European Space Agency
Research and Science Support Department
Planetary Missions Division

Huygens-DWE

Experimenter to Archive Interface Control Document

HUY-DWE-EAICD-1

Issue 2.0

1 April 2006

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Change Log

Date	Sections Changed	Reasons for Change
1.9.2005	All	Different data source due to failure of channel A of Cassini-Huygens link

TBD ITEMS

Section	Description

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1 Introduction

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is twofold. First it provides a detailed description of the DWE instrument, its data products, as well as how these were generated, including data sources and destinations. Secondly, it is the official interface between DWE, ESA-PSA and NASA-PDS [1, 2, 3].

1.2 Contents

This document describes the DWE data flow from the Huygens Probe to its archiving in the PSA/PDS. 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. Software that may be used to access the product are explained.

The data set structure and the format of the data product are provided. Examples of these are given in the appendix.

1.3 Intended Readership

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

1.4 Documentation

1.4.1 Reference Documents

- [1] Planetary Data System Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part 1, http://pds.jpl.nasa.gov/dpw/
- [2] Planetary Data System Standards Reference, October 30, 2002, Version 3.5, JPL, D-7669, Part 2, http://pds.jpl.nasa.gov/stdref/
- [3] Huygens Archive Generation, Validation and Transfer Plan, Issue 1.0, 16 July 2004, HUY-RSSD-PL-001

1.4.2 Applicable Documents

- [4] Data Delivery Interface Document (DDID), September 20, 1996, Issue 2.1, ESOC, HMCS-ICD-DDID
- [5] TM/TC Data Tables, August 20, 1997, Issue 6, Rev. B, HUY.AS/c.100.DB.0204
- [6] DWE User Manual, April 1, 1996, Issue 1, Rev. D, DWE-DASA-1000-TN-0002
- [7] The Doppler Wind Experiment: A Titan Zonal Wind Retrieval Algorithm, Robindro Dutta-Roy, 2002, PhD thesis, University Bonn (Germany),

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URN: urn:nbn:de:hbz:5n-00860

- [8] HUYGENS: Science, Payload and Mission, ESA-SP 1177, 1997
- [9] Huygens User Manual, September 15, 1997, Aerospatiale, Issue 4, Rev. B, HUY.AS/c.100.OP.0201
- [10] The Huygens Doppler Wind Experiment: Titan Winds Derived from Probe Radio Frequency Measurements, M.K. Bird, R. Dutta-Roy, M. Heyl, M. Allison, S.W. Asmar, W.M. Folkner, R.A. Preston, D.H. Atkinson, P. Edenhofer, D. Plettemeier, R. Wohlmut, L. Iess, G.L. Tyler, *Space Science Rev.* **104**, 613-640, 2002
- [11] Report of the Descent Trajectory Working Group, D. Atkinson and B. Kazeminejad, Rev. 3, 2004
- [12] Methodology Development for the Reconstruction of the ESA Huygens Probe Entry and Descent Trajectory, B. Kazeminejad, PhD Thesis, Karl-Franzen-Universität, Graz, Austria, 2005
- [13] Davies, M.E.; Abalakin, V.K.; Bursa, M.; Lieske, J.H.; Morando, B.; Morrison, D.; Seidelmann, P.K.; Sinclair, A.T.; Yallop, B.; Tjuflin, Y.S.: Report of the IAU/IAG/COSPAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites: 1994, *Celestial Mechanics and Dynamical Astronomy* **63**, 127, 1996
- [14] Bird, M.K.; Allison, M.; Asmar, S.W.; Atkinson, D.H.; Avruch, I.M.; Dutta-Roy, R.; Dzierma, Y.; Edenhofer, P.; Folkner, W.M.; Gurvits, L.I.; Johnston, D.V.; Plettemeier, D.; Pogrebenko, S.V.; Preston, R.A.; Tyler, G.L.: The vertical profile of winds on Titan, *Nature* **438**, 2005
- [15] Folkner, W.M.; Asmar, S.W.; Border, J.S.; Franklin, G.W.; Finley, S.G.; Gorelik, J.; Johnston, D.V.; Kerzhanovich, V.V.; Lowe, S.T.; Preston, R.A.; Bird, M.K.; Dutta-Roy, R.; Allison, M.; Atkinson, D.H.; Edenhofer, P.; Plettemeier, D.; Tyler, G.L.: Winds on Titan from ground-based tracking of the Huygens probe, JGR, accepted

1.5 Relationships to Other Interfaces

Any products, software and documents that would be affected by a change in this EAICD will be noted on an as needed basis.

1.6 Acronyms and Abbreviations

AD	Applicable Document
DDB	Descent Data Broadcast
DTWG	Descent Trajectory Working Group
DWE	Doppler Wind Experiment
EAICD	Experiment to Archive Interface Control Document
ERT	Earth Received Time
ESA	European Space Agency
HK	Housekeeping
IAU	International Astronomical Union
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
NAV	Navigation
ODT	Orbiter Delay Time
OWLT	One Way Light Time
PDF	Portable Data Format
PDS	Planetary Data System (NASA)
PI	Principle Investigator
PRL	Probe Relay Link
PSA	Planetary Science Archive (ESA)

RD	Reference Document
RSR	Radio Science Receiver
RUSO	Receiver Ultra Stable Oscillator
SCET	Spacecraft Event Time
TCXO	Temperature Compensated Chrystal Oscillator
TUSO	Transmitter Ultra Stable Oscillator
USO	Ultra Stable Oscillator
UTC	Universal Time Coordinated

1.7 Contact Names and Addresses

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2 Overview of Process and Product Generation

For individuals involved in the generation of DWE data product, see section 1.7.

2.1 Overview of the Experiment

The primary objective of the Doppler Wind Experiment (DWE), one of the six scientific investigations comprising the payload of the ESA Huygens Probe [8, 10], was a determination of the wind velocity in Titan's atmosphere [7, 14]. Contemporary wind models predicted rather strong winds in the zonal (east-west) direction, whereas meridional (north-south) and vertical winds were assumed to be rather weak.

Measurements of the Doppler shift of the S-band (2040 MHz) carrier signal to the Cassini Orbiter were foreseen to be recorded aboard Cassini during the Probe descent in order to deduce wind-induced motion of the Probe. Unfortunately, these measurements failed due to a sequencing error in the software to be executed by Cassini during the Huygens mission. Additionally however, several radio telescopes on Earth recorded the carrier signal's frequency and power level. Using those data, all DWE objectives could be achieved.

Specific secondary science objectives of DWE included measurements of:
(a) Doppler fluctuations to determine the turbulence spectrum and possible wave activity in the Titan atmosphere;
(b) Doppler and signal level modulation to monitor Probe descent dynamics (e.g., spin rate and spin phase, parachute swing);
(c) Probe coordinates and orientation during descent and after impact on Titan.

If the Probe descended through regions of turbulence or vertical wave propagation, the Doppler fluctuations provide information on the associated eddy momentum mixing or planetary waves, respectively.

The largest uncertainty in the DWE wind measurement arose from trajectory errors, which lead to a systematic deviation of the measured wind speed from the true value. The stability of the oscillator

used to generate the signal on the Probe (TUSO) lead to a random error much smaller than the possible systematic error. Furthermore, errors associated with measurements that DWE needs as input affected the accuracy of the zonal wind retrieval [7].

The desired accuracy could be achieved only with a sufficiently stable radio signal over the duration of the descent. The specified frequency stability of $\delta f/f \leq 2 \cdot 10^{-10}$ ($\Rightarrow \delta f \leq 0.4$ Hz at S-band) was met by using rubidium-based Ultra-Stable Oscillators (USOs) in both the transmitter (TUSO) and receiver (RUSO), rather than the standard Temperature Compensated Crystal Oscillators (TCXO) [6].

2.2 Experiment Details

Successful execution of the DWE depended critically on the experiment geometry and sequence of events during Titan descent. In order to measure the presumably dominant zonal wind component, it was essential that the respective positions of Probe and Orbiter or ground-based receiving antenna, respectively, provided a favorable projection of the East-West wind drift motion onto the Probe/Orbiter and Probe/antenna lines-of-sight.

Taking this and many other aspects into account, the Huygens Probe mission was eventually performed at the third targeted Titan flyby. The mission date was 14 January 2005, about 6 months after arrival at Saturn. A backup opportunity with very similar geometrical conditions, but with increased fuel expenditure and extended delay for returning to the Cassini Saturn Tour, could have been arranged for the subsequent Titan flyby 32 days later, if necessary [10].

The Probe was separated from the Orbiter on Christmas Day 2004, only 20 days prior to entry into Titan's atmosphere. Two days later, a deflection maneuver brought the Orbiter into a retrograde flyby trajectory that passed “left” of Titan at a minimum altitude near 60,000 km. The Orbiter Delay Time (ODT) was 2.1 hours after Probe entry.

The target delivery accuracy for Huygens, defined by the 3σ targeting error ellipse at the entry altitude of 1270 km, extended ±306 km in the east-west direction and ±35 km in the north-south direction. This ellipse could be reduced *a posteriori* using sun sensor measurements from Huygens and images of Huygens taken by a Cassini camera right after separation [11]. The *a posteriori* initial positional error of Huygens has been determined to be ±17 km in the east-west and ±16 km in the north-south direction. The transmitter, however, started transmitting only after another 4.5 min, at an altitude of 150 km. At this time, the longitude error had increased by error propagation to ±33 km, the latitude error to ±23 km. The large increase of the longitude error is primarily due to uncertainties in wind velocity in the upper atmosphere [12]. As the frequency measurements aboard Cassini failed, the position and velocity errors of Cassini are not anymore of any significance for DWE.

The initial altitude error of Huygens at the 1270 km reference level was determined to ±30 km, based on accelerometer measurements. By integrating *in-situ* pressure measurements upwards from the Titan surface and combining them with the accelerometer based measurements, it was, however, possible to reduce this error. Near the surface, it amounts to ±70 m. It increases with altitude to ±8.5 km at 145 km altitude [11, 12]. Due to the large distance between Huygens and the receiving antenna, the altitude error is not of any significance for DWE, because it hardly affects the observation geometry (projection angles), in contrast to the errors of the curved position components longitude and latitude. The same is true for the negligible errors of the receiving antenna state vectors.

As the Probe entered the Titan atmosphere, it was subject to a deceleration of the order of 13g at an altitude $h \approx 228$ km. A first parachute was deployed at a speed near Mach 1.5 ($h \approx 162$ km), marking the beginning of the descent phase (time = t_0). Slowing to subsonic velocity, the heat shield was jettisoned and transmission of data initiated. Starting at this moment, the carrier frequency of the transmitted signal, used to derive the zonal wind profile, and the signal power were recorded at the Green Bank telescope in West Virginia (USA) and several other telescopes around the globe. Huygens went behind the horizon as seen from Green Bank after 105 min mission time ($t = t_0$ + 105 minutes). The impact on Titan at $t = t_0$ + 150 minutes was observed with the Parkes telescope in Australia, which picked up the Huygens signal at $t = t_0$ + 130 minutes (thus leaving a 25-min gap in the DWE data) and tracked it for another 210 minutes. So far, DWE has evaluated data from Green Bank and Parkes only, which were equipped with special radio science receivers (RSR) for real time signal detection. Recordings from other telescopes are still to be processed.

The Probe then fell at the terminal velocity governed primarily by the ballistic coefficient of the Probe parachute system. It was assumed that the Probe also drifts in longitude with the east/west winds, remaining at a roughly constant latitude for negligible north/south winds. The large initial parachute was released at $t = t_0$ + 15 minutes ($h \approx 111$ km) and replaced by a smaller drogue parachute in order to decrease the descent time. The time constant for the Probe velocity to adjust for changes in the winds decreased toward lower altitudes due to the increasing atmospheric density [7, 8, 9, 10].

Both telescopes Green Bank and Parkes were used also for VLBI observations of Huygens. VLBI needs a fixed phase reference for continuous calibration during the Huygens descent. As no such source was found within the beam towards Huygens, the antennas had to be regularly pointed away from Huygens toward a nearby pulsar, leading to numerous data gaps with lengths of approximately 70-80 s.

2.3 Overview of Zonal Wind Profile Extraction

2.3.1 Extraction of Probe and PSE HK Parameters

Although the data measured during the Huygens descent were redundantly transmitted to Cassini via two separate chains, only one chain (A) was equipped with USOs. Due to a commanding error of the receiver aboard Cassini, the RUSO was not switched on for the mission. Thus, the receiver could not lock onto the Huygens signal, the carrier frequency could not be measured and all data transmitted via chain A were lost.

The originally expected DWE science data, the carrier Doppler shift on chain A (f_R), is part of the housekeeping (HK) data of the Probe Support Avionics aboard Cassini. These data also contain the measured signal-to-noise level and health check parameters for the RUSO (e.g. internal temperatures, internal lock and selection status) and for the radio link (e.g. the carrier lock status). DWE also evaluates Probe HK data from Huygens to check the status and health of the TUSO. The result, based on HK data received via chain B only, is published in the Health Check document.

All HK data are provided to DWE by ESOC. Their binary structure is described in ADs [4] and [5]. The first step in the evaluation process is the extraction of the parameters relevant for DWE from the binary files into human readable ASCII tables [7].

2.3.2 Extraction of Sky Frequencies from Greenbank and Parkes Telescopes

The recording at radio telescopes of the Huygens downlink carrier utilized Radio Science Receivers (RSRs) borrowed from the NASA Deep Space Network and transported to the Green Bank

Telescope and Parkes Radio Telescope solely for this purpose. An RSR is an open-loop receiver driven by a tuning predictions file generated by the Radio Science group based on the latest navigation solution. The RSR is a digital receiver that has a set of bandwidths for the user's choice. For a given bandwidth, a matching sampling rate produces complex samples that are delivered to the user at the completion of the station pass. The RSR input signal is in the 300 MHz range. Thus the station front-end receiver downconverts the sky frequency (S-band) to this range via a fixed local oscillator. The RSR digitally downconverts the input signal to lower frequencies. The user processes the data by first detecting the signal carrier via software. A phase-locked loop (PLL) or a series of Fast Fourier Transforms (FFT) are typical detection methods depending on factors such as the signal to noise ratio as well as frequency and amplitude dynamics. The Huygens signal was detected via FFT, as it was to weak to be detected in a PLL. Once detected, the signal is converted to sky frequency and then frequency residuals are produced by removing a model of the apparent relative motion between the spacecraft and ground station. The original sky frequency is reconstructed from the FFT-measured frequency and knowledge of the local oscillator. The residuals contain the science information on the atmosphere of the planet, which are extracted via another step of processing. The RSR is typically driven by a highly-stable frequency and timing system based on a hydrogen maser [15].

2.3.3 Processing of Carrier Frequency

Due to the failure of chain A, only the Earth-based measurements can be used for the zonal wind retrieval. The measured sky frequency may include a bias, which results from a bias in the TUSO output frequency. This bias has been measured in pre-launch tests to amount to 9.2 Hz at 2040 MHz [6]. An error of this measurement due to retrace effects and inaccuracy of the phase reference used in the pre-launch tests, which may amount to ±2 Hz can, however, not be excluded [R. Kohl (USO manufacturer), private communication].

The *a posteriori* calibration of the bias was performed using the knowledge that Huygens did not move during the surface phase (the bias is adjusted in such a way that the retrieved zonal wind speed during this phase equals zero) and considering the possible error of the pre-launch TUSO bias measurement. The current best estimate for the bias is 10.0 Hz (see Calibration Report).

Also, relativistic effects must be taken into account. For that purpose, the zonal wind retrieval software computes the velocity between the receiving antenna and Titan as well as the gravitational red- and blue-shifts due to the Sun, Saturn, Titan and Earth and subtracts their impact from the measured sky frequency.

2.3.4 Derivation of Zonal Wind Profile

The zonal wind speed along the Huygens descent path, assumed to be identical to the Huygens zonal speed, can be extracted from the de-biased carrier frequency after the removal of all relativistic effects using a straight-forward approach. In a Titan centered inertial frame, the zonal wind speed v_{EW} (positive towards east) is given by

$$v_{EW} = \frac{1}{\cos(\gamma_{EW})} \cdot (v_{LS} + v_A \cdot \cos(\gamma_A) - v_{des} \cdot \cos(\gamma_{des}) - v_{NS} \cdot \cos(\gamma_{NS})) - v_{rot} \qquad (1)$$

where $v_{LS} = -c \cdot f_R / f_0$ (c: speed of light, f_0 = 2040 MHz + TUSO bias: nominal transmitter frequency) is the processed carrier Doppler shift f_R converted to radial speed, γ_{EW} is the angle between the line of sight and the local east-west direction (zonal Doppler Wind Angle), v_A is the speed of the receiving antenna, γ_A is the angle between the line of sight and the antenna velocity, v_{des} is the Huygens descent speed (positive downwards), γ_{des} is the line of sight nadir angle (if v_{des} is negative downwards, then γ_{des} is the line of sight zenith angle), v_{NS} is the Huygens meridional speed (positive

towards south), γ_{NS} is the angle between the line of sight and the local north-south direction (meridional Doppler wind angle; if v_{NS} is positive towards north, then γ_{NS} is the angle between the line of sight and the local south-north direction) and v_{rot} is the local Titan rotation speed.

Equation (1) contains nine parameters, only one of which, f_R, is measured by DWE. The time tags of f_R must, of course, be corrected by the one way light time. The Huygens Descent Trajectory Working Group (DTWG) provides the parameters v_{des} (smoothed by DWE) and v_{NS} (actually latitude, from which DWE computes the time derivative) based on the results of various instruments [11]. The antenna velocity and position as well as Saturn and Titan ephemerides and planetary constants, which are necessary to transform the result into the IAU-Titan frame [13], are provided as SPICE kernels by NASA/JPL.

The angles γ between the various velocity components and the line of sight appearing in Equation (1) are constructed from the position vectors of the receiving antenna and Huygens by computing the dot product between a unit vector in the direction of the velocity component and the line of sight. For instance, γ_{des} is constructed in the following way:

$$\cos\gamma_{des} = \frac{\vec{e}_z \cdot (\vec{x}_H - \vec{x}_A)}{\left|\vec{x}_H - \vec{x}_A\right|} \qquad (2)$$

where $\vec{e}_z$ is a unit vector pointing in the vertical direction at the Huygens position and $\vec{x}_A$ and $\vec{x}_H$ are the positions of the receiving antenna (considering the one way light time) and Huygens, respectively. As already pointed out, the position of the receiving antenna is provided as a SPICE kernel. The Huygens altitude and latitude are provided by DTWG. The Huygens longitude is computed by integrating the Huygens zonal velocity. For this, DWE needs one independent determination of the Huygens longitude above Titan's surface at some particular moment. This is the Huygens longitude at the moment of the first link acquisition, provided by the DTWG [11].

It is clear that any changes in the DTWG product will affect the derived zonal wind profile, which has to be updated in this case. Significant changes in the SPICE kernels are not expected.

The zonal wind integration is performed in an iterative loop: If at time t_i and longitude lon_i a zonal speed v_i was found, v_i is integrated to find lon_{i+1}, where v_{i+1} is computed. The loop then goes back to lon_i and recalculates lon_{i+1} by integrating $(v_i+v_{i+1})/2$. The loop is passed five times, but the difference to passing the loop only once is not significant. This technique is especially useful when v_i and v_{i+1} differ significantly, as it is the case in several data gaps, which occurred during phases of large wind shear, or especially in the 25-min gap between the Green Bank and Parkes tracks.

The DWE evaluation software uses Equation (1) and a Monte Carlo approach, which allows to include the variance of all input parameters to compute the accuracy of the derived zonal wind speed. A more detailed description of the zonal wind profile extraction algorithm including the derivation of Equation (1) is given in AD [7].

2.4 Overview of Data Products

2.4.1 Pre-Flight Data Products

N/a

2.4.2 Sub-System Tests

N/a

2.4.3 Instrument Calibrations

To evaluate the Earth-based Doppler measurements, the removal of a possible bias is the only calibration necessary. In pre-launch tests of the TUSO, this bias has been measured to be 9.2 Hz at 2040 MHz [6]. It should be noted that the inaccuracy of the absolute value of the TUSO output frequency was specified not to exceed 10^{-8} = 20 Hz, but there was no requirement to measure its exact value. The value of 9.2 Hz could be reconstructed from pre-launch unit level measurements, but these measurements are likely to contain an error of up to ±2 Hz due to retrace effects and a possible inaccurate phase reference used in the unit level tests [R. Kohl (USO manufacturer), private communication]. Due to the use of Rubidium-based USOs instead of quartz USOs, no other errors are expected.

The final *a posteriori* calibration of the bias was performed using the knowledge that Huygens did not move during the surface phase (the bias is adjusted in such a way that the retrieved zonal wind speed during this phase equals zero) and considering the possible error of the pre-launch TUSO bias measurement. The current best estimate for the bias is 10.0 Hz. A more detailed description is given in the Calibration Report.

2.4.4 Titan Mission Data Products

HK parameters other than the received carrier frequency on channel A are part of the Probe archive and were not foreseen to be included in the DWE archive. Thus, as a result of the failure of chain A, no HK parameters are archived by DWE. The DWE health is addressed in a report called DWE Health Report. The report is provided in ASCII and PDF format in the document directory. The health of the DWE TUSO was checked by evaluating the following HK parameters of the Probe:

- TUSO internal temperatures
- TUSO internal lock status
- TUSO power status
- TUSO current
- TUSO selection status
- TUSO box temperature

Six tables are provided for the DWE data archive:

1) CARRFREQ_GBT.TAB contains Time (Earth Received Time) and sky frequency from Green Bank Telescope (level 1c). The mean integration time for these frequency measurements was 10 s. The data contain gaps due to VLBI calibration.

2) CARRFREQ_PARKES.TAB contains Time (Earth Received Time) and sky frequency from Parkes Telescope (level 1c). The mean integration time for these frequency measurements was 10 s. The data contain gaps due to VLBI calibration.

3) ANGLES.TAB contains Time (Spacecraft Event Time) and all angles needed to calculate the zonal wind according to Equation (1) (level 1c). This table will be included in the GEOMETRY directory (level 1c).

4) ANTENNA_STATE.TAB contains Time (Earth Received Time) and state vectors of the receiving antenna (position in IAU-Titan, velocity in J2000). This table will be included in the GEOMETRY directory (level 1c).

5) HUYGENS_STATE.TAB contains Time (Spacecraft Event Time) and state vectors of Huygens (altitude/descent speed and latitude/meridional speed from DTWG, descent speed smoothed by DWE, longitude/zonal speed computed by DWE). This table will be included in the GEOMETRY directory (levels 1c and 3).

6) ZONALWIND.TAB contains Time (Spacecraft Event Time), Altitude (provided by DTWG), Zonal wind and Errors (level 3).

All tables have identical time tags, where ERT and SCET time tags are connected through

$$t_{SCET} = t_{ERT} - OWLT$$

with *OWLT* being the One Way Light Time between Huygens and the receiving antenna.

2.4.5 Software

N/a

2.4.6 Documentation

The following documentation is provided for archive:

- DWE-EAICD (MS-Word, ASCII, PDF)
- DWE contribution to ESA SP-1177 [8] (LaTex, PDF)
- DWE Space Science Reviews paper [10] (LaTex, PDF)
- Robindro Dutta-Roy's PhD-Thesis [7] (LaTex, PDF)
- DWE User Manual [6] (MS-Word, ASCII, PDF)
- Health Check Report (LaTex, PDF)
- Calibration Report (LaTex, PDF)
- DWE Nature paper on initial results and supplementary information (ASCII, PDF)

2.4.7 Derived and other Data Products

N/a

3 Archive Format and Content

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

DWE delivers a single data set (one logical archive volume) comprising the sky frequencies measured at Green Bank and Parkes, other necessary input parameters, documentation and the derived zonal wind speed profile.

3.1.2 Data Set ID Formation

Data set name	DWE data set ID
HUYGENS PROBE DWE RESULTS V1.0	HP-SSA-DWE-2-3-DESCENT-V1.0

3.1.3 Data Directory Naming Convention

There are no subdirectories in the DWE data directory.

3.1.4 Filenaming Convention

File names are chosen in such a way that they provide some information about the content of the file (see Sections 2.4.4 and 3.4.3).

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

PDS3 is used.

3.2.2 Time Standards

The time column in the DWE data files is given in UTC, which is either SCET or ERT. As the DWE data recorded on Earth are pure frequency measurements without any timing information, SCET is computed from ERT in the way described in Section 2.4.4.

3.2.3 Reference Systems

The position vectors for the receiving antennas and Huygens are given in the IAU-Titan reference frame (radius, latitude, west longitude). The velocity vectors for the receiving antenna are given in the J2000 reference system centered at the center of Titan. The velocity vectors for Huygens are given in the IAU-Titan reference frame (descent speed, meridional speed and zonal speed).

3.2.4 Other Applicable Standards

N/a

3.3 Data Validation

Scientific value and completeness is checked internally inside the team. PSA/PDS validation is done with the Huygens data archive management team. All data sets are reviewed by independent reviewers.

3.4 Content

3.4.1 Volume Set

N/a

3.4.2 Data Set

N/a

3.4.3 Directories

This is the structure of the DWE data set:

```
ROOT
|
|- AAREADME.TXT
|- VOLDESC.CAT
|
|--[CATALOG]
|          |- CATINFO.TXT
|          |- MISSION.CAT
|          |- INSTRUMENT.CAT
|          |- INSTRUMENT_HOST.CAT
|          |- REFERENCE.CAT
|          |- PERSONNEL.CAT
|          |- DATASET.CAT
|          |- SOFT.CAT
|          |- TARGET.CAT
|
|------[INDEX]
|          |- INDEXINFO.TXT
|          |- INDEX.LBL
|          |- INDEX.TAB
|
|------[CALIB]
|          |- CALINFO.TXT
|          |- DWE_CALIBRATION_REPORT.PDF
|          |- DWE_CALIBRATION_REPORT.TEX
|          |- DWE_CALIBRATION_REPORT.LBL
|
|---[DOCUMENT]
|          |- DOCINFO.TXT
|          |- DWE_EAICD.ASC
|          |- DWE_EAICD.PDF
|          |- DWE_EAICD.DOC
|          |- DWE_EAICD.LBL
|          |- DWE_SP1177.PDF
|          |- DWE_SP1177.TEX
|          |- DWE_SP1177.LBL
|          |- DWE_SSR2001.PDF
|          |- DWE_SSR2001.LBL
|          |- DWE_SSR2001.TEX
|          |- THESIS.PDF
|          |- THESIS.LBL
|          |- THESIS.TEX
|          |- DWE_USERMANUAL.PDF
|          |- DWE_USERMANUAL.ASC
|          |- DWE_USERMANUAL.LBL
|          |- DWE_USERMANUAL.DOC
|          |- HEALTH_CHECK.PDF
|          |- HEALTH_CHECK.TEX
```

```
|           |- HEALTH_CHECK.LBL
|           |- DWE_NATURE2005.PDF
|           |- DWE_NATURE2005.LBL
|           |- DWE_NATURE2005.ASC
|           |- DWE_NATURE2005_SUPINF.PDF
|           |- DWE_NATURE2005_SUPINF.LBL
|           |- DWE_NATURE2005_SUPINF.ASC
|
|------[DATA]
|           |-CARRFREQ_GBT.TAB
|           |-CARRFREQ_GBT.LBL
|           |-CARRFREQ_PARKES.TAB
|           |-CARRFREQ_PARKES.LBL
|           |-ZONALWIND.TAB
|           |-ZONALWIND.LBL
|
|--[GEOMETRY]
|           |-HUYGENS_STATE.TAB
|           |-HUYGENS_STATE.LBL
|           |-ANTENNA_STATE.TAB
|           |-ANTENNA_STATE.LBL
|           |-ANGLES.TAB
|           |-ANGLES.LBL
```

4 Detailed Interface Specifications

4.1 Label #1: CARRFREQ_GBT.LBL

```
PDS_VERSION_ID                  = PDS3

/* FILE CHARACTERISTICS DATA ELEMENTS */

RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 45
FILE_RECORDS                    = 1749

/* DATA OBJECT POINTER IDENTIFICATION ELEMENTS */

^TABLE                          = "CARRFREQ_GBT.TAB"

/* INSTRUMENT AND DETECTOR DESCRIPTIVE DATA ELEMENTS */

FILE_NAME                       = "CARRFREQ_GBT.TAB"
DATA_SET_ID                     = "HP-SSA-DWE-2-3-DESCENT-V1.0"
DATA_SET_NAME                   = "HUYGENS PROBE DWE RESULTS V1.0"
PRODUCT_ID                      = "CARRFREQ_GBT.TAB"
PRODUCT_NAME                    = "DWE SKY FREQUENCIES FROM GREEN BANK"
MISSION_NAME                    = "CASSINI-HUYGENS"
INSTRUMENT_HOST_NAME            = "HUYGENS PROBE"
INSTRUMENT_HOST_ID              = HP
MISSION_PHASE_NAME              = "DESCENT"
PRODUCT_TYPE                    = EDR
START_TIME                      = 2005-01-14T10:19:27.000
STOP_TIME                       = 2005-01-14T12:03:07.000
SPACECRAFT_CLOCK_START_COUNT    = NULL
SPACECRAFT_CLOCK_STOP_COUNT     = NULL
NATIVE_START_TIME               = NULL /* Elapsed time, from To */
NATIVE_STOP_TIME                = NULL
PRODUCT_CREATION_TIME           = 2006-03-01T12:00:00
PRODUCER_ID                     = DWE_ROBIN
PRODUCER_FULL_NAME              = "ROBINDRO DUTTA-ROY"
PRODUCER_INSTITUTION_NAME       = "UNIVERSITY BONN"
TARGET_NAME                     = "TITAN"

/* INSTRUMENT DESCRIPTION */

INSTRUMENT_ID                   = DWE
INSTRUMENT_NAME                 = "DOPPLER WIND EXPERIMENT"
INSTRUMENT_TYPE                 = "RADIO SCIENCE"

/* IF NECESSARY */

DATA_QUALITY_ID                 = 1
DATA_QUALITY_DESC               = "HIGH"

/* DATA OBJECT DEFINITION */
```

```
OBJECT                          = TABLE
 INTERCHANGE_FORMAT             = ASCII
 ROWS                           = 1749
 COLUMNS                        = 2
 ROW_BYTES                      = 45  /* incl. CR/LF */
 DESCRIPTION                    = "This table gives sky frequencies measured
with the RSR at Green Bank"

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 1
     NAME                       = "EARTH RECEIVED TIME (UTC)"
     UNIT                       = "N/A"
     DATA_TYPE                  = TIME
     START_BYTE                 = 1
     BYTES                      = 23
     FORMAT                     = "A23"
     DESCRIPTION                = "reception time of frequency sample"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 2
     NAME                       = "SKY FREQUENCY"
     UNIT                       = "HZ"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 24
     BYTES                      = 20
     FORMAT                     = "F20.4"
     DESCRIPTION                = "sky frequency, mean integration time 2 s"
 END_OBJECT                     = COLUMN

END_OBJECT                      = TABLE

END
```

4.2 Label #2: CARRFREQ_PARKES.LBL

```
PDS_VERSION_ID                  = PDS3

/* FILE CHARACTERISTICS DATA ELEMENTS */

RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 45
FILE_RECORDS                    = 1166

/* DATA OBJECT POINTER IDENTIFICATION ELEMENTS */

^TABLE                          = "CARRFREQ_PARKES.TAB"

/* INSTRUMENT AND DETECTOR DESCRIPTIVE DATA ELEMENTS */

FILE_NAME                       = "CARRFREQ_PARKES.TAB"
DATA_SET_ID                     = "HP-SSA-DWE-2-3-DESCENT-V1.0"
DATA_SET_NAME                   = "HUYGENS PROBE DWE RESULTS V1.0"
PRODUCT_ID                      = "CARRFREQ_PARKES.TAB"
PRODUCT_NAME                    = "DWE SKY FREQUENCIES FROM PARKES"
```

```
MISSION_NAME                    = "CASSINI-HUYGENS"
INSTRUMENT_HOST_NAME            = "HUYGENS PROBE"
INSTRUMENT_HOST_ID              = HP
MISSION_PHASE_NAME              = "DESCENT"
PRODUCT_TYPE                    = EDR
START_TIME                      = 2005-01-14T12:29:11.500
STOP_TIME                       = 2005-01-14T15:52:46.500
SPACECRAFT_CLOCK_START_COUNT    = NULL
SPACECRAFT_CLOCK_STOP_COUNT     = NULL
NATIVE_START_TIME               = NULL /* Elapsed time, from To */
NATIVE_STOP_TIME                = NULL
PRODUCT_CREATION_TIME           = 2006-05-05T12:00:00
PRODUCER_ID                     = DWE_ROBIN
PRODUCER_FULL_NAME              = "ROBINDRO DUTTA-ROY"
PRODUCER_INSTITUTION_NAME       = "UNIVERSITY BONN"
TARGET_NAME                     = "TITAN"

/* INSTRUMENT DESCRIPTION */

INSTRUMENT_ID                   = DWE
INSTRUMENT_NAME                 = "DOPPLER WIND EXPERIMENT"
INSTRUMENT_TYPE                 = "RADIO SCIENCE"

/* IF NECESSARY */

DATA_QUALITY_ID                 = 1
DATA_QUALITY_DESC               = "HIGH"

/* DATA OBJECT DEFINITION */

OBJECT                          = TABLE
 INTERCHANGE_FORMAT             = ASCII
 ROWS                           = 1166
 COLUMNS                        = 2
 ROW_BYTES                      = 45  /* incl. CR/LF */
 DESCRIPTION                    = "This table gives sky frequencies measured
with the RSR at Parkes"

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 1
     NAME                       = "EARTH RECEIVED TIME (UTC)"
     UNIT                       = "N/A"
     DATA_TYPE                  = TIME
     START_BYTE                 = 1
     BYTES                      = 23
     FORMAT                     = "A23"
     DESCRIPTION                = "reception time of frequency sample"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 2
     NAME                       = "SKY FREQUENCY"
     UNIT                       = "HZ"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 24
     BYTES                      = 20
```

```
     FORMAT                     = "F20.4"
     DESCRIPTION                = "sky frequency, mean integration time 3 s, 5 s
after impact"
 END_OBJECT                     = COLUMN

END_OBJECT                      = TABLE

END
```

4.3 Label #3: ANGLES.LBL

```
PDS_VERSION_ID                  = PDS3

/* FILE CHARACTERISTICS DATA ELEMENTS */

RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 105
FILE_RECORDS                    = 2915

/* DATA OBJECT POINTER IDENTIFICATION ELEMENTS */

^TABLE                          = "ANGLES.TAB"

/* INSTRUMENT AND DETECTOR DESCRIPTIVE DATA ELEMENTS */

FILE_NAME                       = "ANGLES.TAB"
DATA_SET_ID                     = "HP-SSA-DWE-2-3-DESCENT-V1.0"
DATA_SET_NAME                   = "HUYGENS PROBE DWE RESULTS V1.0"
PRODUCT_ID                      = "ANGLES.TAB"
PRODUCT_NAME                    = "DWE PROJECTION ANGLES"
MISSION_NAME                    = "CASSINI-HUYGENS"
INSTRUMENT_HOST_NAME            = "HUYGENS PROBE"
INSTRUMENT_HOST_ID              = HP
MISSION_PHASE_NAME              = "DESCENT"
PRODUCT_TYPE                    = RDR
START_TIME                      = 2005-01-14T09:12:20.596
STOP_TIME                       = 2005-01-14T14:45:40.188
SPACECRAFT_CLOCK_START_COUNT    = NULL
SPACECRAFT_CLOCK_STOP_COUNT     = NULL
NATIVE_START_TIME               = NULL /* Elapsed time, from To */
NATIVE_STOP_TIME                = NULL
PRODUCT_CREATION_TIME           = 2006-05-05T12:00:00
PRODUCER_ID                     = DWE_ROBIN
PRODUCER_FULL_NAME              = "ROBINDRO DUTTA-ROY"
PRODUCER_INSTITUTION_NAME       = "UNIVERSITY BONN"
TARGET_NAME                     = "TITAN"

/* INSTRUMENT DESCRIPTION */

INSTRUMENT_ID                   = DWE
INSTRUMENT_NAME                 = "DOPPLER WIND EXPERIMENT"
INSTRUMENT_TYPE                 = "RADIO SCIENCE"

/* IF NECESSARY */
```

```
DATA_QUALITY_ID                = 1
DATA_QUALITY_DESC              = "HIGH"

/* DATA OBJECT DEFINITION */

OBJECT                         = TABLE
 INTERCHANGE_FORMAT            = ASCII
 ROWS                          = 2915
 COLUMNS                       = 5
 ROW_BYTES                     = 105  /* incl. CR/LF */
 DESCRIPTION                   = "This table lists all DWE projection angles
used for the computation of the zonal wind speed (see Eq.(1) of the DWE-EAICD)"

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 1
     NAME                      = "SPACECRAFT EVENT TIME (UTC)"
     UNIT                      = "N/A"
     DATA_TYPE                 = TIME
     START_BYTE                = 1
     BYTES                     = 23
     FORMAT                    = "A23"
     DESCRIPTION               = "Huygens local time, reconstructed from Earth
Received Time of the corresponding DWE Doppler sample and the one-way light
time between the receiving antenna and Titan"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 2
     NAME                      = "ZONAL DOPPLER WIND ANGLE"
     UNIT                      = "DEGREE"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 24
     BYTES                     = 20
     FORMAT                    = "F20.7"
     DESCRIPTION               = "Angle between the line of sight and the local
east to west direction at the position of Huygens"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 3
     NAME                      = "ANTENNA OBSERVATION ANGLE"
     UNIT                      = "DEGREE"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 44
     BYTES                     = 20
     FORMAT                    = "F20.7"
     DESCRIPTION                = "Angle between the line of sight and the
inertial velocity of the receiving antenna w.r.t. the center of Titan"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 4
     NAME                      = "LINE OF SIGHT ZENITH ANGLE"
     UNIT                      = "DEGREE"
     DATA_TYPE                 = ASCII_REAL
```

```
     START_BYTE                = 64
     BYTES                     = 20
     FORMAT                    = "F20.7"
     DESCRIPTION                = "Angle between the line of sight and the
local zenith direction at the position of Huygens"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 5
     NAME                      = "MERIDIONAL DOPPLER WIND ANGLE"
     UNIT                      = "DEGREE"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 84
     BYTES                     = 20
     FORMAT                    = "F20.7"
     DESCRIPTION                = "Angle between the line of sight and the
local south to north direction at the position of Huygens"
 END_OBJECT                    = COLUMN

END_OBJECT                     = TABLE

END
```

4.4 Label #4: ANTENNA_STATE.LBL

```
PDS_VERSION_ID                 = PDS3

/* FILE CHARACTERISTICS DATA ELEMENTS */

RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 150
FILE_RECORDS                   = 2915

/* DATA OBJECT POINTER IDENTIFICATION ELEMENTS */

^TABLE                         = "ANTENNA_STATE.TAB"

/* INSTRUMENT AND DETECTOR DESCRIPTIVE DATA ELEMENTS */

FILE_NAME                      = "ANTENNA_STATE.TAB"
DATA_SET_ID                    = "HP-SSA-DWE-2-3-DESCENT-V1.0"
DATA_SET_NAME                  = "HUYGENS PROBE DWE RESULTS V1.0"
PRODUCT_ID                     = "ANTENNA_STATE.TAB"
PRODUCT_NAME                   = "RECEIVING ANTENNA STATE VECTOR"
MISSION_NAME                   = "CASSINI-HUYGENS"
INSTRUMENT_HOST_NAME           = "HUYGENS PROBE"
INSTRUMENT_HOST_ID             = HP
MISSION_PHASE_NAME             = "DESCENT"
PRODUCT_TYPE                   = RDR
START_TIME                     = 2005-01-14T10:19:27.000
STOP_TIME                      = 2005-01-14T15:52:46.500
SPACECRAFT_CLOCK_START_COUNT   = NULL
SPACECRAFT_CLOCK_STOP_COUNT    = NULL
NATIVE_START_TIME              = NULL /* Elapsed time, from To */
```

```
NATIVE_STOP_TIME                = NULL
PRODUCT_CREATION_TIME           = 2006-05-05T12:00:00
PRODUCER_ID                     = DWE_ROBIN
PRODUCER_FULL_NAME              = "ROBINDRO DUTTA-ROY"
PRODUCER_INSTITUTION_NAME       = "UNIVERSITY BONN"
TARGET_NAME                     = "TITAN"

/* INSTRUMENT DESCRIPTION */

INSTRUMENT_ID                   = DWE
INSTRUMENT_NAME                 = "DOPPLER WIND EXPERIMENT"
INSTRUMENT_TYPE                 = "RADIO SCIENCE"

/* IF NECESSARY */

DATA_QUALITY_ID                 = 1
DATA_QUALITY_DESC               = "HIGH"

/* DATA OBJECT DEFINITION */

OBJECT                          = TABLE
 INTERCHANGE_FORMAT             = ASCII
 ROWS                           = 2915
 COLUMNS                        = 7
 ROW_BYTES                      = 150  /* incl. CR/LF */
 DESCRIPTION                    = "This table lists the state vector components
of the receiving antenna used for the computation of the DWE projection angles
(see Eq.(1) of the DWE-EAICD)"

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 1
     NAME                       = "EARTH RECEIVED TIME (UTC)"
     UNIT                       = "N/A"
     DATA_TYPE                  = TIME
     START_BYTE                 = 1
     BYTES                      = 23
     FORMAT                     = "A23"
     DESCRIPTION                = "local time at antenna position"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 2
     NAME                       = "ANTENNA WEST LONGITUDE"
     UNIT                       = "DEGREE"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 24
     BYTES                      = 20
     FORMAT                     = "F20.10"
     DESCRIPTION                = "Receiving antenna west longitude in IAU-Titan
(source: NAIF)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 3
     NAME                       = "ANTENNA LATITUDE"
     UNIT                       = "DEGREE"
```

```
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 44
     BYTES                      = 20
     FORMAT                     = "F20.10"
     DESCRIPTION                = "Receiving antenna latitude in IAU-Titan
(source: NAIF)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 4
     NAME                       = "ANTENNA ALTITUDE"
     UNIT                       = "KM"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 64
     BYTES                      = 25
     FORMAT                     = "F25.5"
     DESCRIPTION                = "Receiving antenna altitude in IAU-Titan
(source: NAIF; altitude is defined as radial distance from center of Titan -
2575 km)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 5
     NAME                       = "ANTENNA X SPEED"
     UNIT                       = "M/S"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 89
     BYTES                      = 20
     FORMAT                     = "F20.7"
     DESCRIPTION                = "Receiving antenna speed along J2000 x-axis
(source: NAIF)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 6
     NAME                       = "ANTENNA Y SPEED"
     UNIT                       = "M/S"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 109
     BYTES                      = 20
     FORMAT                     = "F20.7"
     DESCRIPTION                = "Receiving antenna speed along J2000 y-axis
(source: NAIF)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 7
     NAME                       = "ANTENNA Z SPEED"
     UNIT                       = "M/S"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 129
     BYTES                      = 20
     FORMAT                     = "F20.7"
     DESCRIPTION                = "Receiving antenna speed along J2000 z-axis
(source: NAIF)"
 END_OBJECT                     = COLUMN
```

```
END_OBJECT                    = TABLE

END
```

4.5 Label #5: HUYGENS_STATE.LBL

```
PDS_VERSION_ID                = PDS3

/* FILE CHARACTERISTICS DATA ELEMENTS */

RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 145
FILE_RECORDS                  = 2915

/* DATA OBJECT POINTER IDENTIFICATION ELEMENTS */

^TABLE                        = "HUYGENS_STATE.TAB"

/* INSTRUMENT AND DETECTOR DESCRIPTIVE DATA ELEMENTS */

FILE_NAME                     = "HUYGENS_STATE.TAB"
DATA_SET_ID                   = "HP-SSA-DWE-2-3-DESCENT-V1.0"
DATA_SET_NAME                 = "HUYGENS PROBE DWE RESULTS V1.0"
PRODUCT_ID                    = "HUYGENS_STATE.TAB"
PRODUCT_NAME                  = "HUYGENS STATE VECTOR"
MISSION_NAME                  = "CASSINI-HUYGENS"
INSTRUMENT_HOST_NAME          = "HUYGENS PROBE"
INSTRUMENT_HOST_ID            = HP
MISSION_PHASE_NAME            = "DESCENT"
PRODUCT_TYPE                  = RDR
START_TIME                    = 2005-01-14T09:12:20.596
STOP_TIME                     = 2005-01-14T14:45:40.188
SPACECRAFT_CLOCK_START_COUNT  = NULL
SPACECRAFT_CLOCK_STOP_COUNT   = NULL
NATIVE_START_TIME             = NULL /* Elapsed time, from To */
NATIVE_STOP_TIME              = NULL
PRODUCT_CREATION_TIME         = 2006-05-05T12:00:00
PRODUCER_ID                   = DWE_ROBIN
PRODUCER_FULL_NAME            = "ROBINDRO DUTTA-ROY"
PRODUCER_INSTITUTION_NAME     = "UNIVERSITY BONN"
TARGET_NAME                   = "TITAN"

/* INSTRUMENT DESCRIPTION */

INSTRUMENT_ID                 = DWE
INSTRUMENT_NAME               = "DOPPLER WIND EXPERIMENT"
INSTRUMENT_TYPE               = "RADIO SCIENCE"

/* IF NECESSARY */

DATA_QUALITY_ID               = 1
DATA_QUALITY_DESC             = "HIGH"
```

```
/* DATA OBJECT DEFINITION */

OBJECT                          = TABLE
 INTERCHANGE_FORMAT             = ASCII
 ROWS                           = 2915
 COLUMNS                        = 7
 ROW_BYTES                      = 145  /* incl. CR/LF */
 DESCRIPTION                    = "This table lists the state vector components
of Huygens used for the computation of the DWE projection angles (see Eq.(1) of
the DWE-EAICD)"

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 1
     NAME                       = "SPACECRAFT EVENT TIME (UTC)"
     UNIT                       = "N/A"
     DATA_TYPE                  = TIME
     START_BYTE                 = 1
     BYTES                      = 23
     FORMAT                     = "A23"
     DESCRIPTION                = "Huygens local time, reconstructed from Earth
Received Time of the corresponding DWE Doppler sample and the one-way light
time between the receiving antenna and Titan"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 2
     NAME                       = "HUYGENS WEST LONGITUDE"
     UNIT                       = "DEGREE"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 24
     BYTES                      = 20
     FORMAT                     = "F20.5"
     DESCRIPTION                = "Huygens west longitude in IAU-Titan (source
of initial longitude: DTWG; longitude thereafter are computed by DWE by
integrating the zonal wind measurement)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 3
     NAME                       = "HUYGENS LATITUDE"
     UNIT                       = "DEGREE"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 44
     BYTES                      = 20
     FORMAT                     = "F20.5"
     DESCRIPTION                = "Huygens latitude in IAU-Titan (source: DWTG)"
 END_OBJECT                     = COLUMN

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 4
     NAME                       = "HUYGENS ALTITUDE"
     UNIT                       = "KM"
     DATA_TYPE                  = ASCII_REAL
     START_BYTE                 = 64
     BYTES                      = 20
     FORMAT                     = "F20.5"
```

```
     DESCRIPTION               = "Huygens altitude in IAU-Titan (source: DTWG;
altitude is defined as radial distance from center of Titan - 2575 km)"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 5
     NAME                      = "HUYGENS DESCENT SPEED"
     UNIT                      = "M/S"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 84
     BYTES                     = 20
     FORMAT                    = "F20.5"
     DESCRIPTION               = "Huygens descent speed (source: DTWG, smoothed
by DWE)"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 6
     NAME                      = "HUYGENS MERIDIONAL SPEED"
     UNIT                      = "M/S"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 104
     BYTES                     = 20
     FORMAT                    = "F20.5"
     DESCRIPTION               = "Huygens meridional speed (source: time
derivative of DTWG latitude)"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 7
     NAME                      = "HUYGENS ZONAL SPEED"
     UNIT                      = "M/S"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 124
     BYTES                     = 20
     FORMAT                    = "F20.5"
     DESCRIPTION               = "Huygens zonal speed (source: DWE)"
 END_OBJECT                    = COLUMN

END_OBJECT                     = TABLE

END
```

4.6 Label #6: ZONALWIND.LBL

```
PDS_VERSION_ID                 = PDS3

/* FILE CHARACTERISTICS DATA ELEMENTS */

RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 85
FILE_RECORDS                   = 2915

/* DATA OBJECT POINTER IDENTIFICATION ELEMENTS */
```

```
^TABLE                          = "ZONALWIND.TAB"

/* INSTRUMENT AND DETECTOR DESCRIPTIVE DATA ELEMENTS */

FILE_NAME                       = "ZONALWIND.TAB"
DATA_SET_ID                     = "HP-SSA-DWE-2-3-DESCENT-V1.0"
DATA_SET_NAME                   = "HUYGENS PROBE DWE RESULTS V1.0"
PRODUCT_ID                      = "ZONALWIND.TAB"
PRODUCT_NAME                    = "DWE TITAN ZONAL WIND PROFILE"
MISSION_NAME                    = "CASSINI-HUYGENS"
INSTRUMENT_HOST_NAME            = "HUYGENS PROBE"
INSTRUMENT_HOST_ID              = HP
MISSION_PHASE_NAME              = "DESCENT"
PRODUCT_TYPE                    = RDR
START_TIME                      = 2005-01-14T09:12:20.596
STOP_TIME                       = 2005-01-14T14:45:40.188
SPACECRAFT_CLOCK_START_COUNT    = NULL
SPACECRAFT_CLOCK_STOP_COUNT     = NULL
NATIVE_START_TIME               = NULL /* Elapsed time, from To */
NATIVE_STOP_TIME                = NULL
PRODUCT_CREATION_TIME           = 2006-05-05T12:00:00
PRODUCER_ID                     = DWE_ROBIN
PRODUCER_FULL_NAME              = "ROBINDRO DUTTA-ROY"
PRODUCER_INSTITUTION_NAME       = "UNIVERSITY BONN"
TARGET_NAME                     = "TITAN"

/* INSTRUMENT DESCRIPTION */

INSTRUMENT_ID                   = DWE
INSTRUMENT_NAME                 = "DOPPLER WIND EXPERIMENT"
INSTRUMENT_TYPE                 = "RADIO SCIENCE"

/* IF NECESSARY */

DATA_QUALITY_ID                 = 1
DATA_QUALITY_DESC               = "HIGH"

/* DATA OBJECT DEFINITION */

OBJECT                          = TABLE
 INTERCHANGE_FORMAT             = ASCII
 ROWS                           = 2915
 COLUMNS                        = 4
 ROW_BYTES                      = 85  /* incl. CR/LF */
 DESCRIPTION                    = "This table lists the final DWE result"

 OBJECT                         = COLUMN
     COLUMN_NUMBER              = 1
     NAME                       = "SPACECRAFT EVENT TIME (UTC)"
     UNIT                       = "N/A"
     DATA_TYPE                  = TIME
     START_BYTE                 = 1
     BYTES                      = 23
     FORMAT                     = "A23"
```

```
     DESCRIPTION               = "Huygens local time, reconstructed from Earth
Received Time of the corresponding DWE Doppler sample and the one-way light
time between the receiving antenna and Titan"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 2
     NAME                      = "HUYGENS ALTITUDE"
     UNIT                      = "KM"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 24
     BYTES                     = 20
     FORMAT                    = "F20.5"
     DESCRIPTION               = "Huygens altitude above Titan's surface
(source DTWG, altitude is defined as radial distance from center of Titan -
2575 km)"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 3
     NAME                      = "ZONAL WIND SPEED"
     UNIT                      = "M/S"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 44
     BYTES                     = 20
     FORMAT                    = "F20.5"
     DESCRIPTION               = "Huygens zonal speed (positive = eastward)"
 END_OBJECT                    = COLUMN

 OBJECT                        = COLUMN
     COLUMN_NUMBER             = 4
     NAME                      = "ZONAL WIND SPEED ERROR"
     UNIT                      = "M/S"
     DATA_TYPE                 = ASCII_REAL
     START_BYTE                = 64
     BYTES                     = 20
     FORMAT                    = "F20.5"
     DESCRIPTION               = "Possible systematic error of zonal speed due
to initial Huygens delivery error"
 END_OBJECT                    = COLUMN

END_OBJECT                     = TABLE

END
```