                      = "MARSIS_SS_TEC_3129.LBL"

^TABLE                         = "MARSIS_SS_TEC_3129.TAB"

DATA_SET_ID                    = MEX-M-MARSIS-5-DDR-SS-TEC-EXT1-V1.0
DATA_SET_NAME                  = "MARS EXPRESS MARS MARSIS DERIVED
                                  SUBSURFACE TEC DATA EXTEND_1 V1.0"
```

```
PRODUCT_ID                       = MARSIS_SS_TEC_3129
PRODUCT_TYPE                     = DDR
PRODUCT_CREATION_TIME            = 2009-04-06T17:39:33

MISSION_NAME                     = "MARS EXPRESS"
INSTRUMENT_HOST_ID               = MEX
INSTRUMENT_HOST_NAME             = "MARS EXPRESS"
INSTRUMENT_NAME                  = "MARS ADVANCED RADAR FOR SUBSURFACE
                                    AND IONOSPHERE SOUNDING"
INSTRUMENT_ID                    = MARSIS
TARGET_NAME                      = MARS
TARGET_TYPE                      = PLANET
MISSION_PHASE_NAME               = "ME Phase 3"
MISSION_ID                       = MEX
START_TIME                       = 2006-06-17T19:54:18.279
STOP_TIME                        = 2006-06-17T20:06:44.003
SPACECRAFT_CLOCK_START_COUNT     = 1/0098654054.64709
SPACECRAFT_CLOCK_STOP_COUNT      = 1/0098654800.46630
ORBIT_NUMBER                     = 3129
PRODUCER_ID                      = MARSIS_TEAM
PRODUCER_FULL_NAME               = "WLODEK KOFMAN, CYRIL GRIMA"
PRODUCER_INSTITUTION_NAME        = "LAB DE PLANETOLOGIE DE GRENOBLE UJF/CNRS"
DATA_QUALITY_DESC                = "-1: PERCENTAGE OF LOW SNR DATA NOT AVAILABLE
                                     0: NO LOW SNR DATA
                                     1: LESS THAN 25% LOW SNR DATA
                                     2: LESS THAN 50% LOW SNR DATA
                                     3: LESS THAN 75% LOW SNR DATA
                                     4: MORE THAN 75% LOW SNR DATA"
DATA_QUALITY_ID                  = 1

INSTRUMENT_MODE_DESC             = "N/A"
INSTRUMENT_MODE_ID               = "N/A"
INSTRUMENT_TYPE                  = RADAR
PROCESSING_LEVEL_ID              = 5
PROCESSING_LEVEL_DESC            = "DERIVED RESULTS"

FOOTPRINT_POINT_LATITUDE         = (01.6695,-41.2758)
FOOTPRINT_POINT_LONGITUDE        = (295.8152,295.8275)

OBJECT                           = TABLE
INTERCHANGE_FORMAT               = ASCII
ROWS                             = 508
ROW_BYTES                        = 94
COLUMNS                          = 10

END
```

APPENDICES

A - TEC FORMAT FILE CONTENT

```
OBJECT          = COLUMN
  NAME          = "PULSE_NUMBER"
  COLUMN_NUMBER = 1
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 1
  BYTES         = 4
  UNIT          = "N/A"
  DESCRIPTION   = "THE PULSE NUMBER FOR A GIVEN ORBIT, STARTING AT ZERO"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "EPHEMERIS_TIME"
  COLUMN_NUMBER = 2
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 5
  BYTES         = 20
  UNIT          = "SECOND"
  DESCRIPTION   = "NUMBER OF SECONDS ELAPSED SINCE JAN, 1, 2000, 12:00 UTC
                   CORRESPONDING TO THE TIME OF THE OBSERVATION"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "LATITUDE"
  COLUMN_NUMBER = 3
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 25
  BYTES         = 9
  UNIT          = "DEGREE"
  DESCRIPTION   = "PLANETOCENTRIC LATITUDE OF THE OBSERVATION"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "LONGITUDE"
  COLUMN_NUMBER = 4
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 34
  BYTES         = 9
  UNIT          = "DEGREE"
  DESCRIPTION   = "EAST LONGITUDE OF THE OBSERVATION"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "LOCAL_TRUE_SOLAR_TIME"
  COLUMN_NUMBER = 5
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 43
  BYTES         = 8
  UNIT          = "DECIMAL HOURS"
  DESCRIPTION   = "ANGLE BETWEEN THE MERIDIAN PASSING THROUGH THE
                   SUB-SPACECRAFT POINT AND THE MERIDIAN PASSING THROUGH THE
                   SUBSOLAR POINT OF MARS, EXPRESSED ON A 24-HOURS CLOCK.
                   12.000 CORRESPONDS TO AN ANGLE OF 0 DEGREE, WHILE
                   00.000 CORRESPONDS TO AN ANGLE OF 180 DEGREES"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "X_SC_MSO"
  COLUMN_NUMBER = 6
```

```
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 51
  BYTES         = 11
  UNIT          = "KILOMETERS"
  DESCRIPTION   = "X COMPONENT OF THE POSITION VECTOR FROM MARS CENTER TO
                   THE SPACECRAFT EXPRESSED IN MSO COORDINATES.
                   +X POINTS FROM MARS TOWARD THE SUN
                   +Y POINTS OPPOSITE TO THE ORBITAL MOTION OF MARS
                   +Z COMPLETES THE RIGHT-HAND COORDINATES SYSTEM
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "Y_SC_MSO"
  COLUMN_NUMBER = 7
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 62
  BYTES         = 11
  UNIT          = "KILOMETERS"
  DESCRIPTION   = "Y COMPONENT OF THE POSITION VECTOR FROM MARS CENTER TO
                   THE SPACECRAFT EXPRESSED IN MSO COORDINATES.
                   +X POINTS FROM MARS TOWARD THE SUN
                   +Y POINTS OPPOSITE TO THE ORBITAL MOTION OF MARS
                   +Z COMPLETES THE RIGHT-HAND COORDINATES SYSTEM
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "Z_SC_MSO"
  COLUMN_NUMBER = 8
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 73
  BYTES         = 11
  UNIT          = "KILOMETERS"
  DESCRIPTION   = "Z COMPONENT OF THE POSITION VECTOR FROM MARS CENTER TO
                   THE SPACECRAFT EXPRESSED IN MSO COORDINATES.
                   +X POINTS FROM MARS TOWARD THE SUN
                   +Y POINTS OPPOSITE TO THE ORBITAL MOTION OF MARS
                   +Z COMPLETES THE RIGHT-HAND COORDINATES SYSTEM
  DESCRIPTION   = "EAST LONGITUDE OF THE OBSERVATION"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "SZA"
  COLUMN_NUMBER = 9
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 84
  BYTES         = 8
  UNIT          = "DEGREE"
  DESCRIPTION   = "ANGLE BETWEEN THE ZENITH AND THE APPARENT
                   POSITION OF THE SUN. AT 0 THE SUN IS AT THE ZENITH
                   AND 90 AT THE TERMINATOR"
END_OBJECT      = COLUMN

OBJECT          = COLUMN
  NAME          = "TEC"
  COLUMN_NUMBER = 10
  DATA_TYPE     = ASCII_INTEGER
  START_BYTE    = 92
  BYTES         = 12
  UNIT          = "ELECTRONS PER SQUARED METERS"
  DESCRIPTION   = "TOTAL ELECTRON CONTENT DERIVED FROM THE IONOSPHERE
                   DISTORTION CORRECTION METHOD AS DESCRIBED
                   IN MOUGINOT ET AL. 2008 (SEE THE DOCUMENT DIRECTORY)"
END_OBJECT      = COLUMN
```

```
OBJECT           = COLUMN
  NAME           = "A1"
  COLUMN_NUMBER = 11
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 104
  BYTES          = 12
  UNIT           = "SECOND^(-1.0)"
  DESCRIPTION    = "FIRST PARAMETER OF THE CORRECTION.
                    SEE MOUGINOT ET AL. 2008 (IN THE DOCUMENT DIRECTORY)"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = "A2"
  COLUMN_NUMBER = 12
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 116
  BYTES          = 12
  UNIT           = "SECOND^(-3.0)"
  DESCRIPTION    = "2ND PARAMETER OF THE CORRECTION.
                    SEE MOUGINOT ET AL. 2008 (IN THE DOCUMENT DIRECTORY)"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = "A3"
  COLUMN_NUMBER = 13
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 128
  BYTES          = 12
  UNIT           = "SECOND^(-5.0)"
  DESCRIPTION    = "3RD PARAMETER OF THE CORRECTION.
                    SEE MOUGINOT ET AL. 2008 (IN THE DOCUMENT DIRECTORY)"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = "FLAG"
  COLUMN_NUMBER = 14
  DATA_TYPE      = BOOLEAN
  START_BYTE     = 142
  BYTES          = 1
  UNIT           = "N/A"
  DESCRIPTION    = "0/1 : BELOW/ABOVE SIGNAL TO NOISE RATIO THRESHOLD. SEE
                    MARSIS DERIVED ENHANCED IONOSPHERIC CALIBRATION DATA,
                    TECHNICAL REPORT, VOL3."
END_OBJECT       = COLUMN
```