DORA-001

Cassini Radar Instrument Team

Cassini Radar Burst Ordered Data Products SIS

Version 2.0

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California Institute of Technology
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Document Log

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02/28/2004	All	Original.	B. Stiles
03/15/2004	14, 39, 77,78	Added num_bursts_in_flight data field to engineering data segment to handle a special case used in distant scatterometry.	B. Stiles
02/28/2005	14,15, 18, 26, 30, 43,79,103	Added mention that product_id is file name without extension to Table 5. Changed definition of t_sc_clock in intermediate data segment. Cleaned up various typos. Removed "processable bit" (bit 6) of engineer_qual_flag as it was redundant. Explained that spacecraft clock counts are not exactly one second. Added a RINGS target. Provided more details on when science data segment fields will be archived. Modified PRODUCER_FULL_NAME and PRODUCER_INSTITUTION_NAME values. Set data types of altimeter_profile_range_start and altimeter_profile_range_step to real32 in the Appendix. Now they agree with the start byte table.	B. Stiles
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06/27/2005	34	Corrected erroneous SBDR record length of 1204 bytes to the correct length of 1273 bytes.	B. Stiles
06/29/2005	24,34	Corrected inaccurate reference to DOM to TDS, SBDR record length is 1272 bytes. (1273 is start byte of echo data)	B. Stiles
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04/04/2008	Appendix D	Clarified definitions of uncorrected and corrected surface height.	P. Callahan
04/18/2008	10	Clarified definitions and use of time offset variables.	P. Callahan
05/01/2008	All	Changed document properties and formatting of last figure to correct problems when exporting to HTML. Also corrected numerous formatting problems. Fixed various items found in PDS review	J. Shimada, P. Callahan

Table of Contents

1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this Data Product Software Interface Specification (SIS) is to provide users of the Cassini Burst Ordered Data Products (BODP) with a detailed description of the products and a description of how they were generated. Cassini Burst Ordered Data Products are data sets at various stages of processing which are organized as time-ordered records for each burst. The products described in this SIS are listed in Table 1, Cassini Burst Order Data Products.

Table 1: Cassini Radar Burst Ordered Data Products

Data Set ID	Name	Description
CO-V/E/J/S-RADAR-3-SBDR-V1.0	Short Burst Data Records	Instrument Telemetry and Calibrated Science Data in Burst Order. Excludes time sampled echo data and altimeter profiles.
CO-V/E/J/S-RADAR-3-LBDR-V1.0	Long Burst Data Records	Same as SBDR but includes time sampled echo data.
CO-SSA-RADAR-3-ABDR-V1.0	Altimetry Burst Data Records	Same as SBDR but includes altimeter profiles. Only covers time periods in Altimeter mode.
CO-SSA-RADAR-3-ABDR-SUMMARY-V1.0	Altimetry Burst Data Summary	Additional information extracted from altimeter profiles. Only covers time periods in Altimeter mode.

This SIS is intended to provide enough information to enable users to read and understand the Cassini Burst Ordered Data Products. This SIS is intended for software developers, engineers, and scientists interested in accessing and using these products.

This Data Product SIS describes how Cassini Radar Burst Ordered Data Products were processed, formatted, labeled, and uniquely identified. The document discusses standards used in generating the product and software that may be used to access the product. The data product structure and organization is described in sufficient detail to enable a user to read the product.

A description of the BODP product formats and the data contained in them is provided in Section 2.3 – Data Products Description. This description is at a level of detail, which we expect to be useful for the majority of users. For examples of PDS labels (headers) see Appendices A and B. For a detailed description of all the data fields in the BODP products and a table of their locations in the file see Appendix C. The length of records can also be found in Appendix C as well as in the attached PDS label of each BODP file.

1.2 Applicable Documents (References)

This Data Product SIS is responsive to the following Cassini documents:

1) Project Data Management Plan, JPL D-12560, PD 699-061, Rev. B, April 1999, and Science Management Plan, JPL D-9178, PD 699-006, July 1999.
2) Cassini RADAR Basic Image Data Records SIS, JPL D-27889, Feb 2004, Version 1.0.
3) Cassini/Huygens Archive Plan for Science Data, JPL D-15976, 699-068.
4) SIS for Cassini RADAR Digital Map Products, JPL D-xxxx, Version 1.0

This SIS is also consistent with the following Planetary Data System documents:

5) Planetary Data System Data Preparation Workbook, Version 3.1, February 17, 1995, JPL D-7669, Part 1.

6) Planetary Data System Data Standards Reference, June 15, 2001, Version 3.4, JPL D-7669, Part 2.

7) SIS for Cassini Radar Basic Image Data Records, JPL Document #D-27889

8) Volume SIS for Cassini Radar Digital Map Products, JPL Document #D-30412, USGS #IO-AR-014

9) SIS for Cassini Radar Digital Map Products, JPL Document #D-30411, USGS #IO-AR-015

10) Volume SIS for Cassini Radar Instrument Team Data Products, Document # D-27890

Finally, this SIS is meant to be consistent with the contract negotiated between the Cassini Project and the Cassini RADAR Experiment Principal Investigator (PI) in which data products and documentation are explicitly defined as deliverable products.

1.3 Relationships with Other Interfaces

There are two other data product sets that contain data from the Cassini Radar instrument. These are:

the Basic Image Data Records (BIDR) and

the Digital Map Products (DMP).

Both of these product sets are downstream from the data products described in this document. The Cassini Radar Instrument team is responsible for developing and documenting the BIDR data. See SIS [7].

The document that describes the volume which contains BODP and BIDR data is [10].

Randolph Kirk of the US Geological Survey is responsible for developing and documenting the DMP data. The relevant SIS's are [8] and [9].

2 DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

2.1 Instrument Overview

The Cassini RADAR is a facility instrument on the Cassini Orbiter. It is capable of passive (radiometer) and active (scatterometer, altimeter, SAR imaging) operation. During active mode operation interleaved passive measurements are also obtained.

The primary target for Cassini Radar observations is Titan, the largest Saturnian moon. Due to its thick hazy atmosphere, Titan's surface was not imaged successfully by the Pioneer or Voyager spacecraft, though atmospheric "windows" in the near infrared have been exploited by the Hubble Space Telescope and earth-based telescopes to produce low-resolution albedo maps of part of the surface. The Cassini radar instrument will obtain backscatter and altimeter sounding measurements of portions of Titan's surface. High resolution synthetic aperture radar (SAR) backscatter images of 15% of Titan's surface will be obtained. Radiometer measurements covering the entire surface of Titan will also be acquired.

2.2 Instrument Description Summary

Instrument Type: Radar

Modes:

Imaging (13.78 GHz; 0.425 MHz & 0.85 MHz bandwidth)
Altimeter (13.78 GHz; 4.25 MHz bandwidth)
Scatterometer (13.78 GHz; 0.1 MHz bandwidth)
Radiometer (13.78 GHz; 135 MHz bandwidth)

Number of nominal Operational Periods:

One (1) per selected flyby of Titan (approximately 12 to 22 flybys, total)

Duration of nominal Operational Period:

From 300 minutes before to 300 minutes after closest approach to Titan for prime operation.

Peak Power: 86 W

Data Rates:

1 kbps: Radiometer only
30 kbps: Altimeter & Scatterometer / Radiometer
365 kbps: SAR Imaging / Radiometer

2.3 Data Products Description

This document describes the data included in the Burst Ordered Data Products. Burst Ordered Data Products (BODP) are comprehensive data files that include engineering telemetry, radar operational parameters, raw echo data, instrument viewing geometry, and calibrated science data. The BODP files contain time-ordered fixed length records. Each record corresponds to the full set of relevant data for an individual radar burst. The Cassini Radar is operated in "burst mode", which means the radar transmits a number of pulses in sequence then waits to receive the return signals. "Burst" is a descriptive term for the train of pulses transmitted by the radar. We use the term "burst" (somewhat unconventionally) to refer to an entire measurement cycle including transmit, receipt of echo, and radiometric (passive) measurements of the naturally occurring radiation emitted from the surface. In fact, even when the transmitter is turned off and only passive measurements are made we still refer to the measurement cycle as a burst.

Burst Ordered Data Products are fixed header length, fixed record length files. The header is an attached PDS label. See Section 2.4.4 – Labeling and Identification for a description of BODP attached PDS labels and Appendix A and B for examples. Records are rows in a table. Each data field is a column. All one needs to know to read a particular data value from a particular data field is the header length, the record size, and the byte offset of the data field within the record. Since a UTC time tag is included in each record, it is a simple matter to restrict the data one reads to a particular time interval. In order to further facilitate temporal segmentation of the data, we plan to provide a Cassini Radar Transition (CRT) file for each Titan pass. This file will maintain a temporally ordered list of the times and transition types for all scan start and end events, and radar mode transitions (e.g., radiometry to scatterometry mode switch). See the Volume SIS for more information about CRT file formats.

The BODP comprise three separate similar data sets, including the Short Burst Data Record (SBDR) the Long Burst Data Record (LBDR) and the Altimeter Burst Data Record (ABDR) plus the ABDR Summary file. The only difference among the first three formats is whether or not two data fields are included: the sampled echo data, and the altimeter profile.

The altimeter profile is an intermediate processing result between sampled echo data and a final surface height estimate. LBDRs include the echo data but not the altimeter profile. ABDRs include the altimeter profile but not the echo data. SBDRs include neither. Note that the ABDR and ABDR Summary files only cover time periods when the instrument is in altimetry mode (e.g., bandwidth). These trivial differences necessitate different data sets because the two fields in question are much larger than all the other data fields combined. The majority of the bursts in a typical Titan pass are passive measurements. These bursts do not produce echo data or altimeter profiles. Of the active mode bursts most are not in altimeter mode so no altimeter profiles are produced. Including these two data fields when they are invalid would ridiculously increase the size of the archived data. The alternative of having variable length records was deemed to overly complicate data archiving and analysis procedures. Maintaining three data sets reduces data volume while allowing record lengths to remain fixed. The ABDR Summary file is an ASCII comma-separated value file that provides additional information derived from the altimeter profile. The ABDR Summary file is an addition to Version 2 of the data and is described in Appendix D.

Consider a typical Titan pass. When approaching Titan, first only radiometer measurements are obtained. Then the transmitter is turned on and scatterometer measurements are added. When Titan is close enough for useful altimetry, the radar goes into altimeter mode. Finally, about 15 minutes prior to closest approach SAR observation begins. On the outbound portion of the pass these transitions occur in reverse. When the data from a pass is received on the ground, it is processed in the following manner: An SBDR record is produced for every burst throughout the pass. An LBDR file is produced which only contains records for the middle portion of the pass during which the transmitter was on. (Sometimes it is necessary to create multiple LBDR files in order to avoid file lengths > 2Gbytes which are problematic for older operating systems.) An ABDR file is produced which contains records for only the periods (typically one inbound, one outbound) in which the radar is in altimeter mode. If desired, bursts can be easily matched across data sets. One data field in each record is a burst identifier, which uniquely distinguishes a burst from all other bursts in the mission. Records in different data sets that correspond to the same burst have the same burst ID.

Excepting unitless quantities and raw telemetry, all data fields are stored in standard units:

1 time in seconds

2 frequency in Hertz

3 power in Watts

4 current in Amps

5 voltage in Volts

6 length in kilometers

7 temperature in Kelvin

8 angles in degrees

9 velocity in kilometers per second

10 angular velocity in degrees per second

11 energy in Joules

The SBDR data record is divided into three consecutive segments from three different levels of processing: 1) the engineering data segment, 2) the intermediate level data segment (mostly spacecraft geometry), and 3) the science data segment (antenna temperature, backscatter, measurement geometry, etc.). Below, in Sections 2.3.1 – 2.3.3, we describe a subset of the fields in each of these data segments which is likely to be of interest to the average

user. The engineering data segment contains a complete copy of the telemetry data downlinked from the spacecraft and thus has the most fields by far. It includes temperatures, instrument instructions, operational parameters of the radar, and raw measurements (i.e., unnormalized radiometer counts.) For the sake of conciseness, we avoid discussing many of these fields here. For a full description of all SBDR fields see Appendix C. In Section 2.3.4 we describe the raw active mode data, and in Section 2.3.5 we describe the altimeter profile.

2.3.1 Engineering Data Segment

The engineering data segment includes a copy of the radar telemetry contained in the Engineering Ground Support Equipment (EGSE) files obtained from the spacecraft data downlinks. This data is stored to allow investigators to access as much of the information obtained by the spacecraft as possible. Telemetry data is decoded and converted to standard units. The most important fields in this segment are the radar operational parameters and the raw radiometer data. The following table documents each of these fields. Each field in the table is 4 bytes long.

Table 2: Fields of Interest in the Engineering Data Segment

Data Field Name	Data Type	Description
burst_id	integer	An integer which uniquely identifies each burst throughout the mission.
rx_window_pri	integer	The receive window length in units of PRI (pulse repetition interval).
radar_mode	integer	The operational mode of the radar. 0 = Scatterometry, 1 = Altimetry, 2 = Low resolution SAR, 3 = High resolution SAR, 4 = Radiometer only. Adding 8 to any of these values indicates auto-gain is enabled. Auto-gain is N/A for Radiometer only mode.
adc_rate	float	Analog to Digital Converter sampling rate in Hz. This is the rate at which the echo is sampled. Since Cassini uses video offset rather than IQ sampling. Each sample is a real (not complex) value.
antenna_int_period	float	The length of a single radiometer antenna measurement window in seconds.
chirp_time_step	float	Chirp step duration in seconds.
num_rad_meas	float	Number of radiometer antenna measurement windows.
num_chirp_steps	integer	Number of chirp steps. One step means two different frequencies before and after the step, so that the number of distinct frequencies is one more than the number of steps.
chirp_length	float	Total length of chirp in seconds. This is equivalent to the width (during transmission) of an individual pulse.
chirp_freq_step	float	The change in frequency for each chirp step in Hz.
num_pulses	integer	Number of pulses transmitted.
burst_period	float	Time in seconds between consecutive bursts.

Data Field Name	Data Type	Description
PRI	float	Pulse repetition interval in seconds.
rx_window_delay	float	Time in seconds from start of burst to start of receive window.
chirp_start_freq	float	Starting frequency of chirp in Hz.
raw_res_load_meas	integer	Resistive load measurement (raw counts)
raw_antenna_meas	integer	Radiometer antenna measurement summed over all windows (raw counts).
raw_noise_diode_meas	integer	Noise diode measurement (raw counts).
noise_diode_int_period	float	The length of the noise diode measurement window in seconds.
res_load_int_period	float	The length of the resistive load measurement window in seconds.
baq_mode	integer	A flag which identifies the method used to compress the raw active mode data. Usually this value is unimportant to the user because the echo data has been decompressed. When the value is 3, however, the raw echo data has a special meaning. See below.
num_bursts_in_flight	integer	Number of bursts transmitted with a single round trip time. The value is almost always 1. In this case, all the fields in the record correspond to the same measurement. For more details, see num_bursts_in_flight.
raw_active_mode_length	integer	Number of valid data values in the time sampled echo data array after decompression.
raw_active_mode_rms	float	Root mean square of the time sampled echo data after decompression.

2.3.2 Intermediate Level Data Segment

The Intermediate Level Data Segment contains timing and spacecraft geometry information which is computed using various NAIF kernel files in addition to the EGSE raw radar telemetry file. It also contains several temperatures which were obtained from ancillary spacecraft temperature telemetry files.

The SPICE geometry library is used to compute spacecraft ephemeris and attitude information in two coordinate frames: an inertial frame (J2000) centered on the target (typically Titan), and the target body fixed frame (TBF). Although both frames are centered on the target, the orientations of the frames differ. The TBF frame maintains a constant orientation with respect to any point on the surface of the target. For example, if the target were Earth, the TBF coordinates of the point 100 m above the Washington monument would not change with time. The inertial frame coordinate system is the standard J2000 coordinate system translated so that it is centered at the target's (Titan's) center at the time of the start of the burst.

For observations of other icy satellites, Jupiter, Saturn, Earth, or Venus, the target will be the body in question, and the J2000 and TBF coordinate systems will be defined accordingly. (Ring observations will have the target "RINGS" but the TBF coordinate system will be

IAU_SATURN, the official IAU Saturn body fixed coordinate system.) Some observations will be distant microwave sources or cold sky calibration. For these cases the s/c geometry will be Earth centered for J2000, and the TBF fields will have special meaning. TBF fields for cold sky calibrations are invalid. For microwave source scans, TBF spacecraft position is a unit vector pointing from the spacecraft to the microwave source, spacecraft velocity is 0, and all other TBF parameters default to J2000 values. Microwave source scans are readily identified because the target_name field contains a string designating the microwave source (i.e. ORION, M15, etc) rather than a solar system body. Text (character string) fields for the name of the target and the official name of the target body fixed coordinate frame are reported for each burst.

The data fields in this segment include time at start of burst, spacecraft position and velocity, the direction vectors of the axes of the spacecraft coordinate system, and the angular velocity vector of the spacecraft.

The spacecraft position and velocity vectors are obtained at the start time of the burst (t_ephem_time). The geometry for active mode data is calculated at

t_ephem_time + act_geom_time_offset.

act_geom_time_offset is midway between the center of the transmit window and the center of the receive window – the average time that the signal was reflected from the surface.

The geometry for passive mode data is calculated at

t_ephem_time + pass_geom_time_offset.

pass_geom_time_offset is the mid-point of the summed radiometer windows.

Users can compute the spacecraft position at either of these times using values of the position and velocity in an equation shown generically as

new_sc_pos = sc_pos + geom._time_offset * sc_vel

where sc_pos and sc_vel are in the desired coordinate system, the time offset is active or passive, and the equation applies to each component of the position. Performing this position update is crucial to using the altimeter data in the ABDR.

The following table documents each field in detail. Geometry information is often expressed as three dimensional vectors. Such information is stored as three data fields: one for each of the x, y, and z components. In the table only the x components are listed. X-component data field names end in "_x" (e.g., sc_vel_j2000_x), y-component field names in "_y", and z-component field names in "_z". The three components are always consecutive in x, y, z order. Fields with data type "double" are real valued 8 byte numbers. UTC time strings are 24 bytes long. Other strings are multiples of 4 bytes long as specified in the table. All other fields are four bytes long.

Table 3: Fields of Interest in the Intermediate Level Data Segment

Data Field Name	Data Type	Description
engineer_qual_flag	integer	Flag to indicate quality of intermediate level data segment. Bit 0 is the LSB. The following table indicates the meaning of setting each bit to 1. Bit 0 Bad or missing s/c attitude data Bit 1 Other bad of missing geometry data Bit 2 Missing temperature telemetry (scwg_tmp) Bit 3 Missing temperature telemetry (feed_tmp) Bit 4 Missing temperature telemetry (hga_tmp) Bit 5 Downlink error in raw data file The other 26 bits are not currently used but are available for future use.
t_sc_clock	double	Encoded spacecraft clock time at start of burst. This value is used by the SPICE software employed by the Cassini Navigation Team.
t_ephem_time	double	Time at start of burst expressed in seconds since 12:00 AM Jan. 1, 2000.
t_utc_ymd	string	Time at start of burst expressed as a UTC time tag in yyyy-mm-ddThh:mm:ss.sss format. One blank space is padded at the end of the string to make certain the record length is a multiple of 4 bytes.
t_utc_doy	string	Time at start of burst expressed as a UTC time tag in yyyy-doyThh:mm:ss.sss format. Three blank spaces are padded at the end of the string to make certain the record length is a multiple of 4 bytes.
transmit_time_offset	double	Time offset in seconds from t_ephem_time at which the leading edge of the first transmit pulse leaves the antenna.
time_from_closest_approach	double	t_ephem_time - closest_approach_time
time_from_epoch	double	t_ephem_time - epoch_time
target_name	string	Name of body observed during this burst (measurement cycle). The string is 16 characters (bytes) long including space characters padded at the end.
tbf_frame_name	string	Name of the target body fixed frame in the NAIF SPICE system. The string is 24 characters (bytes) long including space characters padded at the end.
pole_right_ascension	double	Right ascension (east positive longitude in the target centered J2000 celestial sphere) of the North pole of the target body in degrees at the epoch time.
pole_declination	double	Declination (latitude in the target centered J2000 celestial sphere) of the North pole of the target body in degrees at the epoch time.

target_rotation_rate	double	Positive east rotation rate in degrees/s of the target body about its axis in the target centered J2000 inertial coordinate system.
target_rotation_angle	double	The rotation about the north pole of the target body required to complete the transformation from J2000 to target body fixed coordinates. Target body fixed coordinates at *epoch_time* can be computed by successively applying the following three rotations to the J2000 coordinates: *pole_right_ascension* degrees about the J2000 Z-axis, 90 - *pole_declination* degrees about the once-rotated Y-axis, and *target_rotation_angle* degrees about the twice rotated Z-axis. An additional rotation of *target_rotation_rate* * *time_from_epoch* degrees about the thrice rotated Z-axis yields the target body fixed coordinates at *t_ephem_time*.
beam_number	integer	The number (1-5) of the beam for which measurements are obtained during this burst.
sc_pos_j2000_x	double	x-component of spacecraft position in target-centered J2000 inertial coordinate system.
sc_vel_j2000_x	double	x component of spacecraft velocity in target-centered J2000 inertial coordinate system.
sc_pos_target_x	double	x-component of spacecraft position in target body fixed (TBF) coordinate system.
sc_vel_target_x	double	x-component of spacecraft velocity in target body fixed (TBF) coordinate system.
sc_x_axis_j2000_x	double	x-component of direction vector representing the spacecraft coordinate system's x-axis in the J2000 coordinate system. This is a unitless quantity. The vector magnitude is one.
sc_y_axis_j2000_x	double	x-component of direction vector representing the spacecraft coordinate system's y-axis in the J2000 coordinate system. This is a unitless quantity. The vector magnitude is one.
sc_z_axis_j2000_x	double	x-component of direction vector representing the spacecraft coordinate system's z-axis in the J2000 coordinate system. This is a unitless quantity. The vector magnitude is one.
sc_x_axis_target_x	double	x-component of direction vector representing the spacecraft coordinate system's x-axis in the TBF coordinate system. This is a unitless quantity. The vector magnitude is one.

sc_y_axis_target_x	double	x-component of direction vector representing the spacecraft coordinate system's y-axis in the TBF coordinate system. This is a unitless quantity. The vector magnitude is one.
sc_z_axis_target_x	double	x-component of direction vector representing the spacecraft coordinate system's z-axis in the TBF coordinate system. This is a unitless quantity. The vector magnitude is one.
rot_vel_j2000_x	double	x-component of spacecraft angular velocity vector in J2000 coordinate system. Units are degrees/s.
rot_vel_target_x	double	x-component of spacecraft angular velocity vector in TBF coordinate system. Units are degrees/s.

2.3.3 Science Data Segment

Two primary estimates of geophysical quantities are available in the science data segment: 1) the normalized backscatter cross-section σ_0 obtained from the scatterometer measurement, 2) the antenna temperature determined from the radiometer measurement. The antenna temperature is computed for every burst. The normalized backscatter cross-section is computed for all bursts with active mode data. For each burst in altimeter mode, the surface height is estimated. In addition to these primary values, ancillary parameters are also computed. The ancillary parameters include intermediate values (e.g., receiver temperature, total echo energy, system gain, etc.), analytical estimates of the standard deviation of the residual error in each of the two primary measurements, and measurement geometry. A "corrected" version of σ_0 is also computed in which the effects of incidence angle are removed by a global average model. This quantity is produced in order to ease the identification of surface features from σ_0 maps. Science team input was used to specify the incidence angle correction method. Synthetic Aperture Radar (SAR) ancillary data is also included in the science data segment when available. The SAR images themselves are stored in the Basic Image Data Record (BIDR) files.

Measurement geometry information is available for both the active and passive mode measurements. Some of the active and passive mode quantities are likely to be identical (e.g. polarization orientation angle). However, separate data fields are reported, because the differences in the passive and active mode measurement times can in principle cause the two cases to differ. Passive geometry is computed for the time corresponding to the midpoint of the passive receiver window (summed radiometer windows). Active mode geometry is computed for the time halfway between the midpoint of the transmission and the midpoint of the active mode receiver window. The full set of measurement geometry for each case includes: the polarization orientation angle, emission/incidence angle, azimuth angle, the measurement centroid, and four points on the 3 dB gain contour of the measurement. The centroid and contour points are specified in latitude and longitude, using the standard west longitude positive geodetic coordinate system sanctioned by the IAU. The geodetic part of the definition is moot since Titan is modeled by a sphere. See [1] and [3] for a more rigorous definition of the coordinate system. The measurement geometry will not be available and will be flagged as invalid for cases in which there is no target body or the measurement extends beyond the limb of the target body. There is no plan to compute the science data segment for non-Titan bodies with the exception of radiometric observations of Saturn and its rings. For other bodies these fields will be flagged as invalid. For most non-Titan icy satellite observations, due to SNR effects, only a single antenna temperature or backscatter measurement will be computable rather than values for each burst.

For these observations a single backscatter value and a single antenna temperature value will be reported in the AAREADME.TXT file in the root directory of the volume. (No altimetry data will be obtained for bodies other than Titan.)

The following table summarizes the data fields in the science data segment. All fields are 4 bytes long except doubles which are 8 bytes. When a field is invalid its value is set to zero and the science_qual_flag bits are set accordingly.

Table 4: Science Data Segment Data Fields

Data Field Name	Date Type	Description
science_qual_flag	integer	Quality flag specifying which of the science data elements are valid. Zero value indicates all data fields are valid. The meaning of a set bit (bit =1) is as follows for each bit. (Bit 0 is the LSB). Bit 0 All passive mode fields are invalid. Bit 1 All active mode fields are invalid. Bit 2 All altimeter fields are invalid. Bit 3 All scatterometer fields are invalid. Bit 4 All radiometer fields are invalid. Bit 5 Passive boresight is not on surface. Bit 6 One or more of passive ellipse points is not on surface. Bit 7 Active boresight is not on surface. Bit 8 One or more of active ellipse points is not on surface. Bit 9 All SAR fields are invalid. Remaining 22 bits are currently unassigned but may be utilized at a later time.
system_gain	float	Coefficient used to convert radiometer counts to antenna temperature.
antenna_temp	float	Antenna contribution to overall system temperature.
receiver_temp	float	Receiver contribution to overall system temperature.
ant_temp_std	float	Estimated standard deviation of the residual error in antenna temperature estimate.
pass_geom_time_offset	float	Time offset in seconds from burst reference time (t_ephem_time) for which the passive geometry fields were computed
pass_pol_angle	float	Angle of orientation of the electric field vector about the look vector during receipt of the passive mode measurement. Angle is zero when the electric field vector is perpendicular to the plane of incidence as defined by the look vector and the target surface normal, and increases counterclockwise.

Data Field Name	Date Type	Description
pass_emission_angle	float	The angle between the antenna look direction and the surface normal during receipt of the passive mode measurement.
pass_azimuth_angle	float	The direction of the projection of the antenna look vector in the plane tangent to the surface at the measurement centroid, expressed by the angle counterclockwise from East (e.g. North is 90 degrees).
pass_centroid_lon	float	Longitude of the passive (one-way) antenna boresight.
pass_centroid_lat	float	Latitude of the passive (one-way) antenna boresight.
pass_major_width	float	Width of major axis of ellipse representing passive measurement one-way 3-dB gain pattern contour.
pass_minor_width	float	Width of minor axis of ellipse representing passive measurement one-way 3-dB gain pattern contour.
pass_ellipse_pt1_lon	float	Longitude of first point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
pass_ellipse_pt2_lon	float	Longitude of second point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
pass_ellipse_pt3_lon	float	Longitude of third point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
pass_ellipse_pt4_lon	float	Longitude of fourth point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
pass_ellipse_pt1_lat	float	Latitude of first point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
pass_ellipse_pt2_lat	float	Latitude of second point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
pass_ellipse_pt3_lat	float	Latitude of third point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
pass_ellipse_pt4_lat	float	Latitude of fourth point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.

Data Field Name	Date Type	Description
num_pulses_received	integer	Number of pulses that were received completely within the echo window. Partial pulses are ignored.
total_echo_energy	float	Estimate of the total energy in the receiver window in Joules.
noise_echo_energy	float	Estimate of the noise contribution to the energy in the receiver window.
x_factor	float	Ratio of received signal energy to normalized backscatter cross-section.
sigma0_uncorrected	float	Normalized backscatter cross-section. Quantity is unitless. Scale is physical (linear) not dB (logarithmic),
sigma0_corrected	float	Normalized backscatter cross-section corrected to minimize dependence on incidence angle. Quantity is unitless. Scale is physical (linear) not dB (logarithmic).
sigma0_uncorrected_std	float	Estimated standard deviation of residual error in normalized backscatter cross-section.
surface_height	float	Estimated height of the body surface above the center (reference point) in km. Computed from the active mode data when the radar is in altimeter mode. No corrections for off-nadir pointing are applied. For other radar modes this data field is invalid, as indicated by science_qual_flag. See Appendix D. This value corresponds to the PDS Data Dictionary element definition derived_planetary_radius.
surf_ht_std	float	Estimated uncertainty in the surface_height measurement from the second moment of the compressed pulse.
act_geom_time_offset	float	Time offset in seconds from burst reference time (t_ephem_time) for which the active geometry fields were computed.
act_pol_angle	float	Angle of orientation of the electric field vector about the look vector during the active mode measurement. Angle is zero when the electric field vector is perpendicular to the plane of incidence as defined by the look vector and the target surface normal, and increases counterclockwise. Angle is computed for the time halfway between the transmission midpoint and the midpoint of the active mode receiver window.
act_incidence_angle	float	The angle between the antenna look direction and the surface normal halfway between transmission and receipt of the active mode signal.

Data Field Name	Date Type	Description
act_azimuth_angle	float	The direction of the projection of the antenna look vector in the plane tangent to the surface at the measurement centroid expressed by the angle counterclockwise from East (e.g. North is 90 degrees).
act_centroid_lon	float	Longitude of the active (two-way) antenna boresight.
act_centroid_lat	float	Latitude of the active (two-way) antenna boresight.
act_major_width	float	Width of major axis of ellipse representing active measurement two-way 3-dB gain pattern contour.
act_minor_width	float	Width of minor axis of ellipse representing active measurement two-way 3-dB gain pattern contour.
act_ellipse_pt1_lon	float	Longitude of first point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
act_ellipse_pt2_lon	float	Longitude of second point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
act_ellipse_pt3_lon	float	Longitude of third point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
act_ellipse_pt4_lon	float	Longitude of fourth point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
act_ellipse_pt1_lat	float	Latitude of first point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
act_ellipse_pt2_lat	float	Latitude of second point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.
act_ellipse_pt3_lat	float	Latitude of third point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
act_ellipse_pt4_lat	float	Latitude of fourth point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.
altimeter_profile_range_start	float	Range to the beginning of the buffer containing the altimeter profile.
altimeter_profile_range_step	float	Difference in range between consecutive range bins in altimeter profile.
altimeter_profile_length	integer	Number of valid entries in altimeter profile
sar_azimuth_res	float	Effective SAR image resolution in km along azimuth dimension.

Data Field Name	Date Type	Description
sar_range_res	float	Effective SAR image resolution in km along range dimension.
sar_centroid_bidr_lon	float	Longitude of active measurement centroid in the BIDR oblique cylindrical map projection.
sar_centroid_bidr_lat	float	Latitude of active measurement centroid in the BIDR oblique cylindrical map projection.

2.3.4 Sampled Echo Data

The sampled echo data array is located at the end of each record in the LBDR data files. It constitutes the only difference between SBDR records and LBDR records. The array consists of 32,768 4-byte floating-point values. It contains the active mode time-sampled data obtained during the receive window. The data was encoded prior to downlinking from the spacecraft in order to minimize the data transfer rate, and then decoded during the ground processing (the data stored in the array has already been decoded). The length of the array corresponds to the maximum amount of echo data that can ever be obtained from a single burst. Only the first N elements in the array are valid data. These data are N floating point values in the range [-127.5, 127.5] sampled consecutively at a rate of B Hz. N is stored in the raw_active_mode_length data field in the engineering data segment. B is in the adc_rate field in the same segment. The raw_active_mode_rms field (also in the engineering data segment) contains the root mean square of the N sampled echo data values. We suspect that only a few investigators will actually need to make use of the sampled echo data.

There is one special case in which the sampled echo data takes on a different meaning. When the baq_mode field is set to 3 that signifies the compressed scatterometer mode. In this mode all data samples are not downlinked from the spacecraft. Instead, the absolute values of the samples are summed across all the pulses in the pulse train. The summation is stored in the sampled echo data array. (Since it is a summation, the values may be outside the nominal range.) In this case an additional data value is appended after the N=raw_active_mode_length array. The (N+1)st sample corresponds to the DC offset of the entire pulse train.

2.3.5 Altimeter Profile

The altimeter profile is an intermediate result in the altimeter processing. The altimeter profile is the range compressed active mode data obtained while the radar is in altimeter mode (bandwidth). It is located at the end of each record in the ABDR files. It is an array of floating point values with the number of values stored in the altimeter_profile_length data field in the science data segment. During range compression the active mode data is segmented by pulse. Each pulse is correlated with a real -valued replica of the chirped transmit waveform in order to distribute the energy within each returned pulse into range bins. The range for the first sample of the altimeter profile and the range step are data fields in the science data segment. The number of pulses received is also stored in the science data segment. Dividing the profile length by the number of pulses yields the number of range bins. The profile array is arranged so that the range bins for each pulse are contiguous in the array (i.e., (Pulse1, Range1), (Pulse1, Range2) ..., (Pulse1, Range n), (Pulse2, Range1), (Pulse2, Range2), ...).

During the development of the altimeter processor it was found that the altimeter signal was rather complex and had unique characteristics that were not well-represented by just the two values in the SBDR portion of the record. It was decided to partially analyze the data into a

stand-alone data product that could be used by more people than might be willing to use the altimeter profiles. This additional ABDR Summary file is described in Appendix D.

2.4 Data Processing

This document uses the "Committee of Data Management and Computation" (CODMAC) data level number system. The data products referred to in this document are "level 3."

2.4.1 Data Product Generation

The JPL Cassini RADAR science data products will be produced by the radar processing group in Section 334. The pre-processor (part of the radar analysis software (RAS)) creates SBDR and LBDR files for each radar observation (i.e., each Titan pass). Initially these files only contain valid data in the engineering and intermediate level data segments. These files will then be used as inputs for the various science processing (SP) routines. Processors for the radiometer and scatterometer are applied to the SBDR and LBDR files. The scatterometer processor puts data into the scatterometer fields in the science data segment. The radiometer processor fills the radiometer data fields. The altimeter processor will generate an ABDR file (only for altimeter mode data) and populate the altimeter data fields in the BODP files. The SAR processor will produce a Basic Image Data Record file containing a SAR image and populate the SAR ancillary data fields in the BODP files. These programs will also apply low level (instrument based) calibration to the resulting data records, but will generally not attempt to perform data-driven calibration techniques. In some cases, the calibration model will be produced by other RAS software and communicated via configuration file. Configuration files will be archived along with the data. RAS and SP software will ingest telemetry data and other ancillary data (NAIF SPICE files) which are separately archived by other elements of the Cassini project.

2.4.2 Science Processing and Calibration Algorithms

When the development of the radiometer, scatterometer, SAR, and altimeter processors is complete, each of these algorithms will be summarized here. References to peer-reviewed articles will be provided when available to further document the algorithms employed along with the calibration methods contained in those algorithms.

2.4.3 Data Flow

Cassini RADAR telemetry packets are transmitted to earth along with other spacecraft and instrument telemetry at the conclusion of each data take. The radar data packets are queried from the telemetry data system (TDS) on a computer in the radar testbed which has access to TDS. These packets are placed sequentially into a raw data file. The raw file is initially processed by radar software on the testbed computer which identifies radar science activity blocks (SAB) within the telemetry stream and reformats the data and provides some quick look displays and limit checking. The reformatted data file (L0) is then delivered to the radar processing group for processing by RAS and then SP. Temperature telemetry files from the spacecraft are also queried from TDS and delivered to the processing group for RAS and SP to use. All other ancillary data is obtained from SPICE kernel files which are delivered by different elements of the project to an ftp site. These files are separately archived into the PDS system.

The RAS pre-processor reads the radar L0 file, associated temperature telemetry files, and the SPICE kernel files; and all relevant data are placed into the SBDR/LBDR engineering and intermediate data segments. The science processors ingest the SBDR/LBDR files and produce mode specific science data products and modify science data segment fields. These

products will be delivered to PDS and to the mapping group at the United State Geological Survey (USGS) in Flagstaff AZ. There, the data products will be processed into higher level map products documented in the DMP SIS. During the primary mission (July 2004 through July 2008) approximately 18 Titan flybys will have radar data takes. In addition, various radar observations will be conducted on other icy satellites, the rings, and Saturn's atmosphere. The processing chain will be operated about once per month to produce the relevant science data products for each data take.

2.4.4 Labeling and Identification

The data products discussed in this SIS all have attached PDS labels. For a general description of PDS labels and for the file naming conventions for this data set see the Volume SIS.

A PDS label is object-oriented and describes the objects in the data file. The PDS label contains keywords for product identification, and storing and organizing ancillary data. The label also contains descriptive information needed to interpret or process the data objects in the file.

PDS labels are written in Object Description Language (ODL) [ref. 5]. PDS label statements have the form of "keyword = value". Each label statement is terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects in the file:

^object = location

where the carat character (^, also called a pointer) is followed by the name of the specific data object. The location is the starting record number for the data object within the file. The keywords used are listed in the following table. The text following the description keyword includes several UTC times of interest in day of year (doy) format including the closest approach time of the pass, the trigger time of the radar instrument command sequence, and the epoch time (usually the same as the closest approach time). See Appendices A and B for example PDS labels.

Table 5: PDS Label Keywords

Keyword	Values	Description
PDS_VERSION_ID	"PDS3"	PDS Version Number
RECORD_TYPE	"FIXED_LENGTH"	Records are fixed length for each product type.
RECORD_BYTES	ASCII INTEGER	Number of bytes in a record.
FILE_RECORDS	ASCII INTEGER	Number of records in entire file.
LABEL_RECORDS	ASCII INTEGER	Number of records comprising the label (header).
DATA_SET_ID	See Table 1.	ID code of Burst Ordered Data Product Set
DATA_SET_NAME	"CASSINI RADAR SHORT BURST DATA RECORD"	Name of the data set
PRODUCER_ID	JPL	Abbreviation of producer organization.

Keyword	Values	Description
PRODUCER_FULL_NAME	"INST LEAD CHARLES ELACHI CONTACT BRYAN STILES"	Name of individual responsible for producing data set.
PRODUCER_INSTITUTION_ NAME	"JET PROPULSION LABORATORY"	Name of producer organization
PRODUCT_ID	"xxxx_yy_Dzzz_[Pm_]Vnn"	This is the filename of the product without its extension. xxxx = The acronym for the data set LBDR, SBDR, or ABDR yy = The radar mode of the data in the file represented as a two digit decimal integer between 00 and 15. This value represents a 4-bit binary flagging scheme. Bit 0 (LSB) = 1 means radiometer only mode data is present in the file. Bit 1 = 1 means scatterometer mode data is present in the file Bit 2 = 1 means altimeter mode data is present in the file. Bit 3 = 1 means SAR mode data is present in the file. The only yy values expected to occur are 01=radiometer mode only, 02=scatterometer mode only, 07= all but SAR modes, 08= SAR mode only, and 15=all four modes, but all possibilities are covered. zzz = 3 digit radar observation counter. One observation corresponds to a single up-linked radar command sequence. For example, a Titan fly-by is one observation. [Pm_] = an optional piece of the LBDR (only) identifier where m = 1 or 2 for the two parts of an LBDR that exceeds the 2 GB file size limit. If the LBDR is less than 2 GB so that only 1 file is needed, this part of the identifier is omitted. [nn= 2 digit version number
PRODUCT_VERSION_ID	NN	Two digit integer indicating the version number of a product file.

Keyword	Values	Description
INSTRUMENT_HOST_NAME	"CASSINI ORBITER"	Name of host spacecraft
INSTRUMENT_HOST_ID	"CO"	Abbreviation of host spacecraft name
INSTRUMENT_NAME	"CASSINI RADAR"	Name of instrument
INSTRUMENT_ID	"RADAR"	Abbreviation of instrument name
TARGET_NAME	"TITAN"	Target of observation
START_TIME	YYYY-DOYTHH:MM:SS.sss	Earliest time data acquired
STOP_TIME	YYYY-DOYTHH:MM:SS.sss	Latest time data acquired
SPACECRAFT_CLOCK_START_COUNT	ASCII INTEGER	Earliest S/C clock count
SPACECRAFT_CLOCK_STOP_COUNT	ASCII INTEGER	Latest S/C clock count
PRODUCT_CREATION_TIME	YYYY-DOYTHH:MM:SS.sss	Time data file was created
MISSION_NAME	"CASSINI-HUYGENS"	Official name of Cassini Mission
SOFTWARE_VERSION_ID	"V1.0"	Version of processor software
DESCRIPTION	TEXT	Description of data file
PROCESSING_HISTORY_TEXT	TEXT	Description of chain of processing which created file

2.5 Standards Used in Generating Data Products

2.5.1 Coordinate Systems

Geometrical data such as spacecraft position, velocity and attitude, are reported in the inertial target-centered J2000 coordinate frame as well as in a target body fixed (TBF) rotating frame. Measurement locations are reported in the TBF frame as planetodetic surface coordinates (latitude and longitude). The PDS Navigation and Ancillary Information Facility (NAIF) definitions are used for the frames. The TBF frame for each target is defined in the NAIF planetary kernel file (PCK) for the Saturnian system. This file will be updated during tour as Cassini observations improve knowledge of the states of bodies in the Saturnian system. In particular, the spin state of Titan has been updated based on an initial analysis of the Radar images (B.W. Stiles et al, 2008, “Determining Titan’s Spin State from Cassini Radar Images”, *Astron. Journal*, 135, 1669). In order to fully document the coordinates used, the PCK file used in the processing is included in the EXTRAS directory. A s of this writing, the solution from Stiles et al is being used for data takes Ta through T30 for which it was fit, while a simpler long-term solution from NAIF is used for data takes after T30.

For convenience, the set of angles used to transform coordinates from the inertial frame to the target body fixed (TBF) frame is also included in the BODP files (see Intermediate Data Segment, e.g., pole_right_ascension, pole_declination, target_rotation_rate, target_rotation_angle).

2.5.2 PDS Standards

The Cassini Burst Ordered Data Products comply with the Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference [4].

2.5.3 Data Storage Conventions

The Cassini Burst Ordered Data Products contain binary data. Data is stored as 32 bit integers, 32-bit IEEE floating point, or 64-bit IEEE floating point as appropriate. The files are generated on a PC running the Linux operating system so little endian byte ordering is employed. The PDS label sections are stored as ASCII character strings conforming to the conventions outlined in the PDS Standards Reference [4].

2.6 Data Validation

Cassini Radar Burst Ordered Data products will be validated before being released to the PDS. Validation is accomplished in two parts: validation for scientific integrity and validation for compliance with PDS standards. The Cassini Science Archive Working Group (SAWG) Data Validation Team will oversee validation, which includes representatives from Radar Team and PDS. Science team members are expected to conduct validation for scientific integrity in the course of their analysis of the products. The details of the science validation process are the responsibility of the Radar Science Team.

Validation for compliance with PDS standards is also the responsibility of the Radar Science Team with help from the PDS Imaging Node that will receive the data products. PDS will provide software tools, examples, and advice to help make this part of the validation as efficient as possible.

A data set will pass a peer review before it is accepted by PDS. The Cassini Radar Team and the associated PDS Node will convene a peer review committee made up of scientists and data engineers. The committee will examine the data set to make sure it is complete, meets the product specifications as defined in the SIS. The committee will include a PDS representative to ensure that the data set is in compliance with PDS standards.

3 Applicable PDS Software Tools

PDS-labeled tables can be viewed with the program ***NASAView*** developed by the PDS and available for a variety of computer platforms from the PDS web site at

http://pdsproto.jpl.nasa.gov/Distribution/license.html

There is no charge for NASAView.

4 Appendix A Example LBDR PDS Label

```
PDS_VERSION_ID = PDS3

/* FILE FORMAT AND LENGTH */

RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 132344
FILE_RECORDS = 1000
LABEL_RECORDS = 1

/* POINTERS TO START RECORDS OF OBJECTS IN FILE */

^LBDR_TABLE = 2

/* FILE DESCRIPTION */

DATA_SET_ID = "CO-V/E/J/S-RADAR-3-LBDR-V1.0"
DATA_SET_NAME = "CASSINI ORBITER RADAR LONG BURST DATA RECORD"
PRODUCER_INSTITUTION_NAME = "JPL CAL TECH"
PRODUCER_ID = JPL
PRODUCER_FULL_NAME = "INST LEAD CHARLES ELACHI CONTACT BRYAN STILES"
PRODUCT_ID = LBDR_IO_D001_V01
PRODUCT_VERSION_ID = 01
INSTRUMENT_HOST_NAME = "CASSINI ORBITER"
INSTRUMENT_HOST_ID = CO
INSTRUMENT_NAME = "CASSINI RADAR"
INSTRUMENT_ID = RADAR
TARGET_NAME = TITAN
START_TIME = YYYY-DOYThh:mm:ss
STOP_TIME = YYYY-DOYThh:mm:ss
SPACECRAFT_CLOCK_START_COUNT = nnnnnnnnn
SPACECRAFT_CLOCK_STOP_COUNT = nnnnnnnnn
PRODUCT_CREATION_TIME = YYYY-DOYThh:mm:ss.sss
MISSION_NAME = "CASSINI-HUYGENS"
SOFTWARE_VERSION_ID = "V1.0"
DESCRIPTION = "CASSINI RADAR LONG BURST DATA RECORD FOR THE TA TITAN
PASS WITH CLOSEST APPROACH TIME YYYY-DOYThh:mm:ss.sss TRIGGER TIME
YYYY-DOYThh:mm:ss.sss and EPOCH TIME YYYY-DOYThh:mm:ss.sss."
PROCESSING_HISTORY_TEXT="....."

/* DESCRIPTIONS OF OBJECTS CONTAINED IN FILE */

OBJECT = LBDR_TABLE
INTERCHANGE_FORMAT = BINARY
ROWS = 999
COLUMNS = 236
ROW_BYTES = 132344
^STRUCTURE = "LBDR.FMT"
```

DESCRIPTION = "This is the table definition for a Cassini Radar Long Burst Data Record, which includes a Short Burst Data Record (engineering telemetry, spacecraft geometry, and calibrated science data) plus the raw counts of the sampled echo data."
END_OBJECT = LBDR_TABLE

5 Appendix B.1: Partial Contents of SBDR.FMT

```
OBJECT = COLUMN
NAME = SYNC
DATA_TYPE = PC_UNSIGNED_INTEGER
START_BYTE = 1
BYTES = 4
UNIT = "NO UNIT OF MEASUREMENT DEFINED"
END_OBJECT = COLUMN

OBJECT = COLUMN
NAME = SPACECRAFT_CLOCK
DATA_TYPE = PC_UNSIGNED_INTEGER
START_BYTE = 5
BYTES = 4
UNIT = "SECOND"
END_OBJECT = COLUMN

OBJECT = COLUMN
NAME = BURST_ID
DATA_TYPE = PC_UNSIGNED_INTEGER
START_BYTE = 9
BYTES = 4
UNIT = "NO UNIT OF MEASUREMENT DEFINED"
END_OBJECT = COLUMN

OBJECT = COLUMN
NAME = CDS_PICKUP_RATE
DATA_TYPE = PC_REAL
START_BYTE = 13
BYTES = 4
UNIT = "BITS PER SECOND"
END_OBJECT = COLUMN

OBJECT = COLUMN
NAME = BURST_START_TIME
DATA_TYPE = PC_REAL
START_BYTE = 17
BYTES = 4
UNIT = "SECOND"
END_OBJECT = COLUMN
```

.(..... Continues for 235 columns totaling 1272 bytes.)

6 Appendix B.2: Contents of LBDR.FMT

^SBDR_STRUCTURE = "SBDR.FMT"

OBJECT = COLUMN
NAME = ECHO_DATA
DATA_TYPE = PC_REAL
START_BYTE = 1205
ITEMS = 32768
ITEM_BYTES = 4
DESCRIPTION = "Array of 32,768 real samples of the RADAR echo return. Each real value is an antenna voltage estimate at a particular instant in time. These estimates are proportional to voltage but are expressed in data numbers and need to be converted to engineering units. The values may or may not have passed through a lossy BAQ compression/decompression algorithm. The timing of the samples and other relevant RADAR instrument parameters are included in the engineering data segment of each LBDR record."
END_OBJECT = COLUMN

7 Appendix: B.3 Contents of ABDR.FMT

^SBDR_STRUCTURE = "SBDR.FMT"

OBJECT = COLUMN
NAME = RANGE_PROFILE
DATA_TYPE = PC_REAL
START_BYTE = 1205
ITEMS = 32768
ITEM_BYTES = 4
DESCRIPTION = "Array of 32,768 values resulting from range compression of the sampled echo data counts obtained while in altimeter mode. Detailed description pending altimeter processor development."
END_OBJECT = COLUMN

8 Appendix C: Detailed Description of Fields in SBDR record

8.1 SBDR Start Byte Table

The following table lists the starting byte of each field in a SBDR record along with long and short names for each field and its length in bytes. The long names are the names used to document the field and the names employed in the PDS format file `SBDR.FMT' (See Appendix B). The short names are values occurring in the ground processing software and are included here to assist the software developers. An SBDR record is 1272 bytes long.

SBDR Start Byte Table

Long Name	Short Name	Start Byte	Length
sync	sync	1	4
spacecraft_clock	sclk	5	4
burst_id	burst_id	9	4
cds_pickup_rate	scpr	13	4
burst_start_time	brst	17	4
header_tfi	header_tfi	21	4
header_tnc	header_tnc	25	4
header_typ	header_typ	29	4
header_tca	header_tca	33	4
header_tcb	header_tcb	37	4
header_tcc	header_tcc	41	4
pwri	pwri	45	4
vicc	vicc	49	4
vimc	vimc	53	4
tail_len	tail_len	57	4
tail_id	tail_id	61	4
sab_counter	sab_counter	65	4
sab_len	sab_len	69	4
fswm	fswm	73	4
fswc	fswc	77	4
ctbc	ctbc	81	4
rx_window_pri	ctrx	85	4
ctps	ctps	89	4
ctbe	ctbe	93	4
ctps_ctbe	ctps_ctbe	97	4
header_end	header_end	101	4
slow_tfi	slow_tfi	105	4

Long Name	Short Name	Start Byte	Length
data_take_number	dtn	109	4
slow_typ	slow_typ	113	4
calibration_source	csr	117	4
radar_mode	r_mode	121	4
sin	sin	125	4
bem	bem	129	4
baq_mode	baq_mode	133	4
tro	tro	137	4
receiver_bandwidth	rc_bw	141	4
adc_rate	adc	145	4
at1_tot	at1_tot	149	4
at3_tot	at3_tot	153	4
at4_tot	at4_tot	157	4
at1_each	at1_each	161	4
at3_each	at3_each	165	4
at4_each	at4_each	169	4
antenna_int_period	rip	173	4
chirp_time_step	csd	177	4
num_rad_meas	rad	181	4
num_chirp_steps	csq	185	4
chirp_length	chirp_length	189	4
chirp_freq_step	slow_cfs	193	4
fast_tfi	fast_tfi	197	4
fin	fin	201	4
fast_type	fast_type	205	4
num_pulses	pul	209	4
bii	bii	213	4
burst_period	bpd	217	4
pri	pri	221	4
rx_window_delay	rwd	225	4
chirp_start_freq	fast_csf	229	4
iebtth	iebtth	233	4
iebttl	iebttl	237	4
bgcalls	bgcalls	241	4
delvmn	delvmn	245	4
delvda	delvda	249	4
delvyr	delvyr	253	4

Long Name	Short Name	Start Byte	Length
raw_res_load_meas	cnt_rl	257	4
raw_antenna_meas	cnt_radio	261	4
raw_noise_diode_meas	cnt_nd	265	4
eout	eout	269	4
subr	subr	273	4
space_craft_time	space_craft_time	277	4
noise_diode_int_period	hip	281	4
res_load_int_period	cip	285	4
fwdtmp	fwdtmp	289	4
be1tmp	be1tmp	293	4
be2tmp	be2tmp	297	4
be3tmp	be3tmp	301	4
be4tmp	be4tmp	305	4
be5tmp	be5tmp	309	4
diptmp	diptmp	313	4
rlotmp	rlotmp	317	4
tadcal1	tadcal1	321	4
nsdtmp	nsdtmp	325	4
lnatmp	lnatmp	329	4
evdtmp	evdtmp	333	4
mratmp	mratmp	337	4
mruttm	mruttm	341	4
dcgttm	dcgttm	345	4
cucttm	cucttm	349	4
twttmp	twttmp	353	4
epctmp	epctmp	357	4
tw1ttm	tw1ttm	361	4
ep1ttm	ep1ttm	365	4
p_stmp	p_stmp	369	4
p_sttm	p_sttm	373	4
fguttm	fguttm	377	4
tadcal4	tadcal4	381	4
esstmp	esstmp	385	4
wgb1t1	wgb1t1	389	4
wgb3t1	wgb3t1	393	4
wgb3t2	wgb3t2	397	4
wgb3t3	wgb3t3	401	4

Long Name	Short Name	Start Byte	Length
wgb5t1	wgb5t1	405	4
pcutmp	pcutmp	409	4
adctmp	adctmp	413	4
tadcal2	tadcal2	417	4
ecltmp	ecltmp	421	4
cputmp	cputmp	425	4
memtmp	memtmp	429	4
sadctmp	sadctmp	433	4
tadcal3	tadcal3	437	4
frwdpw	frwdpw	441	4
dcgmon	dcgmon	445	4
lpltlm	lpltlm	449	4
nsdcur	nsdcur	453	4
hpapsm	hpapsm	457	4
catcur	catcur	461	4
p_smon	p_smon	465	4
svlsta	svlsta	469	4
usotmp	usotmp	473	4
cpbnkv	cpbnkv	477	4
essvlt	essvlt	481	4
tadcal5	tadcal5	485	4
pcu5v_pos	pcu5v_pos	489	4
pcu5i_pos	pcu5i_pos	493	4
pcu5v_neg	pcu5v_neg	497	4
pcu5i_neg	pcu5i_neg	501	4
pcu15v_pos	pcu15v_pos	505	4
pcu15i_pos	pcu15i_pos	509	4
pcu15v_neg	pcu15v_neg	513	4
pcu15i_neg	pcu15i_neg	517	4
pcu12v_neg	pcu12v_neg	521	4
pcu12i_neg	pcu12i_neg	525	4
pcucur	pcucur	529	4
pllmon	pllmon	533	4
ctu5i	ctu5i	537	4
tadcal6	tadcal6	541	4
pcu9v_pos	pcu9v_pos	545	4
pcu9i_pos	pcu9i_pos	549	4

Long Name	Short Name	Start Byte	Length
pcu9v_neg	pcu9v_neg	553	4
pcu9i_neg	pcu9i_neg	557	4
tadcal7	tadcal7	561	4
shpttm	shpttm	565	4
num_bursts_in_flight	num_bursts_in_flight	569	4
raw_active_mode_length	num_radar_data	573	4
raw_active_mode_rms	rms_radar_data	577	4
engineer_qual_flag	qual_flag	581	4
t_sc_clock	t_sclk	585	8
t_ephem_time	t_et	593	8
t_utc_ymd	t_utc_ymd	601	24
t_utc_doy	t_utc_doy	625	24
transmit_time_offset	transmit_time_offset	649	8
time_from_closest_approach	time_from_closest_approach	657	8
time_from_epoch	time_from_epoch	665	8
target_name	target_name	673	16
tbf_frame_name	tbf_frame_name	689	24
pole_right_ascension	pole_right_ascension	713	8
pole_declination	pole_declination	721	8
target_rotation_rate	target_rotation_rate	729	8
target_rotation_angle	target_rotation_angle	737	8
scwg_tmp	scwg_tmp	745	4
feed_tmp	feed_tmp	749	4
hga_tmp	hga_tmp	753	4
beam_number	beam_number	757	4
sc_pos_j2000_x	sc_pos_j2000_x	761	8
sc_pos_j2000_y	sc_pos_j2000_y	769	8
sc_pos_j2000_z	sc_pos_j2000_z	777	8
sc_vel_j2000_x	sc_vel_j2000_x	785	8
sc_vel_j2000_y	sc_vel_j2000_y	793	8
sc_vel_j2000_z	sc_vel_j2000_z	801	8
sc_pos_target_x	sc_pos_target_x	809	8
sc_pos_target_y	sc_pos_target_y	817	8
sc_pos_target_z	sc_pos_target_z	825	8
sc_vel_target_x	sc_vel_target_x	833	8
sc_vel_target_y	sc_vel_target_y	841	8
sc_vel_target_z	sc_vel_target_z	849	8

Long Name	Short Name	Start Byte	Length
sc_x_axis_j2000_x	sc_x_axis_j2000_x	857	8
sc_x_axis_j2000_y	sc_x_axis_j2000_y	865	8
sc_x_axis_j2000_z	sc_x_axis_j2000_z	873	8
sc_y_axis_j2000_x	sc_y_axis_j2000_x	881	8
sc_y_axis_j2000_y	sc_y_axis_j2000_y	889	8
sc_y_axis_j2000_z	sc_y_axis_j2000_z	897	8
sc_z_axis_j2000_x	sc_z_axis_j2000_x	905	8
sc_z_axis_j2000_y	sc_z_axis_j2000_y	913	8
sc_z_axis_j2000_z	sc_z_axis_j2000_z	921	8
sc_x_axis_target_x	sc_x_axis_target_x	929	8
sc_x_axis_target_y	sc_x_axis_target_y	937	8
sc_x_axis_target_z	sc_x_axis_target_z	945	8
sc_y_axis_target_x	sc_y_axis_target_x	953	8
sc_y_axis_target_y	sc_y_axis_target_y	961	8
sc_y_axis_target_z	sc_y_axis_target_z	969	8
sc_z_axis_target_x	sc_z_axis_target_x	977	8
sc_z_axis_target_y	sc_z_axis_target_y	985	8
sc_z_axis_target_z	sc_z_axis_target_z	993	8
rot_vel_j2000_x	rot_vel_j2000_x	1001	8
rot_vel_j2000_y	rot_vel_j2000_y	1009	8
rot_vel_j2000_z	rot_vel_j2000_z	1017	8
rot_vel_target_x	rot_vel_target_x	1025	8
rot_vel_target_y	rot_vel_target_y	1033	8
rot_vel_target_z	rot_vel_target_z	1041	8
norm_cnt_rl	norm_cnt_rl	1049	4
norm_cnt_nd	norm_cnt_nd	1053	4
norm_cnt_radio	norm_cnt_radio	1057	4
science_qual_flag	science_qual_flag	1061	4
system_gain	system_gain	1065	4
antenna_temp	antenna_temp	1069	4
receiver_temp	receiver_temp	1073	4
ant_temp_std	ant_temp_std	1077	4
pass_geom_time_offset	pass_geom_time_offset	1081	4
pass_pol_angle	pass_pol_angle	1085	4
pass_emission_angle	pass_emission_angle	1089	4
pass_azimuth_angle	pass_azimuth_angle	1093	4
pass_centroid_lon	pass_centroid_lon	1097	4

Long Name	Short Name	Start Byte	Length
pass_centroid_lat	pass_centroid_lat	1101	4
pass_major_width	pass_major_width	1105	4
pass_minor_width	pass_minor_width	1109	4
pass_ellipse_pt1_lon	pass_ellipse_pt1_lon	1113	4
pass_ellipse_pt2_lon	pass_ellipse_pt2_lon	1117	4
pass_ellipse_pt3_lon	pass_ellipse_pt3_lon	1121	4
pass_ellipse_pt4_lon	pass_ellipse_pt4_lon	1125	4
pass_ellipse_pt1_lat	pass_ellipse_pt1_lat	1129	4
pass_ellipse_pt2_lat	pass_ellipse_pt2_lat	1133	4
pass_ellipse_pt3_lat	pass_ellipse_pt3_lat	1137	4
pass_ellipse_pt4_lat	pass_ellipse_pt4_lat	1141	4
num_pulses_received	num_pulses_received	1145	4
total_echo_energy	total_echo_energy	1149	4
noise_echo_energy	noise_echo_energy	1153	4
x_factor	x_factor	1157	4
sigma0_uncorrected	sigma0	1161	4
sigma0_corrected	sigma0_corrected	1165	4
sigma0_uncorrected_std	sigma0_uncorrected_std	1169	4
surface_height	surface_height	1173	4
surf_ht_std	surf_ht_std	1177	4
act_geom_time_offset	act_geom_time_offset	1181	4
act_pol_angle	act_pol_angle	1185	4
act_incidence_angle	act_incidence_angle	1189	4
act_azimuth_angle	act_azimuth_angle	1193	4
act_centroid_lon	act_centroid_lon	1197	4
act_centroid_lat	act_centroid_lat	1201	4
act_major_width	act_major_width	1205	4
act_minor_width	act_minor_width	1209	4
act_ellipse_pt1_lon	act_ellipse_pt1_lon	1213	4
act_ellipse_pt2_lon	act_ellipse_pt2_lon	1217	4
act_ellipse_pt3_lon	act_ellipse_pt3_lon	1221	4
act_ellipse_pt4_lon	act_ellipse_pt4_lon	1225	4
act_ellipse_pt1_lat	act_ellipse_pt1_lat	1229	4
act_ellipse_pt2_lat	act_ellipse_pt2_lat	1233	4
act_ellipse_pt3_lat	act_ellipse_pt3_lat	1237	4
act_ellipse_pt4_lat	act_ellipse_pt4_lat	1241	4
altimeter_profile_range_start	altimeter_profile_range_start	1245	4

Long Name	Short Name	Start Byte	Length
altimeter_profile_range_step	altimeter_profile_range_step	1249	4
altimeter_profile_length	altimeter_profile_length	1253	4
sar_azimuth_res	sar_azimuth_res	1257	4
sar_range_res	sar_range_res	1261	4
sar_centroid_bidr_lon	sar_centroid_bidr_lon	1265	4
sar_centroid_bidr_lat	sar_centroid_bidr_lat	1269	4

8.2 List of SBDR Field Descriptions

Data items below are numbered 8.2.n.#, where n = 1, 2, 3 for Engineering, Intermediate, Science Data Segments in order to keep a running count of the items.

8.2.1 Engineering Data Segment Fields

8.2.n.1 sync

Constant hexadecimal value used for binary format checking.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 77746B6A hexadecimal
maximum_value: 77746B6A hexadecimal

8.2.n.2 spacecraft_clock (sclk)

Reference spacecraft clock count for each burst. The LSB is nearly 1 second but not exactly. For exact time references use t_ephem_time

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: 1 spacecraft clock count
minimum_value: 0
maximum_value: 2^{32} -1

8.2.n.3 burst_id

An identifier for each burst which is unique for the course of the mission.

Consecutive bursts within a data take have consecutive record_id values.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4

units:	none
minimum_value:	0
maximum_value:	2^{32} -1

8.2.n.4 cds_pickup_rate (scpr)

CDS pickup rate.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	bits/s
valid_values:	364800, or 30400

8.2.n.5 burst_start_time (brst)

Burst start time expressed as an offset from the reference spacecraft clock count.

The precise spacecraft time at the start of the burst is sclk + brst in seconds.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	s
minimum_value:	0.0
maximum_value:	1.0

8.2.n.6 header_tfi

Specified execute time of test and control instruction expressed as time after IEB trigger, bits 0-15 of Test and Control IEB instruction.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s
minimum_value: 0
maximum_value: 65535 (18.2 hours)

8.2.n.7 header_tnc

Test and control mode, bits 24-31 of Test and Control IEB.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.8 header_typ

Instruction type (test and control), bits 22-23 of Test and Control IEB.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
possible value:	1

8.2.n.9 header_tca

Test and Control Parameter A, bits32-47 of Test and Control IEB

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	65535

8.2.n.10 header_tcb

Test and Control Parameter B, bits 48-63 of Test and Control IEB

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	65535

8.2.n.11 header_tcc

Test and Control Parameter C, bits 64-79 of Test and Control IEB

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	65535

8.2.n.12 pwri

Most recent power instruction.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32

number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 2^{32} -1

8.2.n.13 vicc

Valid/invalid spacecraft command count (least significant 16 bits). Bit 0 (MSB) 0=valid, 1=invalid. Bits 1-15 represent command counter.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.14 vimc

Valid/invalid spacecraft message count (least significant 16 bits). Bit 0 (MSB) 0=valid, 1=invalid. Bits 1-15 represent message counter.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.15 tail_len

Word (16-bit) count of SAR/ Altimeter Block (SAB) tail.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
possible values: 0 (no tail), 32, 16384

8.2.n.16 tail_id

Running count of non-zero length SAB tails.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0

maximum_value: 65535

8.2.n.17 sab_counter

Running count of SABs.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.18 sab_len

Word (16-bit) count of SAB data field.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.19 fswm

Flight software error module ID.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 255

8.2.n.20 fswc

Flight software error code.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 255

8.2.n.21 ctbc

Count down for bursts in instruction.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.22 rx_window_pri (ctrx)

Current receive window size.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.23 ctps

This field is 11 bits read from the 16 bit DCREG register in the CTU: the format of this field is:

L, P/SLKD, P/SLKD, HPALKD, HPALKD, C, B, A, C, B, A

(L = DCREG[15] = DCREG MSB = CTPS MSB)

In terms of DCREG bits the CTPS format is: DCREG[15, 14, 13, 10, 9, 8, 7, 6, 5, 4, 3]

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	2047

8.2.n.24 ctbe

Current beam number in unitary code, e.g. 100002 = beam 5 enabled.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
possible values:	100002, 010002, 001002, 000102, 000012

8.2.n.25 ctps_ctbe

Original telemetry 16 bit encoding of CTPS (Most significant 11 bits) and CTBE (least significant 5 bits) stored as a 32 bit integer.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	64094

8.2.n.26 header_end

Instruction read back disagree (IRBD) which consists of 17 single bit flags at the end of a SAB header.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255
maximum_value:	2^{17} - 1

8.2.n.27 slow_tfi

Time from IEB trigger for slow field instruction.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	65535 (18.2 hours)

8.2.n.28 data_take_number (dtn)

Data take number.

Definition: 000000002 = the first IEB Sequence Table uploaded after launch.

The MOS will increment this parameter by one for every new IEB Sequence Table that is uploaded. This value will "roll over" from 255 to 0 if necessary.

Typical events that will cause the generation and uploading of a new IEB Sequence Table include:

- Normal Radar SAR or ALT operation at Titan
- Calibration not associated with normal operation (e.g. period Cruise Phase calibration)
- Icy satellite measurements, imaging
- "Target-of-opportunity" measurements, imaging

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 255

8.2.n.29 slow_typ

Slow field instruction type (3).

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
possible value: 3

8.2.n.30 calibration_source (csr)

Calibration source.

The following bit patterns are assigned to the various Calibration Sources: (the three or four character mode name is in parenthesis)

00002 = Normal Operation. (norm)

00012 = Antenna being used as the Calibration Source. (ant)

00102 = Noise Diode being used as the Calibration Source. (diod)

00112 = Resistive Load being used as the Calibration Source. (load)

01002 = Rerouted Chirp being used as the Calibration Source. (chrp)

01012 = Leakage Signal being used as the Calibration Source. (leak)

01102 = Radiometer Only Calibration Mode. (rado)

01112 = Transmit Only Calibration Mode. (xmto)

10002 = Auto-Gain Control. (agc)

10012 - 11112 = (reserved by the CTU)

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 15

8.2.n.31 radar_mode (r_mode)

This field represents the radar mode, and is defined as follows:
(the four character mode name is in parenthesis)

00002 = ALTL: Altimeter, Low-Resolution (altl)

00012 = ALTH: Altimeter, High-Resolution (alth)

00102 = SARL: Synthetic Aperture Radar, Low-Resolution (sarl)

00112 = SARH: Synthetic Aperture Radar, High-Resolution (sarh)

01002 = Radiometer Only (rado)

01012 = Inter-Galactic Object (IGO) Calibration (igoc)

01102 = Earth Viewing Calibration (evca)

01112 = Bi-Static Operation (bsop)

10002 = ALTL with Auto Gain (alag)

10012 = ALTH with Auto Gain (ahag)

10102 = SARL with Auto Gain (slag)

10112 = SARH with Auto Gain (shag)

11002-11112 = (spare)

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	15

8.2.n.32 sin

Slow field instruction number. The MOS will reset this parameter to zero (000000002) for every Data Take, and will increment this parameter by one for every slow field instruction. This value will "roll over" from 255 to 0 if necessary.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.33 bem

Beam mask.

The following bit patterns describe the possible Beam Masks used by the Cassini RADAR DSS:

000002 = All beams disabled (Used during internal source Calibration modes such as noise diode, resistive load and rerouted chirp).

000012 = Beam #1 Only enabled.

000102 = Beam #2 Only enabled.

000112 = Beams #2 and #1 enabled.

100002 = Beam #5 Only enabled.

110102 = Beams #5, #4 and #2 enabled.

111112 = All Five Beams enabled.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	31

8.2.n.34 baq_mode

BAQ compression mode.

The following bit patterns are assigned to the various BAQ Modes:

0002 = 8-to-2 bit Block Adaptive Quantization (normally used SAR mode)

0012 = 8-to-1 bit Block Adaptive Quantization (i.e. sign bit and thresholds, only)

0102 = 8 bit to 0 (no active mode data)

0112 = 8 bit to 2 MSB's

1002 = 8 bit to 4 MSB's

1012 = 8 bits straight (normally used Calibration mode)

1102 = 8-to-4 bit Block Adaptive Quantization (normally used Low Res ALT mode)

1112 = 8-to-4 bit Block Adaptive Quantization (normally used Hi Res ALT mode)

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	7

8.2.n.35 tro

Transmit Burst/Receive Window Offset.

The Transmit Burst/Receive Window Offset is the difference between the length of the Transmit Burst and the length of the Receive Window.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32

number_of_bytes: 4
units: s
minimum_value: -8 PRI
maximum_value: +7 PRI

8.2.n.36 receiver_bandwidth (rc_bw)

Receiver bandwidth.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: Hz
possible values: 117 kHz, 468 kHz, 935 kHz, 4.675 MHz

8.2.n.37 adc_rate (adc)

ADC sample rate.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: Hz
possible values: 250 kHz, 1.0 MHz, 2.0 MHz, 10.0 MHz

8.2.n.38 at1_tot

Total receiver attenuation beams 1 and 2. This value is calibrated using pre-launch test data and is not identical to the nominal value encoded by at1_each.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: none (not dB)
minimum_value: 1
maximum_value: 2.512×10^7

8.2.n.39 at3 _tot

Total receiver attenuation beam 3. This value is calibrated using pre-launch test data and is not identical to the nominal value encoded by at3_each.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: none (not dB)

minimum_value: 1

maximum_value: 2.512×10^7

8.2.n.40 at4 _tot

Total receiver attenuation beam 4 and 5. This value is calibrated using pre-launch test data and is not identical to the nominal value encoded by at4_each.

PDS_Object: Column of Table

conceptual_type: real

storage_type: float32

number_of_bytes: 4

units: none (not dB)

minimum_value: 1

maximum_value: 2.512×10^7

8.2.n.41 at1_each

This parameter describes the attenuation for the Microwave Receiver (MR) in the RFES when *__either Antenna Beam #1 or #2__* are selected. The least significant twelve bits actually report three separate attenuators in the RFES MR.

From MSB to LSB:

Bits [11,...,07] report the commanded attenuation (0dB - 31dB) of attenuator #1 (resolution of 1 dB). Bits [06,...,02] report the commanded attenuation (0dB - 31dB) of attenuator #2 (resolution of 1 dB). Bits [01,00] report the commanded attenuation (0dB - 12dB) of attenuator #3 (resolution of 4 dB). The total nominal attenuation is the sum of the three attenuator settings (in dB).

PDS_Object: Column of Table

conceptual_type: real

storage_type: unint32

number_of_bytes: 4

units: none

minimum_value: 0

maximum_value: 4095

8.2.n.42 at3_each

This parameter describes the attenuation for the Microwave Receiver (MR) in the RFES when *__Antenna Beam #3__* is selected. The least significant twelve bits actually report three separate attenuators in the RFES MR.

From MSB to LSB:

Bits [11,...,07] report the commanded attenuation (0dB - 31dB) of attenuator #1 (resolution of 1 dB). Bits [06,...,02] report the commanded attenuation (0dB - 31dB) of attenuator #2 (resolution of 1 dB). Bits [01,00] report the commanded attenuation (0dB - 12dB) of attenuator #3 (resolution of 4 dB). The total nominal attenuation is the sum of the three attenuator settings (in dB).

PDS_Object: Column of Table

conceptual_type: real

storage_type: unint32

number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 4095

8.2.n.43 at4_each

This parameter describes the attenuation for the Microwave Receiver (MR) in the RFES when *either Antenna Beam #4 or #5* are selected. The least significant twelve bits actually report three separate attenuators in the RFES MR.

From MSB to LSB:

Bits [11,...,07] report the commanded attenuation (0dB - 31dB) of attenuator #1 (resolution of 1 dB). Bits [06,...,02] report the commanded attenuation (0dB - 31dB) of attenuator #2 (resolution of 1 dB). Bits [01,00] report the commanded attenuation (0dB - 12dB) of attenuator #3 (resolution of 4 dB). The total nominal attenuation is the sum of the three attenuator settings (in dB).

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 4095

8.2.n.44 antenna_int_period (rip)

Radiometer integration period. This parameter is the length of time during which passive signal energy received by the antenna is measured during each radiometer measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s
minimum_value: 0.010 s
maximum_value: 0.075 s

8.2.n.45 chirp_time_step (csd)

Chirp step duration, the duration in time of each single frequency step.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s
possible_values: should always be 666.7 ns

8.2.n.46 num_rad_meas (rad)

Radiometer window counts. The number of times within a "burst" that radiometer measurements occur.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	1
maximum_value:	255

8.2.n.47 num_chirp_steps (csq)

Chirp step quantity, number of frequency changes used to perform a chirp.

(For example, a chirp estimated by two discrete frequencies exhibits one frequency change, hence csq=1.)

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	216
maximum_value:	749

8.2.n.48 chirp_length

Total length of a chirped signal in time, i.e. csd(csq+1).

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	s
minimum_value:	0.144 ms
maximum_value:	0.5 ms

8.2.n.49 chirp_freq_step (slow_cfs)

Chirp frequency step size.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	Hz
minimum_value:	0 Hz
maximum_value:	117.2 kHz

8.2.n.50 fast_tfi

Time from IEB trigger for fast field instruction.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	s
minimum_value:	0
maximum_value:	65535 (18.2 hours)

8.2.n.51 fin

Fast field instruction number. The MOS will reset this parameter to zero (000000002) for every Data Take, and will increment this parameter by one for every fast field Instruction. This value will "roll over" from 255 to 0 if necessary.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.52 fast_typ

Instruction type (fast field=2)

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
possible_value:	2

8.2.n.53 num_pulses (pul)

Number of pulses per burst.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.54 bii

Bursts in instruction.

Bursts in Instruction represents to total number of Bursts (i.e., Burst Periods) to be generated per Fast Field Instruction.

Hardware in the DSS maintains a count of the number of Bursts generated for each Fast Field Instruction, and when the appropriate number of complete Burst Periods has elapsed, that hardware generate an interrupt to the Flight Computer, and stops generating Bursts.

If Bursts in Instruction is zero, the DSS is in the so-called "Perpetual Instruction" mode. In this mode, the Digital Subsystem generates waveforms based on a given Fast/Slow instruction pair for an indefinite amount of time (i.e., it will not be limited by the upper range of the bii parameter).

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	255

8.2.n.55 burst_period (bpd)

Burst period. The Burst Period is the total time interval allocated for the transmission of pulses, the receipt of echoes, and the taking of Radiometry data.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	s
minimum_value:	10 ms
maximum_value:	4.095 s

8.2.n.56 pri

Pulse repetition interval. This parameter is the time interval between successive transmitted (chirped) pulses.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	s
minimum_value:	0.002 ms
maximum_value:	4.092 ms

8.2.n.57 rx_window_delay (rwd)

The Receive Window Delay (as defined in the DSS) is measured from the beginning of the first pulse in the first PRI that makes up the Transmit Burst. It includes the PRIs that make up the Transmit Burst and the PRIs between the end of Transmit Burst and the beginning of the Receive Window. The Receive Window Delay will always be an integer number of PRIs.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4

units: s
minimum_value: 0
maximum_value: 1023 PRI

8.2.n.58 chirp_start_freq (fast_csf)

Chirp start frequency is defined as the frequency of the first frequency step that forms the chirp.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: Hz
minimum_value: 0 Hz
maximum_value: 30 MHz

8.2.n.59 iebtth

Most significant 16 bits of the IEB trigger time or the ILX execution time.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.60 iebttl

Least significant 16 bits of the IEB trigger time or the ILX execution time.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.61 bgcalls

Number of calls to the background task during one ETA interrupt period.

(Flight S/W only)

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 65535

8.2.n.62 delvmn

BSL or CROC-FSW delivery date: month.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	month
minimum_value:	1
maximum_value:	12

8.2.n.63 delvda

BSL or CROC-FSW delivery date: day.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	day of month
minimum_value:	1
maximum_value:	31

8.2.n.64 delvyr

BSL or CROC-FSW delivery date: year

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	year
minimum_value:	1990
maximum_value:	2010

8.2.n.65 raw_res_load_meas (cnt_rl)

Raw counts for resistive load measurement.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	unint32
number_of_bytes:	4
units:	none
minimum_value:	0
maximum_value:	4095

8.2.n.66 raw_antenna_meas (cnt_radio)

Raw counts for antenna (radiometer) measurement summed over all measurement windows.

PDS_Object:	Column of Table
conceptual_type:	real

storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 2^{20} -1

8.2.n.67 raw_noise_diode_meas (cnt_nd)

Raw counts for noise diode measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 4095

8.2.n.68 eout

3 LSBs of Engineering Flight Computer Output Discretes. These discrete bits are: OUT*2, OUT*1 and OUT*0; they correspond to SWD*, TIS* and RMC* in the SDB. See Cassini RADAR DSS High Level Design document Section 4.6.1 for more information.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 7

8.2.n.69 subr

SubCom row number for this burst. Indicates which elements of engineering telemetry were most recently updated. See Cassini RADAR DSS High Level Design document Section 7.3 for more information.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32
number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 15

8.2.n.70 space_craft_time

Twelve Least significant bits of spacecraft clock logged when the Engineering data in this SubCom data set was acquired.

PDS_Object: Column of Table
conceptual_type: real
storage_type: unint32

number_of_bytes: 4
units: none
minimum_value: 0
maximum_value: 4095

8.2.n.71 noise_diode_int_period (hip)

Integration time of noise diode measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s
minimum_value: 0.0
maximum_value: 0.02

8.2.n.72 res_load_int_period (cip)

Integration time of resistive load measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s
minimum_value: 0.0
maximum_value: 0.08

8.2.n.73 fwdtmp

Forward diode temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.74 be1tmp

Beam 1 temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.75 be2tmp

Beam 2 temperature.

PDS_Object: Column of Table
conceptual_type: real

storage_type: float32
number_of_bytes: 4
units: K

8.2.n.76 be3tmp

Beam 3 temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.77 be4tmp

Beam 4 temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.78 be5tmp

Beam 5 temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.79 diptmp

Diplexer temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.80 rlotmp

Resistive load temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.81 tadcal1

Thermistor calibration temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.82 nsdtmp

Noise diode temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.83 lnatmp

Low noise amplifier temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.84 evdtmp

Envelope detector temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.85 mratmp

Microwave receiver temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.86 mruttm

Microwave receiver unit base plate temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32

number_of_bytes: 4
units: K

8.2.n.87 dcgttm

Digital chirp generator base plate temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.88 cucttm

Chirp up converter and amplifier base plate temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.89 twttmp

Traveling Wave Tube (TWT) temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.90 epctmp

Electronic power converter (EPC) temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.91 tw1ttm

TWT base plate temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.92 ep1ttm

EPC base plate temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.93 p_stmp

Power supply temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.94 p_sttm

Power supply base plate temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.95 fguttm

Frequency generator unit base plate temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.96 tadcal4

Thermistor calibration temperature 2.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.97 esstmp

Energy storage subsystem heat sink temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.98 wgb1t1

Beam 1 lower waveguide temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.99 wgb3t1

Beam 3 lower wave guide temperature 1.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.100 wgb3t2

Beam 3 lower wave guide temperature 2.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.101 wgb3t3

Beam 3 lower waveguide temperature 3.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.102 wgb5t1

Beam 5 lower waveguide temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.103 pcutmp

Power converter unit temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32

number_of_bytes: 4
units: K

8.2.n.104 adctmp

Radiometer analog to digital converter temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.105 tadcal2

Thermistor extended range calibration temperature #1.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.106 ecltmp

Emitter coupled logic portion temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.107 cputmp

Engineering flight computer CPU board temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.108 memtmp

Engineering flight computer memory board temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.109 sadctmp

Science analog to digital converter temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.110 tadcal3

Thermistor extended range calibration temperature #2.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.111 frwdpw

Forward power telemetry.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: W

8.2.n.112 dcgmon

Chirp envelope monitoring point. An envelope reflecting the presence of a DCG output signal is developed by the Digital CHIRP Generator. In effect, this envelope represents each burst of transmission by the RADAR. It will have an amplitude of 2 to 5 volts and widths of 500 microseconds to 75 milliseconds. The envelope is differentially received, peak detected, and then sequentially sampled by the Analog signal Multiplexer. A drooping peak detector level without regenerative resurgence is indicative of delayed or missing envelopes.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: none
minimum_value: 100
maximum_value: 4000

8.2.n.113 lpltlm

The low power level telemetry signal is generated in the RFES. It is the envelope of the transmitted burst out of the CUCA. This envelope has an amplitude of 4 to 5 volts and widths of 500 microseconds to 75 milliseconds. It is differentially received, peak detected, and then sequentially sampled by the Analog Signal Multiplexer. This peak detected output will also produce a decaying level between transmission envelopes, with a resurgence to maximum initiated by each envelope. Each resurgence serving to confirm a transmission. Missing envelopes will identify with a decayed peak detector level.

PDS_Object: Column of Table

conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: W

8.2.n.114 nsdcur

Noise diode current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.115 hpapsm

High power amplifier Ku-band transmitter current

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.116 catcur

TWT cathode current

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.117 p_smon

Power supply current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.118 svlsta

Secondary line voltage status.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: V

8.2.n.119 usotmp

Ultra-stable oscillator temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.120 cpbnkv

Capacitor bank voltage.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	V

8.2.n.121 essvlt

Energy storage subsystem output voltage.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	V

8.2.n.122 tadcal5

Conditioned voltage calibration #1.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	V

8.2.n.123 pcu5v_pos

Power converter unit +5 V voltage.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	V

8.2.n.124 pcu5i_pos

Power converter unit +5 V current.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32

number_of_bytes: 4
units: A

8.2.n.125 pcu5v_neg

Power converter unit -5 V voltage.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: V

8.2.n.126 pcu5i_neg

Power converter unit -5 V current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.127 pcu15v_pos

Power converter unit +15 V voltage.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: V

8.2.n.128 pcu15i_pos

Power converter unit +15 V current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.129 pcu15v_neg

Power converter unit -15 V voltage.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: V

8.2.n.130 pcu15i_neg

Power converter unit -15 V current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.131 pcu12v_neg

Power converter unit -12 V voltage.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: V

8.2.n.132 pcu12i_neg

Power converter unit -12 V current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.133 pcucur

Power converter unit 30 V current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.134 pllmon

Phase locked loop 20 MHz frequency.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: Hz

8.2.n.135 ctu5i

Control and timing unit +5 V current.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: A

8.2.n.136 tadcal6

TADC Mux calibration.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	none

8.2.n.137 pcu9v_pos

Power converter unit +9 V voltage.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	V

8.2.n.138 pcu9i_pos

Power converter unit +9 V current.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	A

8.2.n.139 pcu9v_neg

Power converter unit -9 V voltage.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	V

8.2.n.140 pcu9i_neg

Power converter unit -9 V current.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	A

8.2.n.141 tadcal7

Conditioned voltage calibration #2.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32

number_of_bytes:	4
units:	V

8.2.n.142 shpttm

Inboard shearplate temperature.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	K

8.2.n.143 num_bursts_in_flight

Number of transmitted bursts simultaneously in flight. This number is usually 1. The only exceptions are distant scatterometer measurements. For values greater than one the returned echo data from a transmitted burst is not stored in the same record with the radar instrument parameters used to command that burst.

For example, consider the case in which num_bursts_in_flight =2 in record #2 of the file. All of the engineering data segment fields in record #2 refer to the burst transmitted in measurement cycle #2, except num_raw_active_mode_data and rms_raw_active_mode_data which correspond to data received in measurement cycle #2 but transmitted in a previous cycle. The intermediate level data segment field definitions are unaffected by the value of num_bursts_in_flight. The science data segment fields correspond to data collected in measurement cycle #2. The active mode science data fields would (if valid) correspond to a burst transmitted in a previous cycle. (In practice, active mode science data fields will not be valid for num_bursts_in_flight> 1, because distant scatterometry does not have a high enough SNR to compute a measurement for each individual burst.) In the LBDR file, the active mode data array contains data collected in measurement cycle #2, but transmitted in a previous measurement cycle.

To obtain the active mode data for the burst transmitted in measurement cycle #2 one needs to look ahead num_bursts_in_flight-1 records. For our example (num_bursts_in_flight =2) the received echo data is in measurement cycle #3.

The active mode measurement geometry is always defined for a point in time midway between the centers of the transmit and receive windows in a single measurement cycle. This results in a temporal bias when num_bursts_in_flight> 1.

PDS_Object:	Column of Table
conceptual_type:	integer
storage_type:	unint32
number_of_bytes:	4
units:	none

8.2.n.144 raw_active_mode_length

Number of valid entries in the time sampled echo data array.

PDS_Object:	Column of Table
conceptual_type:	integer
storage_type:	unint32
number_of_bytes:	4
units:	none

maximum value:	32000
minimum value:	0

8.2.n.145 raw_active_mode_rms

Root mean square of valid echo data array entries.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	none

8.2.2 Intermediate Level Data Segment Fields

8.2.n.146 engineer_qual_flag

Flag to indicate quality of intermediate level data segment. Bit 0 is the LSB. The following table indicates the meaning of setting each bit to 1.

Bit 0 Bad or missing s/c attitude data

Bit 1 Other bad of missing geometry data

Bit 2 Missing temperature telemetry (scwg_tmp)

Bit 3 Missing temperature telemetry (feed_tmp)

Bit 4 Missing temperature telemetry (hga_tmp)

Bit 5 Downlink error in raw data file

The other 26 bits are not currently used but are available for future use.

PDS_Object:	Column of Table
conceptual_type:	integer
storage_type:	unint32
number_of_bytes:	4
units:	none
possible values:	0, 1, 2, 255

8.2.n.147 t_sc_sclk

Encoded spacecraft clock time. This value is used by the SPICE software employed by the Cassini Navigation Team.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	N/A

8.2.n.148 t_et

Ephemeris time in seconds since J2000.

PDS_Object:	Column of Table
conceptual_type:	real

storage_type: float64
number_of_bytes: 8
units: s

8.2.n.149 t_utc_ymd

UTC time in yyyy-mm-ddThh:mm:ss.sss format. One space character is padded at the end to ensure file size is a multiple of 4 bytes.

PDS_Object: Column of Table
conceptual_type: text
storage_type: ASCII string
number_of_bytes: 24
units: none

8.2.n.150 t_utc_doy

UTC time in yyyy-doyThh:mm:ss.sss format. Three space characters are padded at the end to ensure file size is a multiple of 4 bytes.

PDS_Object: Column of Table
conceptual_type: text
storage_type: ASCII string
number_of_bytes: 24
units: none

8.2.n.151 transmit_time_offset

Time offset in seconds from t_ephem_time at which the leading edge of the first transmit pulse leaves the antenna.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: s

8.2.n.152 time_from_closest_approach

t_ephem_time - closest_approach_time. The closest approach time is estimated by the ground processor and included in the value of the DESCRIPTION keyword in the PDS label (header) in UTC format to the nearest ms.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: s

8.2.n.153 time_from_epoch

t_ephem_time - epoch_time. The value of epoch_time is usually the same as the closest approach time but may differ occasionally for logistic reasons.

PDS_Object: Column of Table
conceptual_type: real

storage_type: float64
number_of_bytes: 8
units: s

8.2.n.154 target_name

Name of body observed during this burst. Space characters are padded at the end to ensure the string is 16 bytes long.

PDS_Object: Column of Table
conceptual_type: text
storage_type: ASCII string
number_of_bytes: 16
units: none

8.2.n.155 tbf_frame_name

Name of target body fixed frame in the NAIF SPICE system (i.e., "IAU_TITAN"). Space characters are padded at the end to ensure the string is 24 bytes long.

PDS_Object: Column of Table
conceptual_type: text
storage_type: ASCII string
number_of_bytes: 24
units: none

8.2.n.156 pole_right_ascension

Right ascension (east positive longitude in the target centered J2000 celestial sphere) of the North pole of the target body in degrees at the epoch time.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: degrees

8.2.n.157 pole_declination

Declination (latitude in the target centered J2000 celestial sphere) of the North pole of the target body in degrees at the epoch time.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: degrees

8.2.n.158 target_rotation_rate

The rotation about the north pole of the target body required to complete the transformation from J2000 to target body fixed coordinates.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64

number_of_bytes: 8
units: degrees/s

8.2.n.159 target_rotation_angle

The rotation about the north pole of the target body required to complete the transformation from J2000 to target body fixed coordinates.

Target body fixed coordinates at epoch_time can be computed by successively applying the following three rotations to the J2000 coordinates: pole_right_ascension degrees about the J2000 Z-axis, 90 - pole_declination degrees about the once-rotated Y-axis, and target_rotation_angle degrees about the twice rotated Z-axis.

An additional rotation of target_rotation_rate * time_from_epoch degrees about the thrice rotated Z-axis yields the target body fixed coordinates at t_ephem_time.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: degrees

8.2.n.160 scwg_tmp

Ku-band waveguide 3 temperature 9

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.161 feed_tmp

X, Ka, Ku-band feed temperature 5

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.162 hga_tmp

High gain antenna reflector rear temperature 1

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.163 beam_number

Number of the current beam.

PDS_Object: Column of Table

conceptual_type: integer
storage_type: unint32
number_of_bytes: 4
units: none
possible values: 1, 2, 3, 4, 5

8.2.n.164 sc_pos_j2000_x

X component of the spacecraft position vector in the J2000 frame.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: km

8.2.n.165 sc_pos_j2000_y

Y component of the spacecraft position vector in the J2000 frame.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: km

8.2.n.166 sc_pos_j2000_z

Z component of the spacecraft position vector in the J2000 frame.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: km

8.2.n.167 sc_vel_j2000_x

X component of the spacecraft velocity vector in the J2000 frame.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: km/s

8.2.n.168 sc_vel_j2000_y

Y component of the spacecraft velocity vector in the J2000 frame.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: km/s

8.2.n.169 sc_vel_j2000_z

Z component of the spacecraft velocity vector in the J2000 frame.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km/s

8.2.n.170 sc_pos_target_x

X component of the spacecraft position vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km

8.2.n.171 sc_pos_target_y

Y component of the spacecraft position vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km

8.2.n.172 sc_pos_target_z

Z component of the spacecraft position vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km

8.2.n.173 sc_vel_target_x

X component of the spacecraft velocity vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km/s

8.2.n.174 sc_vel_target_y

Y component of the spacecraft velocity vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km/s

8.2.n.175 sc_vel_target_z

Z component of the spacecraft velocity vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	km/s

8.2.n.176 sc_x_axis_j2000_x

X component of the unit vector in the J2000 frame parallel to the X axis of the spacecraft coordinate system.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.177 sc_x_axis_j2000_y

Y component of the unit vector in the J2000 frame parallel to the X axis of the spacecraft coordinate system.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.178 sc_x_axis_j2000_z

Z component of the unit vector in the J2000 frame parallel to the X axis of the spacecraft coordinate system.

PDS_Object:	Column of Table
conceptual_type:	real

storage_type: float64
number_of_bytes: 8
units: none
minimum_value: -1
maximum_value: 1

8.2.n.179 sc_y_axis_j2000_x

X component of the unit vector in the J2000 frame parallel to the Y axis of the spacecraft coordinate system.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: none
minimum_value: -1
maximum_value: 1

8.2.n.180 sc_y_axis_j2000_y

Y component of the unit vector in the J2000 frame parallel to the Y axis of the spacecraft coordinate system.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: none
minimum_value: -1
maximum_value: 1

8.2.n.181 sc_y_axis_j2000_z

Z component of the unit vector in the J2000 frame parallel to the Y axis of the spacecraft coordinate system.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: none
minimum_value: -1
maximum_value: 1

8.2.n.182 sc_z_axis_j2000_x

X component of the unit vector in the J2000 frame parallel to the Z axis of the spacecraft coordinate system.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8

units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.183 sc_z_axis_j2000_y

Y component of the unit vector in the J2000 frame parallel to the Z axis of the spacecraft coordinate system.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.184 sc_z_axis_j2000_z

Z component of the unit vector in the J2000 frame parallel to the Z axis of the spacecraft coordinate system.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.185 sc_x_axis_target_x

X component of the unit vector in the target body frame parallel to the X axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.186 sc_x_axis_target_y

Y component of the unit vector in the target body frame parallel to the X axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1

maximum_value: 1

8.2.n.187 sc_x_axis_target_z

Z component of the unit vector in the target body frame parallel to the X axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.188 sc_y_axis_target_x

X component of the unit vector in the target body frame parallel to the Y axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.189 sc_y_axis_target_y

Y component of the unit vector in the target body frame parallel to the Y axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.190 sc_y_axis_target_z

Z component of the unit vector in the target body frame parallel to the Y axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.191 sc_z_axis_target_x

X component of the unit vector in the target body frame parallel to the Z axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.192 sc_z_axis_target_y

Y component of the unit vector in the target body frame parallel to the Z axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.193 sc_z_axis_target_z

Z component of the unit vector in the target body frame parallel to the Z axis of the spacecraft coordinate system. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	none
minimum_value:	-1
maximum_value:	1

8.2.n.194 rot_vel_j2000_x

X component of the spacecraft angular velocity vector in the J2000 frame.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float64
number_of_bytes:	8
units:	rad/s

8.2.n.195 rot_vel_j2000_y

Y component of the spacecraft angular velocity vector in the J2000 frame.

PDS_Object:	Column of Table
conceptual_type:	real

storage_type: float64
number_of_bytes: 8
units: rad/s

8.2.n.196 rot_vel_j2000_z

Z component of the spacecraft angular velocity vector in the J2000 frame.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: rad/s

8.2.n.197 rot_vel_target_x

X component of the spacecraft angular velocity vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: rad/s

8.2.n.198 rot_vel_target_y

Y component of the spacecraft angular velocity vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: rad/s

8.2.n.199 rot_vel_target_z

Z component of the spacecraft angular velocity vector in the target body frame. Value is zero if target name is `NONE' or `CALIBRATION.'

PDS_Object: Column of Table
conceptual_type: real
storage_type: float64
number_of_bytes: 8
units: rad/s

8.2.n.200 norm_cnt_rl

Normalized radiometer resistive load measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4

units: counts/s
minimum_value: 0
maximum_value: N/A

8.2.n.201 norm_cnt_nd

Normalized radiometer noise diode measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: counts/s
minimum_value: 0
maximum_value: N/A

8.2.n.202 norm_cnt_radio

Normalized radiometer antenna measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: counts/s
minimum_value: 0
maximum_value: N/A

8.2.3 Science Data Segment Fields

8.2.n.203 science_qual_flag

Quality flag specifying which of the science data elements are valid. Zero value indicates all data fields are valid. The meaning of a set bit (bit =1) is as follows for each bit. (Bit 0 is the LSB).

Bit 0 All passive mode fields are invalid.
Bit 1 All active mode fields are invalid.
Bit 2 All altimeter fields are invalid.
Bit 3 All scatterometer fields are invalid.
Bit 4 All radiometer fields are invalid.
Bit 5 Passive boresight is not on surface.
Bit 6 One or more of passive ellipse points is not on surface.
Bit 7 Active boresight is not on surface.
Bit 8 One or more of active ellipse points is not on surface.

PDS_Object: Column of Table
conceptual_type: real
storage_type: int32
number_of_bytes: 4
units: none
minimum_value: 0

maximum_value: N/A

8.2.n.204 system_gain

Coefficient used to convert radiometer counts to antenna brightness temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: dB

8.2.n.205 antenna_temp

Antenna contribution to overall system temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.206 receiver_temp

Internally generated receiver noise contribution to overall system temperature.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.207 ant_temp_std

Estimated standard deviation of the residual error in antenna temperature estimate.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: K

8.2.n.208 pass_geom_time_offset

Time offset from t_ephem_time for which passive geometry fields are computed. This time is defined to be the mid-point of the summed radiometer windows.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s

8.2.n.209 pass_pol_angle

Angle of orientation of the electric field vector about the look vector during receipt of the passive mode measurement. Angle is zero when the electric field vector is perpendicular to the plane of incidence as defined by the look vector and the target surface normal, and increases counterclockwise.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.210 pass_emission_angle

The angle between the antenna look direction and the surface normal during receipt of the passive mode measurement.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.211 pass_azimuth_angle

The direction of the projection of the antenna look vector in the plane tangent to the surface at the measurement centroid, expressed by the angle counterclockwise from East (e.g. North is 90 degrees).

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.212 pass_centroid_lon

Longitude of the passive (one-way) antenna boresight.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.213 pass_centroid_lat

Latitude of the passive (one-way) antenna boresight.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.214 pass_major_width

Width of major axis of passive best fit ellipse, the distance along the map projection reference sphere between point 1 and point 2.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	km

8.2.n.215 pass_minor_width

Width of minor axis of passive best fit ellipse, the distance along the map projection reference sphere between point 3 and point 4.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	km

8.2.n.216 pass_ellipse_pt1_lon

Longitude of first point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse. Each point on the best fit ellipse is computed in the plane tangent to the surface at the boresight and then extended to the reference surface along the line of site of the antenna.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.217 pass_ellipse_pt2_lon

Longitude of second point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.218 pass_ellipse_pt3_lon

Longitude of third point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.219 pass_ellipse_pt4_lon

Longitude of fourth point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.220 pass_ellipse_pt1_lat

Latitude of first point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.221 pass_ellipse_pt2_lat

Latitude of second point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the major axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.222 pass_ellipse_pt3_lat

Latitude of third point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.223 pass_ellipse_pt4_lat

Latitude of fourth point in ellipse representing passive measurement one-way 3-dB gain pattern contour. This point is on the minor axis of the best fit ellipse.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.224 num_pulses_received

Number of pulses which were received completely within the echo window. Partial pulses are ignored.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	none

8.2.n.225 total_echo_energy

Estimate of the total energy in the receiver window in Joules.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	J

8.2.n.226 noise_echo_energy

Estimate of the noise contribution to the energy in the receiver window.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	J

8.2.n.227 x_factor

Ratio of received signal energy to normalized backscatter cross-section.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	J

8.2.n.228 sigma0_uncorrected (sigma0)

Normalized backscatter cross-section. Quantity is unitless. Scale is physical (linear) not dB (logarithmic).

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	none

8.2.n.229 sigma0_corrected

Normalized backscatter cross-section corrected to minimize dependence on incidence angle. Quantity is unitless. Scale is physical (linear) not dB (logarithmic).

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	none

8.2.n.230 sigma0_uncorrected_std

Estimated standard deviation of residual error in normalized backscatter cross-section.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	none

8.2.n.231 surface_height

Estimated height of body surface above the center (reference point) determined from the first moment of the compressed waveform after noise subtraction. The quantity is computed by subtracting the measured range to target from the spacecraft distance to body center from the ephemeris. No correction for off-nadir pointing is included. Computed from the active mode data when the radar is in altimeter mode. For other radar modes this data field is invalid, as indicated by science_qual_flag. This value corresponds to the PDS Data Dictionary element definition derived_planetary_radius.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	km

8.2.n.232 surf_ht_std

Estimated uncertainty of the surface_height measurement based on the second central moment of the noise-subtracted waveform distribution. This quantity is more a measure of signal spread and surface variation than of “noise” in the measurement itself.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	km

8.2.n.233 act_geom_time_offset

Time offset from t_ephem_time for which active geometry fields are computed. This time is defined to be the midway between the center of the transmit window and the center of the receive window.

PDS_Object:	Column of Table

conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: s

8.2.n.234 act_pol_angle

Angle of orientation of the electric field vector about the look vector during the active mode measurement. Angle is zero when the electric field vector is perpendicular to the plane of incidence as defined by the look vector and the target surface normal, and increases counterclockwise. Angle is determined for a time halfway between transmission and receipt of the active mode signal.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.235 act_incidence_angle

The angle between the antenna look direction and the surface normal halfway between transmission and receipt of the active mode signal.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.236 act_azimuth_angle

The direction of the projection of the antenna look vector in the plane tangent to the surface at the measurement centroid expressed by the angle counterclockwise from East (e.g. North is 90 degrees).

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.237 act_centroid_lon

Longitude of the active (two-way) antenna boresight.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.238 act_centroid_lat

Latitude of the active (two-way) antenna boresight.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.239 act_major_width

Width of major axis of active best fit ellipse, the distance along the map projection reference sphere between point 1 and point 2.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: km

8.2.n.240 act_minor_width

Width of minor axis of active best fit ellipse, the distance along the map projection reference sphere between point 3 and point 4.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: km

8.2.n.241 act_ellipse_pt1_lon

Longitude of first point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-major axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.242 act_ellipse_pt2_lon

Longitude of second point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-major axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.243 act_ellipse_pt3_lon

Longitude of third point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-minor axis of the best fit ellipse.

PDS_Object: Column of Table

conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.244 act_ellipse_pt4_lon

Longitude of fourth point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-minor axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.245 act_ellipse_pt1_lat

Latitude of first point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-major axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.246 act_ellipse_pt2_lat

Latitude of second point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-major axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.247 act_ellipse_pt3_lat

Latitude of third point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-minor axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.248 act_ellipse_pt4_lat

Latitude of fourth point in ellipse representing active measurement two-way 3-dB gain pattern contour. This point is on the semi-minor axis of the best fit ellipse.

PDS_Object: Column of Table
conceptual_type: real

storage_type: float32
number_of_bytes: 4
units: deg

8.2.n.249 altimeter_profile_range_start

Range to the beginning of the buffer containing the altimeter profile.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: km

8.2.n.250 altimeter_profile_range_step

Difference in range between consecutive range bins in altimeter profile.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: km

8.2.n.251 altimeter_profile_length

Number of valid entries in altimeter profile.

PDS_Object: Column of Table
conceptual_type: integer
storage_type: unint32
number_of_bytes: 4
units none
minimum value: 0
maximum value: 32000

8.2.n.252 sar_azimuth_res

Effective SAR image resolution along azimuth dimension. The value is the width on the ground of a nominal Doppler bin (1bin width = 1/(pulse train duration)) for the current burst multiplied by a constant factor which depends on filter parameters used during azimuth compression.

PDS_Object: Column of Table
conceptual_type: real
storage_type: float32
number_of_bytes: 4
units: km

8.2.n.253 sar_range_res

Effective SAR image resolution along range dimension. The value is the width on the ground of a nominal range bin (1bin width = speed of light/(chirp bandwidth)) for the current burst multiplied by a constant factor which depends on filter parameters used during range compression.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	km

8.2.n.254 sar_centroid_bidr_lon

Longitude of the active (two-way) antenna boresight in the BIDR oblique cylindrical map projection.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

8.2.n.255 sar_centroid_bidr_lat

Latitude of the active (two-way) antenna boresight in the BIDR oblique cylindrical map projection.

PDS_Object:	Column of Table
conceptual_type:	real
storage_type:	float32
number_of_bytes:	4
units:	deg

9 Appendix D: ABDR Summary File (ASCII CSV)

This Appendix describes the Altimeter ABDR Summary file which is created during altimeter processing to provide additional information about the altimeter signal in an easy-to-use, stand-alone format (comma separated value, or CSV). Additional information about the altimeter data as of the generation of this document is also provided to help users understand the information in these data. Following the algorithm descriptions, a brief overview of the altimeter measurement is given.

File name structure: ABDR_SUMMARY_yy_Dzzz_Vnn.CSV, corresponding to the ABDR*.DAT, and the detached label is ABDR*.LBL, where

yy = Radar mode

zzz = 3-digit Radar observation counter (unique through the mission)

nn = 2-digit version number

The structure of the Cassini Radar Altimeter ABDR Summary file is given in the following table.

Each row in the file contains the 17 parameters listed in the table.

Each row in the file represents one burst of data. All pulses within a burst are averaged before the parameters are derived.

The algorithms for producing the items that are not copied from the LBDR are described following the table.

These data are Version 2. The format has been updated to allow predictable record lengths for the PDS SPREADSHEET object. Data produced after January 1, 2008 use the new Radar-determined Titan pole location.

Parameter	Method	Units	Format	Algorithm
SAB Counter	Copy from LBDR	Count	Integer (I9)	
Spacecraft Event Time (UTC) for beginning of burst	Copy from LBDR	None	UTC yyyy-mm-ddThh:mm:ss.sss	
Time from closest approach	Copy from LBDR	sec	Float (F8.2)	
Range to antenna boresight intercept with surface	First moment of waveform. Not corrected for off-nadir pointing.	meter	Integer (F8.0)	Note: used in surface height correction
Active Centroid Longitude (west 0-360)	Copy from LBDR	deg	Float (F7.2)	

Parameter	Method	Units	Format	Algorithm
Active Centroid Latitude	Copy from LBDR	deg	Float (F7.2)	
Threshold surface height	From threshold range detection	meter	Integer (I8)	Algo 1 (from center, so ~2575000)
MLE surface height	MLE estimate of surface height	meter	Integer (I8)	Algo 8
First moment surface height	From first moment of waveform range (Range to Surface)	meter	Integer (I8)	Algo 2 (In ABDR field surface_height)
Corrected first moment surface height	First moment height corrected for off-nadir angle and altitude	meter	Integer (I8)	Algo 3
Corrected threshold surface height	Threshold height corrected for off-nadir angle and altitude	meter	Integer (I8)	Algo 4
Height span of backscatter Distribution ("depth")	Square root of the second central moment	meter	Integer (I8)	Algo 5 (In ABDR field surf_ht_std)
Skewness of backscatter distribution	Third central moment normalized	dimensionless	Float (F8.2)	Algo 6
Incidence angle	Copy from LBDR	degrees	Float (F8.3)	
Sigma0	Calibrated MLE amplitude estimate	dB	Float (F8.2)	Algo 9 (see note)
SNR	Ratio of peak to estimated noise backscatter value	dB	Float (F8.2)	Algo 7
MLE fit quality	Difference between data and model	%	Float (F8.2)	Final value of err_ML in algo 8

Algo 1: Threshold Detected Surface Height

Data samples are shifted to put the maximum value at the middle of the received window (1000 points).
A noise level is computed as the average over the first 200 samples.
The threshold bin is the first sample > 15 times the noise level.
The total range is computed by transforming bin with altimeter constants and resolving the range ambiguity.
The corresponding Titan surface height is found without taking into account the slant geometry for the computed incidence angle (see Corrected Threshold Surface Height).

Algo 2: First Moment Surface Height

Data samples are shifted to put the maximum value at the middle of the received window (1000 points).
A noise level is computed as the average over the first 200 samples.
All values < 10 * noise are put to zero (if 10 * noise is > max(data) the threshold 10 * noise is iteratively reduced by dividing by 2).
The first moment bin is estimated as Sum(bin*value) / Sum(value).
The total range is computed by transforming bin with altimeter constants and resolving the range ambiguity.
The corresponding Titan surface height is found without taking into account the slant geometry for the computed incidence angle (see Corrected First Moment Surface Height).
(This value corresponds to the PDS Data Dictionary element definition derived_planetary_radius.)

Algo 3: Corrected First Moment Surface Height

The first moment height is corrected for spacecraft range to surface and off-nadir pointing effects based on simulations including surface curvature and RMS surface height over the altimeter footprint as it varies with range.

Algo 4: Corrected Threshold Surface Height

The threshold height is corrected for spacecraft range to surface and off-nadir pointing effects based on simulations including surface curvature and RMS surface height over the altimeter footprint as it varies with range.

Algo 5: Height Span (Depth) – Square root of second central moment

Data samples are shifted to put the maximum value at the middle of the received window (1000 points).
A noise level is computed as the average over the first 200 samples.
All values < 10 * noise are put to zero (if 10 * noise is > max(data) the threshold 10 * noise is iteratively reduced by dividing by 2).
Bin values relative to the first moment (bin_c) are used to estimate the second moment bin as Sum(bin_c^2*value) / Sum(value).
The second moment range is computed by transforming this bin with altimeter constants.

Algo 6: Height Skewness – Normalized third central moment

Data samples are shifted to put the maximum value at the middle of the received window (1000 points).
A noise level is computed as the average over the first 200 samples.
All values < 10 * noise are put to zero (if 10 * noise is > max(data) the threshold 10 * noise is iteratively reduced by dividing by 2).
Bin values relative to the first moment (bin_c) are used to estimate the third moment bin as Sum(bin_c^3*value) / Sum(value).
The third moment range is computed by transforming this bin with altimeter constants.
The value is normalized by dividing by the second moment raised to the 1.5 power.

Algo 7: Signal to Noise Ratio

Data samples are shifted to put the maximum value at the middle of the received window (1000 points).
A noise level is computed as the average over the first 200 samples.
MAX = maximum of data values.
The SNR value is found: SNR=10*log10(MAX/noise) .

Algo 8: Maximum Likelihood Estimate of Height

A model of the expected return for the Cassini altimeter pulse for the given off-nadir angle and RMS surface height distribution is fit to the observed values with an iterative Maximum Likelihood Estimator (MLE). The procedure is widely used in processing ocean altimeter data such as TOPEX and Jason-1. The resulting estimates are usually comparable to the first moment estimates. The algorithm can be confused if the observed pulse is significantly different (e.g., double-peaked) from the assumed model. The solutions intrinsically correct for range and off-nadir effects that must be explicitly corrected for the threshold and first moment estimates. A complete description of this processing is in press for publication in Transactions on Geoscience and Remote Sensing (Alberti et al).

Algo 9: Backscatter (sigma0) Estimate

Constants & definitions:
k=1.38e-23
B = transmitted signal bandwidth
G0 = antenna gain 53.1 dB
sigma_p = sqrt(1/log(2)/8)/B
PT = peak transmitted power (48.084 W)
Lambda = transmitted central wavelength
T = transmitted pulse length

For each fly-by calibration data are processed (ALTH mode).
Data with antenna calibration source are used (csr = 1): to give noise_antenna_mean = mean of power detected data
ATT_cal = value of attenuation used during acquisition of antenna data.
Using system temperature test data (L1=-27 and T1 = 814, L2=-31 and T2=956), the two parameters for the linear approximation of system temperature are found:
b=(T2-T1)/(L2-L1) ; a=T1-b*L1
The system temperature during calibration is found:
T_sys = a + b*10*log10(ATT_cal)
The calibration constant is found:
C = k*B*T_sys/ noise_antenna_mean*ATT_cal
The final value of AMP output of the MLE method (see algo 8) is used to evaluate the final sigma0:
K=(G0^2) * (lambda^2) * c / 2 / ((4*pi)^2) ./ (H^3) * PT .* B .* T .* pi .* sigma_p
sigma_0 = 2./ATT.*AMP*C/K, where ATT = attenuation value used.

NOTE: The AMP value is the amplitude estimate from the MLE. For waveforms that do not conform to the pulse model used in the MLE, the amplitude estimate may not be a good representation of the total backscatter. In particular, for multi-peaked or diffuse waveforms, this value will underestimate the total return power. The SBDR and LBDR files contain a backscatter estimate from the scatterometer processing which does include all returned power.

Overview of Cassini Radar Altimetry

The Cassini RADAR instrument is described in detail in Elachi et al. (2004). The central antenna beam (Beam 3 for SAR) of Cassini's 4-m high gain antenna is roughly circular, with a full-width half maximum of 0.35 degrees (6 milliradians). This beam is used for non-SAR observations, including altimetry. Altimetry is performed with the beam pointed at nadir, and thus altimetry data is confined to short segments of the spacecraft ground track. Typical altimeter observations ("tracks") are 300 to 600 km long. A unique observation was obtained on T30 that was about 3500 km long, much of it over the T28 SAR image swath.

The raw altimeter data product is an echo profile – intensity versus propagation time delay referenced to the spacecraft clock – resulting from matched filter processing ("compressing") 10-MHz samples of the frequency-encoded ("chirped", 4.2-MHz bandwidth) pulse to give one-way range resolution of 30 m ("range bin"). Time delay is determined from the echo profile as described above in algorithms 1, 2, 8. The delay corresponds (via a factor of two and the speed of light) to the range to the target. Data are taken in bursts of pulses (typically 15) separated by 1-3 seconds. Determining the surface height relative to a reference point (in this case the center of mass) also depends upon an independent measurement of the position of the point relative to the altimeter. The Cassini-Titan distance is found using the ephemeris determined by the project navigation team. The Cassini-Titan distance is reconstructed after a flyby to an accuracy of better than 100 m. As noted in Section 2.3.2, the spacecraft position and velocity vectors are obtained at the start time of the burst (t_ephem_time). The geometry for altimeter data is calculated at

t_ephem_time + act_geom_time_offset.

Users can compute the spacecraft position at this time using values of the position and velocity in an equation shown generically as

new_sc_pos = sc_pos + act_geom._time_offset * sc_vel

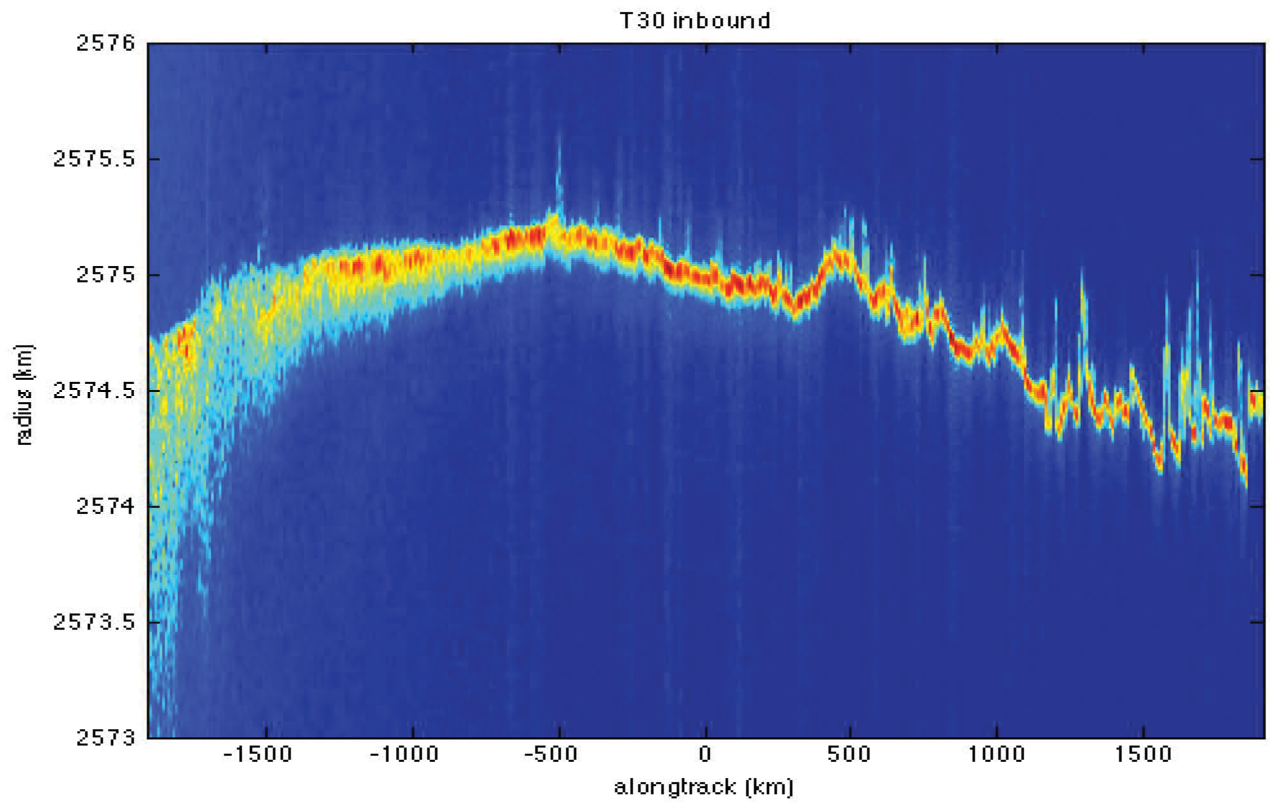
where sc_pos and sc_vel are in the desired coordinate system and the equation applies to each component of the position. Performing this position update is crucial to using the altimeter data (but as noted, it is already done for the altimeter bursts).

The echo profile is defined by the surface radar backscatter cross section as a function of range weighted by the antenna beam pattern. If the beam is not directed vertically (at nadir), the estimated range may not correspond exactly to the altitude. The spacecraft attitude is maintained near nadir-pointing by Cassini's attitude control system. The beam nominally intersects the surface within about 2 milliradians (0.12 degrees, approximately 1/3 of a beam width) of nadir. For the early flybys Ta and T3 when the Titan ephemeris, and thus the relative position of the spacecraft and Titan, was less well-known, the off-nadir angle was somewhat larger than 2 milliradians (mrad). The error from these variations is corrected above in algorithms 3, 4. For off-nadir angles greater than the nominal ~1 mrad, the error grows rapidly.

For locally flat surfaces with ample signal to noise like the Earth's oceans, modeling of the altimeter return in the pulse-limited case using the Brown model (Brown, 1977) can yield range resolutions of better than 0.1 of the nominal range resolution. The

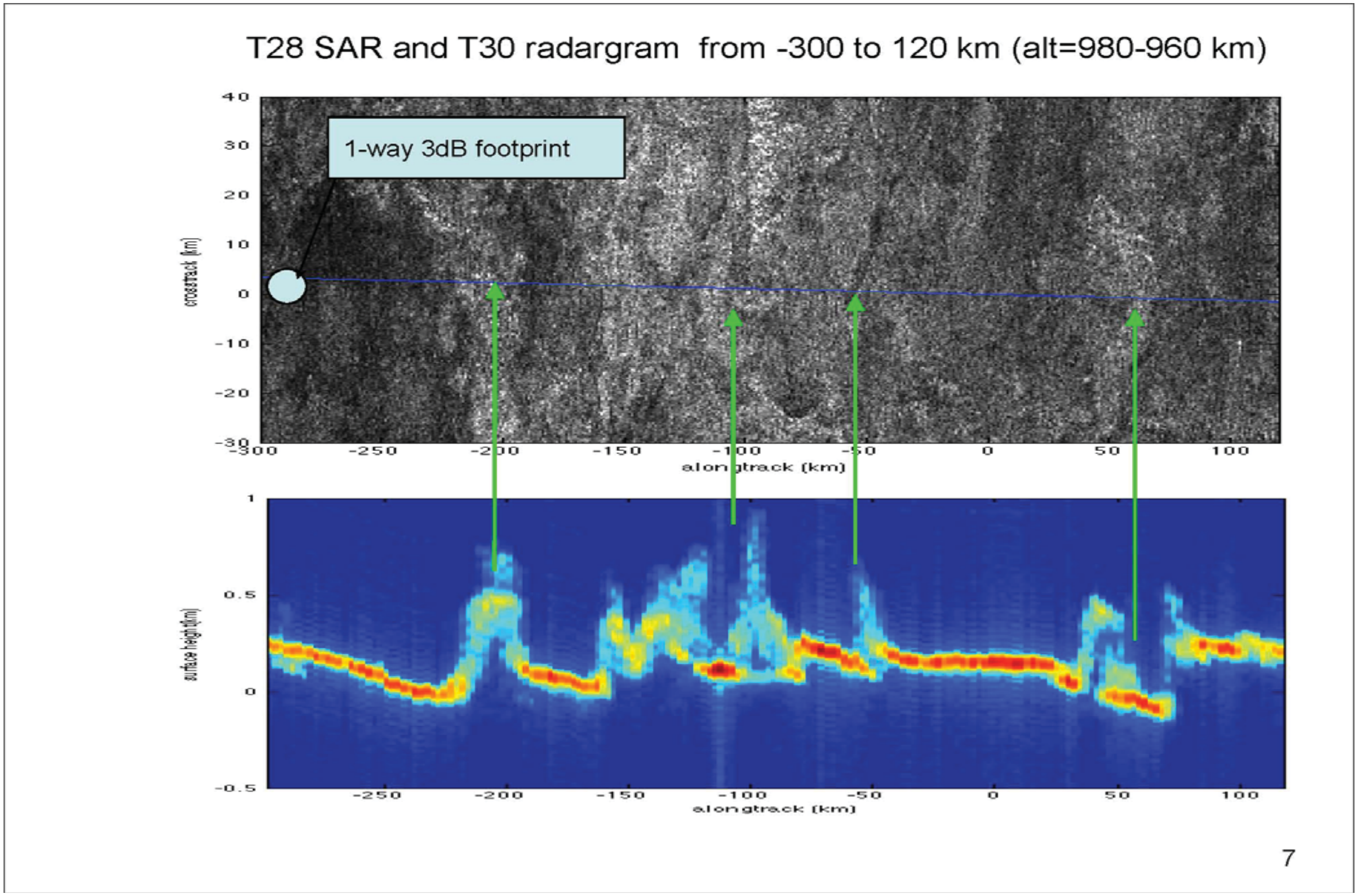
early observations of Titan suggested that this model could be applicable to the data so that using the Brown model in a Maximum Likelihood Estimator (MLE) the range could have a precision of a few meters. Unfortunately, later data have shown that the pulses are sometimes more complex than predicted by the Brown model. Improved MLE fits require a better pulse model. The MLE algorithm for single peaked waveforms gives a height estimate similar to that from the first moment. Single peak waveforms occur over most of Titan, the main exception being the brightest, apparently hilly and complex areas.

The figure below shows a "radargram" – signal strength vs height above the center of Titan for T30. As noted above, T30 was unique in being a very long track of altimeter data (about 3500 km) over the T28 SAR swath. The track goes from a typical altimeter altitude of 10,000 km above the surface to closest approach at approximately 1000 km. At the lower altitude the antenna footprint becomes much smaller (~6 km rather than ~60 km) providing improved spatial resolution. The second figure below shows the end of the track (the right edge of the first figure – the along track scales are centered at different places).


T30 inbound
radius (km)
2576
2575.5
2575
2574.5
2574
2573.5
2573
-1500
-1000
-500
0
500
1000
1500
alongtrack (km)

19

The T30 altimeter track provided significant insight into the altimeter data. The main conclusion was that the much of the return width, or “depth,” seen in the radargrams is sub-footprint surface height variation. With this understanding, simulations with RMS surface height variations of approximately 100-200 m and including surface curvature and off nadir pointing are able to reproduce many of the characteristics of the radargrams. After additional analysis, it was decided to include the signal second central moment and the skewness – the third moment normalized by the second moment as shown in algorithm 6 – to provide numerical data to represent the depth and complexity seen in the radargrams. As can be seen below, there is small-scale information, usually much smaller scale than the antenna footprint, that cannot be easily conveyed by statistics. Thus, the data in the ASCII file provide a starting point for understanding the altimeter data; but much additional information can be obtained from the waveforms in the ABDR.



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