TRMM SCIENCE USER - INTERFACE CONTROL SPECIFICATION (ICS)

TSDIS.MDL-02.5

TROPICAL RAINFALL MEASURING MISSION SCIENCE DATA AND INFORMATION SYSTEM

Interface Control Specification Between the Tropical Rainfall Measuring Mission Science Data and Information System (TSDIS) and the TSDIS Science User (TSU)

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Volume 3

File Specifications for TRMM Products - Level 1

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Version 1	7/31/95	N/A	Draft Release
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Version 4	9/22/98	185-190, 196-201, 204, 205, 207, 208, 223, 227, 237, 240-244, 246, 249, 247, 253, 259, 261, 263, 266-268, 272-275, 278, 280, 281, 282, 279, 285-287, 292-294, 299, 305, 306, 311	Update file specifications to Version 4 Algorithm
Version 5	11/10/99	316, 324	Update file specifications to Version 5 Algorithm / Update to version 5a Algorithm (post orbit boost)

Version 6	8/25/04	331, 337, 342, 343, 346	Update file Specifications for 1B21 Minimum Echo Flag and Land/Ocean Flag were added. Added Appendix C - Non-Standard Algorithms : 2N-25, 3A-12, and CSH. Made Changes to 1B21 algorithm specifications. Add information to 3A-12 Monthly TMI profiling (additions to "nlayer" specification and the new "nlevel" listing). Made Correction to Ray Header to replace Attribute with "Vdata Table in section 6.5.2. Error correction in VIRS Range and Accuracy (Table 5.5.2-4) for 1B01- Changed Channel 1 Maximum from 65.5 to 55.84 and changed channel 2 Maximum from 32.7 to 8.9. Added and corrected information to section C. Changed specification on Figure C-2 "Data Format Structure for 3A-12, Monthly TMI Profiling" - Changed Array: nlat x nlon x nlevel "3A-12 Monthly TMI Profiling" for "nlevel" and "LatentHeat" specifications. Pages C-3 and C-4. Added coordinate information Appendix C.2, after the nlayer line and Appendex C.3, after the nh line. Added information about changed header format of PR, TMI and VIRS 1A binary files under PPS' Linux based systems.

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1. INTRODUCTION

The Tropical Rainfall Measuring Mission (TRMM) is an integral part of the National Aeronautics and Space Administration (NASA) Earth Science Enterprise. The TRMM observatory was launched in 1997 into a near circular orbit of approximately 350 kilometers altitude with an inclination of 35 degrees and a period of 91.5 minutes (15.7 orbits per day). During August 2001, the TRMM altitude was raised to approximately 402.5 kilometers with a period of 92.5 minutes (15.6 orbits per day). The TRMM Science Data and Information System (TSDIS) is the data processing and science information system for TRMM. The Earth Observing System Data and Information System (EOSDIS) serves as the long-term archive for all TRMM data products.

1.1 IDENTIFICATION

This is the TRMM Science Data and Information System (TSDIS) - TSDIS Science Users (TSU) Interface Control Specification Volume 3 File Specifications for TRMM Products - Level 1.

1.2 SCOPE

This document describes the file formats for Level 1 TSDIS products. Level 2 and 3 products are described in Volume 4. Browse specifications are described in Volume 5.

1.3 PURPOSE AND OBJECTIVES

The purpose of this file specification document is to define the file content and format for the TRMM Level-1 data products. Level-1 data products can be divided into Level-1A, Level-1B, and Level-1C data products.

The TRMM Science Requirements references intermediate products for the purpose of monitoring instruments and product production, which this document refers to as “Instrument Analysis Products.” Since this data is not archived at EOSDIS, these formats are not described in this document.

The specifications in this document incorporate the results from a series of meetings with EOSDIS for agreements on file structure, and TRMM science team members for file contents. Discussions with other missions that have similar data sets have helped to form the initial basis for the file specifications. In addition, characteristics from popular formats were incorporated into the file formats (e.g., the Wentz format is used to help develop the TMI file specification).

1.4 DOCUMENT STATUS AND SCHEDULE

The file specifications have been reviewed by the algorithm developers and are expected to be fairly stable. The file specifications will be instrumental in developing the algorithm software, the TSDIS toolkit and refining the Data Volume Estimates. The schedule is as follows:

• Version 1	11/07/94	Complete
• Version 2	12/07/94	Complete
• Version 3	4/14/95	Updated metadata with new EOSDIS definitions and updated orbit definition.
• ICS Release 2	8/31/95	Incorporates comments from algorithm developers
• ICS Release 3 Draft	3/14/96	Incorporates file structure and metadata updates from EOSDIS.
• ICS Release 3	6/28/96	Incorporates Level-1 PR modifications from NASDA
• ICS Release 4	9/01/98	Incorporates PR modifications and removes Metadata information from Appendices.
• ICS Release 5	10/01/99	Updates for Version 5 product.
• ICS Release 6	8/24/04	Updates for Version 6 products. See Change Record History.

1.5 DOCUMENT ORGANIZATION

This document is organized so that a section is dedicated to each instrument. The organization is as follows:

Section 2.0 EOSDIS AND HDF - This section describes EOSDIS structures, aspects of Hierarchical Data Format (HDF) which are used in the TSDIS file formats, and the approach to recording metadata.

Section 3.0 FORMATTING CONVENTIONS - This section describes general formatting conventions used in this document.

Section 4.0 TRMM MICROWAVE IMAGER (TMI) - This section describes the file specifications for the TMI instrument. It provides a brief description of the instrument and the scan geometry as an introduction. The structure of the TMI file is provided, along with descriptions of the data objects and the associated metadata.

Section 5.0 VISIBLE AND INFRARED SCANNER (VIRS) - This section describes the file specifications for the VIRS instrument. It provides a brief description of the instrument and the scan geometry as an introduction. The structure of the VIRS file is provided, along with descriptions of the data objects and the associated metadata.

Section 6.0 PRECIPITATION RADAR (PR) - This section describes the file specifications for the PR instrument. It provides a brief description of the instrument and the scan geometry as an introduction. The structure of the PR file is provided, along with descriptions of the data objects and the associated metadata.

Section 7.0 GROUND-BASED VALIDATION RADAR (GV) - This section describes the file specifications for the Ground Validation (GV) Radars. It provides a brief description of the instrument and the scan geometry as an introduction. The structure of the GV file is provided, along with descriptions of the data objects and the associated metadata.

Section 8.0 ISSUES - This section identifies any outstanding issues from the discussions with EOSDIS or with the TRMM science team members.

2. EOSDIS AND HDF

2.1 EOSDIS STRUCTURES

2.1.1 Swath Structure

The swath structure was created by EOSDIS to store satellite data which are organized by scans. TSDIS implements the swath structure in Levels 1B, 1C, 2A, and 2B satellite products. Figure 2.1.1-1 shows a generic swath structure as it is used in TSDIS data products. The swath structure is contained in a Vgroup (Vgroups are defined in Section 2.2), with the name SwathData and the class SwathData. In the SwathData Vgroup are SwathStructure, Scan Time, Geolocation, scan data, and IFOV data. For all of these objects, the scan dimension has the least rapidly varying index. SwathStructure (details below) is a text block which specifies which geolocations and times apply to which elements of the IFOV data. The Scan Time is a Vdata (8-byte float or several integers whose sizes sum to 8 bytes; Vdata is defined in Section 2.2). The Geolocation is an SDS (defined in Section 2.2) containing latitude and longitude (4-byte float). Scan data are data that apply to the whole scan and can take the form of one or more Vdatas or SDSs. The IFOV data occur at every pixel or at regular pixel intervals (e.g., every 10 pixels) and take the form of one or more SDSs.

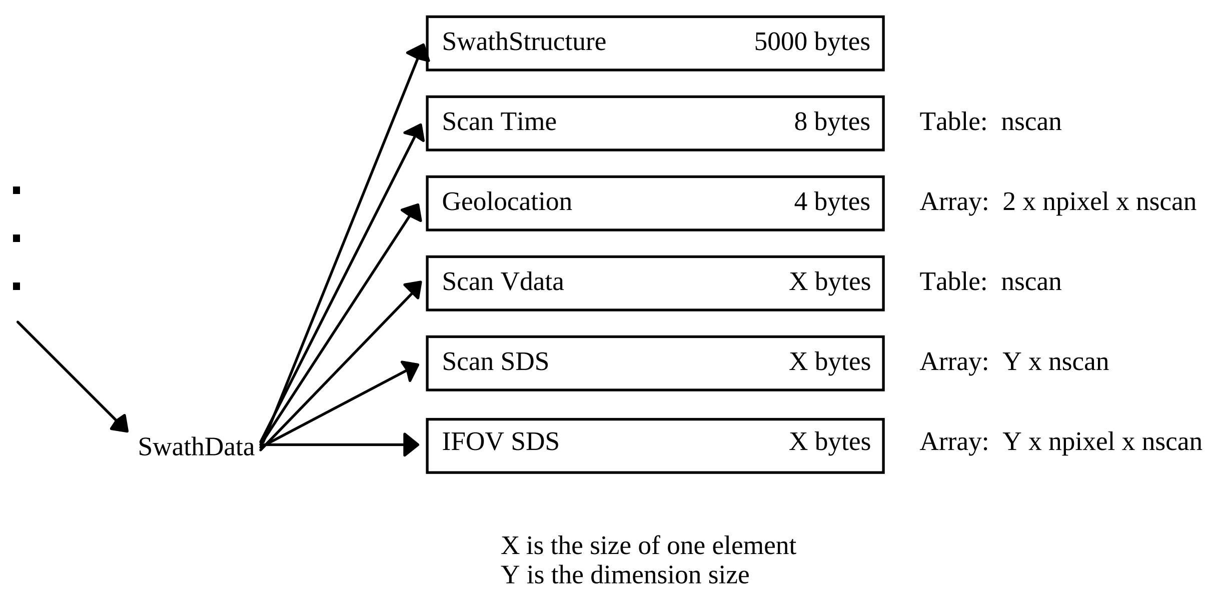


Figure 2.1.1-1
Generic Swath Structure

The purpose of the SwathStructure is to allow EOSDIS to ingest data into their archive; therefore, the Algorithm Developer will not need to read or write the data contained within this object. SwathStructure is an object that mimics an attribute, since HDF has not yet defined attributes for Vgroups. This imitation of an attribute is implemented as a single Vdata with the name SwathStructure, the class "Attr0.0", one field named "VALUES", number type of DFNT_CHAR8, and order equal to the length of the text. This specification of SwathStructure anticipates the HDF development of attributes for Vgroups. The maximum expected size for SwathStructure is 5000 bytes. The fields within SwathStructure are written in Object Development Language (ODL), which is defined in the Planetary Data System Standard Reference.

SwathStructure relates Geolocation (including time) to the IFOV data. SwathStructure specifies this relationship first by defining each "dimension," where dimension means the size of one index of an array (not a physical dimension such as height). Dimensions of Scan Time, Geolocation, and IFOVs are defined. The names of the dimensions can be any name, but it is recommended to use names similar to those used in the following example. Second, parameters are defined. Examples of parameters are time, latitude, and brightness temperature. In the parameter definition, dimensions are stated in "C order," opposite to the order used in the format definitions later in this document. Parameters used to specify geolocation (normally Latitude, Longitude, and Time) are defined as GeoParameters. Data parameters (for example, radiance or rainfall) are defined as DataParameters. Third, the relationships (i.e., mappings) between geolocation and data parameters are defined in DimensionMap. The following example applies to Level-1B TMI, where the number of low resolution pixels in one scan is 104, the number of high resolution pixels in one scan is 208, the number of scans in one granule is 2991, the number of low resolution channels is 7, and the number of high resolution channels is 2.

```
OBJECT = Dimension
        Name = "nscan"
        Size = 2991
END_OBJECT

OBJECT = Dimension
        Name = "npixel_low"
        Size = 104
END_OBJECT

OBJECT = Dimension
        Name = "npixel_high"
        Size = 208
END_OBJECT

OBJECT = Dimension
        Name = "nchannel_low"
        Size = 7
```

END_OBJECT

OBJECT = Dimension
    Name = “nchannel_high”
    Size = 2
END_OBJECT

OBJECT = GeoParameter
    Name = “Latitude”
    DataType = float32
    Dimension = “nscan”
    Dimension = “npixel_high”
END_OBJECT

```
OBJECT = GeoParameter
        Name = "Longitude"
        DataType = float32
        Dimension = "nscan"
        Dimension = "npixel_high"
END_OBJECT

OBJECT = GeoParameter
        Name = "Time"
        DataType = float64
        Dimension = "nscan"
END_OBJECT

OBJECT = DataParameter
        Name = "Low Resolution Channels"
        DataType = int16
        Dimension = "nscan"
        Dimension = "npixel_low"
        Dimension = "nchannel_low"
END_OBJECT

OBJECT = DataParameter
        Name = "High Resolution Channels"
        DataType = int16
        Dimension = "nscan"
        Dimension = "npixel_high"
        Dimension = "nchannel_high"
END_OBJECT

OBJECT = DimensionMap
        DataDimension = "npixel_low"
        GeoDimension = "npixel_high"
        Offset = 0
        Increment = -2
END_OBJECT
```

DimensionMap specifies the relationship between a DataDimension and a GeoDimension. If the relationship is one-to-one, the DimensionMap may be omitted. In the example, both the High Resolution Channels and the Latitude and Longitude share the npixel_high dimension so no DimensionMap is written.

When the relationship between a DataDimension and a GeoDimension is not one-to-one, a DimensionMap specifies that relationship through Offset and Increment. The fields Offset and Increment specify which elements of the Geolocation or Scan Time array apply to which elements of the IFOV array. To understand Offset and Increment, consider the pixel dimension as an example. Offset is the pixel number (in zero based notation) of the first IFOV pixel to which the first geolocation applies. Increment is the pixel interval to which to apply the Geolocation. In the normal case, Offset = 0 and Increment = 1, meaning Geolocations 1, 2, 3, ... apply to IFOV pixels 1, 2, 3, ... The case where, for example, the second Geolocation applies to the first IFOV pixel is handled with a negative Offset. The case where, for example, every other Geolocation applies to every pixel is handled with a negative Increment. These and other examples for various relations between Geolocation and pixels are shown in Table 2.1.1-1.

Table 2.1.1-1
Relations Between Geolocation and Pixels

OFFSET	Increment	Geolocation Pixels	IFOV Pixels
0	1	1, 2, 3, ...	1, 2, 3, ...
0	2	1, 2, 3, ...	1, 3, 5, ...
0	-2	1, 3, 5, ...	1, 2, 3, ...
1	1	1, 2, 3, ...	2, 3, 4, ...
-1	1	2, 3, 4, ...	1, 2, 3, ...

To avoid repetitious text, certain defaults are used in this document for the formats of an IFOV object: in the scan dimension, Offset = 0 and Increment = 1 always; in the pixel dimension, Offset = 0 and Increment = 1 unless otherwise specified; the names of the dimensions are as above.

2.1.2 Planetary Grid Structure

The Planetary Grid Structure is a structure created by EOSDIS to store earth located grids. The grid is an array of grid boxes, rather than grid points. TSDIS employs the Planetary Grid Structure in Level 3A and 3B satellite products. Figure 2.1.2-1 shows a generic Planetary Grid Structure as it is used in TSDIS formats. The Planetary Grid Structure occupies part of a file. This structure is contained in a Vgroup, with the name PlanetaryGrid and the class PlanetaryGrid. In that Vgroup appear one GridStructure, one or more Data Grids, and other Data. GridStructure is a single Vdata which allows the geometric interpretation of the grids. GridStructure is an object that mimics an attribute, since HDF has not yet defined attributes for Vgroups. This imitation of an attribute is implemented as a Vdata with the name GridStructure and the class “Attr0.0” , one field named “VALUES”, number type of DFNT_CHAR8, and order equal to the length of the text. This specification of GridStructure anticipates the HDF development of attributes for Vgroups. The maximum expected size for GridStructure is 5000 bytes. Since the purpose of GridStructure is to allow EOSDIS to ingest data into their archive, Algorithm Developers do not need to read from or write to GridStructure. Table 2.1.2-1 specifies the fields within GridStructure. Six of the fields (the resolutions and bounding coordinates) are also found in Core Metadata. Three fields (bin_meth, registration, and Origin) are not found in Core Metadata.

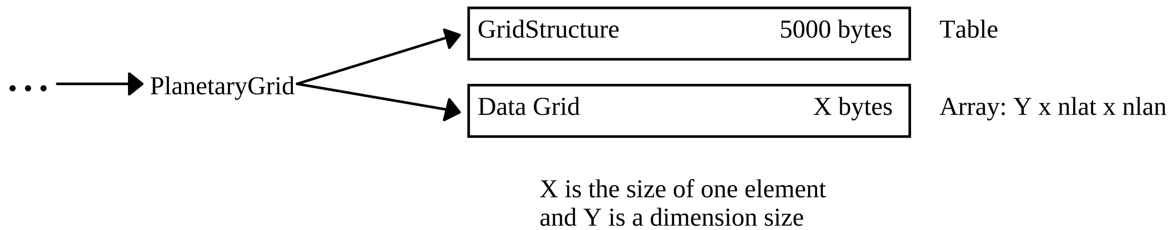


Figure 2.1.2-1
Generic Planetary Grid Structure

Table 2.1.2-1
GridStructure Fields

Name	Estimated Size (bytes)	Description
bin_meth	50	Method used to obtain the value in the bin. A simple mean would have the value “ARITHMEAN”. Currently, no other values have been defined.
registration	50	Representative location within the bin. For example, if the center of the bin is the most representative location, the value “CENTER” would be used. Currently, no other values have been defined.
Latitude Resolution	50	North-south size of a bin (degrees latitude).
Longitude Resolution	50	East-west size of a bin (degrees longitude).
North Bounding Coordinate	50	Northern-most latitude (degrees) covered by the grid.
South Bounding Coordinate	50	Southern-most latitude (degrees) covered by the grid.
West Bounding Coordinate	50	Western-most longitude (degrees) covered by the grid.
East Bounding Coordinate	50	Eastern-most longitude (degrees) covered by the grid.
Origin	100	Origin of the grid indices. For example, “SOUTHWEST”

The fields of GridStructure are written as text using ODL. An example for the field named Registration follows:

```
OBJECT = Registration
        Value = “CENTER”
END_OBJECT = Registration
```

Unless otherwise specified, bin_meth = “ARITHMEAN” and registration = “CENTER.” TSDIS Planetary Grids will always have North Bounding Coordinate = 40, South Bounding Coordinate = -40, West Bounding Coordinate = -180, East Bounding Coordinate = 180, and Origin = “SOUTHWEST”. Unless otherwise specified, Latitude Resolution = Longitude Resolution = 5.

Each Data Grid is an SDS with dimensions Y x nlat x nlon, where Y is the number of variables and nlat and nlon are the number of North-South and East-West grid points, respectively. The names of the latitude and longitude dimensions are Latitude_X and Longitude_X, where X is the name of the Data Grid SDS. Other dimensions have the names specified in the Swath description. The name of the SDS is the name of the variable contained in the grid.

To avoid repetitious text, certain defaults are used in this document for the formats of a Data Grid SDS: unless otherwise specified, the names of the dimensions are as above.

2.1.3 Radar Grid Structure

The Radar Grid Structure is a structure used to store TSDIS GV Level-2 and Level-3 grids. The Radar Grid Structure is a TSDIS defined EOSDIS structure. The grid is equivalent to the grid created by the NCAR SPRINT software and does not correspond to any standard projection. It is neither equal area nor equal angle. The grid is an array of grid points, rather than grid boxes. It has a fixed horizontal distance between grid points and an odd number of grid points in the x and y directions. The origin is in the central grid point of the lowest grid plane. Distances along the x and y directions are measured on a flat plane tangent to the earth's surface directly below the origin. The z distances are measured from mean sea level, perpendicular to this tangent plane. The x dimension coincides with east-west only along the x-direction grid line that intersects the origin. Similarly, the y dimension coincides with north-south only along the y-direction grid line that intersects the origin and the z dimension coincides with vertical only directly above the origin. The constant z grid planes follow the curvature of the earth.

Figure 2.1.3-1 shows a generic Radar Grid Structure as it is used in TSDIS formats. The Radar Grid Structure occupies part of a file. The Radar Grid Structure is contained in a Vgroup, with the name RadarGrid and the class RadarGrid. In that Vgroup appear one or more Data Grids along with other objects. Each Data Grid is an SDS with dimensions nx x ny x nz x nvol, where nx, ny, and nz are the grid dimensions in the x, y, and z dimensions and nvol is the number of Volume Scans (VOSs) in the granule. The fields needed to specify the grid, shown in Table 2.1.3-1, are specified in Product Specific (PS) metadata. The values of these fields are shown in Table 2.1.3-2.

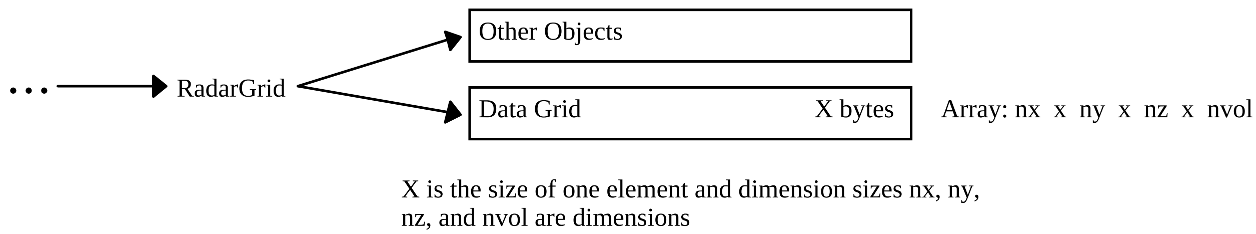


Figure 2.1.3-1
Generic Radar Grid Structure

Table 2.1.3-1
Fields in PS Metadata which Specify the Radar Grid Structure

Name	Estimated Size (bytes)	Description
Radar Grid Origin Latitude	50	Latitude (degrees) of the origin.
Radar Grid Origin Longitude	50	Longitude (degrees) of the origin.
Radar Grid Origin Altitude	50	Altitude (km) of the origin.
Radar Grid Spacing x	50	The zonal interval (km) between grid points.
Radar Grid Spacing y	50	The meridional interval (km) between grid points.
Radar Grid Spacing z	50	The vertical interval (km) between grid points.
Radar Grid Size x	50	The number of grid points in the zonal grid direction.
Radar Grid Size y	50	The number of grid points in the meridional grid direction.
Radar Grid Size z	50	The number of grid points in the vertical grid direction.

Table 2.1.3-2
Values of Radar Grid Structure Fields

Name	Texas	Florida	Single radar sites
Radar Grid Origin Latitude	28^o 56' 59.0"	26^o 21' 19.4"	Radar latitude
Radar Grid Origin Longitude	-95^o 56' 12.5"	-81^o 24' 26.3"	Radar longitude
Radar Grid Origin Altitude	1.5	1.5	1.5
Radar Grid Spacing x	2	2	2
Radar Grid Spacing y	2	2	2
Radar Grid Spacing z	1.5	1.5	1.5
Radar Grid Size x	285	353	151
Radar Grid Size y	363	257	151
Radar Grid Size z	13	13	13

2.1.4 Radar Structure

The Radar Structure is simply the navigation information within the GV Level-1B and Level-1C formats. The information to geolocate (radar latitude and longitude and the range, elevation, and azimuth of each bin) are contained in the formats.

2.2 HIERARCHICAL DATA FORMAT (HDF)

Level-1B and higher data products, except 2A-52, produced by TSDIS will be sent to EOSDIS in the Hierarchical Data Format (HDF). HDF was developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign and is the selection for the common data format for EOSDIS. HDF manuals and software may be obtained via anonymous ftp at ftp.ncsa.uiuc.edu Communications to NCSA concerning HDF may be made by email to softdev@ncsa.uiuc.edu or by postal mail to:

NCSA Software Tools Group HDF
152 Computing Applications Bldg.
605 E. Springfield Ave.
Champaign, IL 61820
USA

HDF is a multi-object file format for the transfer of graphical and numerical data between heterogeneous machines. The design of this format allows self-definition of data content, and easy extensibility for future enhancements or compatibility with other standard formats. HDF provides these benefits to algorithm developers and data users:

- **versatile file format**: HDF supports six different data models (8-bit raster model, palette model, 24-bit raster model, scientific data (SDS) model, annotation model, and the virtual data (Vdata) model).
- **extensible file format**: Although HDF currently supports six different data models, new data models will need to be incorporated in the future. HDF can easily accommodate new data models either through NCSA or HDF users.
- **self-describing**: HDF permits the inclusion of a data index (metadata) inside the data file which describes the contents of the file. This simplifies data sharing among diverse scientists.
- **portable file format**: HDF files are portable across heterogeneous computer systems. This allows for an HDF file created on one system (e.g., UNIX) to be used on a different system (e.g., Macintosh).
- **data abstraction**: When either reading or writing to an HDF file, the user does not have to be concerned with the phsical layout of the file.

2.2.1 Relevant HDF Data Models

The EOSDIS data structures are composed of Vgroups and simple HDF models that are well tested and common to the science community. A Vgroup is like a node in a tree structure. The members of a Vgroup can be data models or more Vgroups. Of the six defined data models, the TSDIS file specifications use the following models:

a) *Scientific Data Set* - An SDS is an HDF structure that stores rectangular gridded arrays of data, together with information about the data. An SDS can contain data that are multi-dimensional, but must be of a singular data type and composed of the following elements:
   - The actual data values.
   - The number of dimensions (rank) and the size of each dimension
   - The type of the data (e.g., integer or floating point)
   - (optional) Scales to be used along the different dimensions when interpreting or displaying the data
   - (optional) Labels for all dimensions and for the data
   - (optional) Units for all dimensions and for the data
   - (optional) Format specifications to be used when displaying values for the dimensions and for the data
   - (optional) A range, attributing maximum and minimum values for the data set.

- (optional) Calibration information including an offset and scale factor.
- (optional) A fill value for representing missing data in a data set.
- (optional) The coordinate system to be used when interpreting or displaying the data

b) *VData* - The HDF VData model provides a framework for storing related data in a table-like structure in HDF files. Each table is comprised of a collection of similar records called VData records, whose values are stored in fixed-length fields. Each field can support its own data types, however, every VData record in a table must contain the same types of fields.

2.2.2 <u>HDF Structures for Metadata</u>

Metadata are defined as information about data sets which provide a description of the content, format, and utility of the data set. The word metadata is derived from the Greek word Meta, meaning "with". Metadata may be used to select data for a particular scientific investigation. Each metadata element will have the "label = value" structure. The "label" will be defined by EOSDIS for the core metadata, and by TSDIS for the product specific metadata; the "value" will be supplied by TSDIS. For some core fields though, the values will need to comply with EOSDIS guidelines.

EOSDIS has decided that metadata should be stored in file attributes. Attributes are blocks of text that are attached to either files or SDSs.

2.3 METADATA IMPLEMENTATION

The metadata elements contained in these file specifications were derived from the Proposed ECS Core Metadata Standard Release 2.0, the TSDIS - TSDIS Science User (TSU) Interface Control Specification, and personal communication with algorithm developers.

EOSDIS has divided the metadata elements into two (2) types: core metadata and product specific metadata. Core metadata are common to all or most products in EOSDIS and have been defined by EOSDIS. Product Specific metadata are only related to a particular product, or a group of similar products, and have been defined by TSDIS. Metadata elements are written using ODL.

Core metadata is stored in one file attribute named CoreMetadata.0. CoreMetadata.0 will contain the following structure:

```
OBJECT = <object_name1>;
        Value = <object_value1>;
        Data_Location = <data_location1>;
        Mandatory = <mand_value1>;
END_OBJECT = <object_name1>;
```

```
OBJECT = <object_name2>;
        Value = <object_value2>;
        Data_Location = <data_location2>;
        Mandatory = <mand_value2>;
END_OBJECT = <object_name2>;

.
.
.

OBJECT = <object_nameN>;
        Value = <object_valueN>;
        Data_Location = <data_locationN>;
        Mandatory = <mand_valueN>;
END_OBJECT = <object_nameN>;
END;
```

Product Specific Metadata is stored in another file attribute named ProductMetadata.0. ProductMetadata.0 will contain the following structure:

```
OBJECT = <object_name1>;
        Value = <object_value1>;
        Data_Location = <data_location1>;
        Mandatory = <mand_value1>;
END_OBJECT = <object_name1>;

OBJECT = <object_name2>;
        Value = <object_value2>;
        Data_Location = <data_location2>;
        Mandatory = <mand_value2>;
END_OBJECT = <object_name2>;

.
.
.

OBJECT = <object_nameM>;
        Value = <object_valueM>;
        Data_Location = <data_locationM>;
        Mandatory = <mand_valueM>;
END_OBJECT = <object_nameM>;
END;
```

where <object_name> is the name of the metadata element, <object_value> is the value of the metadata element, Data_Location is always “PGE”, Mandatory is “TRUE” or “FALSE” depending on whether the data is required by TSDIS to be included. For example, if the metadata element named UTCF_SECONDS had a value of 23 and was not required, it would be stored as follows:

```
OBJECT = UTCF_SECONDS;
        Value = 23;
        Data_Location = “PGE”;
        Mandatory = “FALSE”;
END_OBJECT = UTCF seconds;
```

If the value is a list, for example with three elements, then Value is written as:

(Element1, Element2, Element3)

3. FORMATTING CONVENTIONS

3.1 FILE STRUCTURE FIGURES

The figures that illustrate file structure contain either Vgroups or data objects (metadata objects, SDSs, or Vdatas). Figure 3.1-1 is an example of a product structure with annotations shown in italics. Vgroups are represented as the name of the Vgroup without a box. Data objects are represented as the name of the object inside a box. The order of the data objects in the file may differ from their order in the file specification. For metadata objects the estimated maximum total size appears on the right hand side of the box. If the object is a Vdata table, the size of one record appears on the right side of the box and the number of records appears next to the box. If the object is a SDS array, the size of one element appears on the right side of the box and the dimensions of the array appear next to the box.

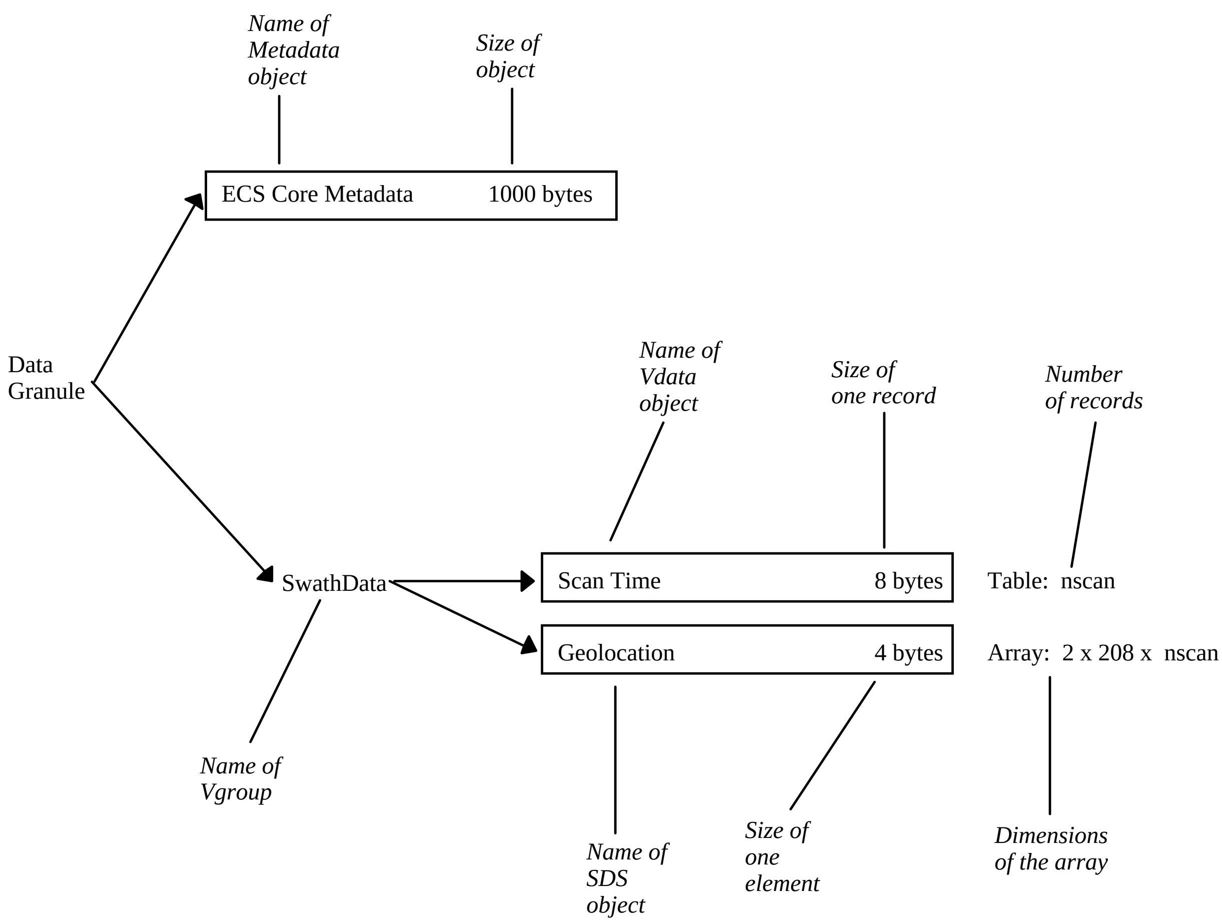


Figure 3.1-1
Example Product Structure

The sizes for the metadata objects are estimated maxima since the values of many metadata are free text and may vary in length and not all metadata elements are used for all products. None of the sizes take HDF overhead into account. Previous (unpublished) experience gained in the TSDIS prototype study and the HDF internal feasibility study has shown HDF overhead to be less than 10% of the total file size for TSDIS products.

3.2 FILE CONTENTS

In the description of the contents of each object within a file, each object is defined in the following format:

> **Name** (Type of HDF structure, Dimensions, word size and type):
> Description

3.3 MISSING DATA AND EMPTY GRANULES

Missing satellite scans are filled with standard values denoting missing data. Missing satellite scans also have the "missing" byte in Scan Status set to 1. Values less than or equal to -99, -9999, -9999, -9999.9, -9999.9 denote missing or invalid data for 1-byte integer, 2-byte integer, 4-byte integer, 4-byte float, and 8-byte float, respectively. Any exceptions to the use of these standard values are explicitly noted in the description of the object. For the PR instrument, scans whose mode is other than observation mode are filled with missing values.

If an entire granule is missing, an empty granule may be created. If an entire orbit of Level 1B, 1C, 2A, or 2B satellite data is missing, scan data is omitted and the PS metadata named "Orbit Size" has the value zero. If an entire hour of Level 1B, 1C, 2A53, 2A54, or 2A55 GV data is missing, volume scan data is omitted and the PS metadata named "Number of VOS" has the value zero. An empty granule is not defined for pentad or monthly averaged data.

3.4 ARRAY DIMENSION ORDER

In the definition of array dimensions, e.g., npixel x nscan, the first dimension (npixel) has the most rapidly varying index and the last dimension (nscan) has the least rapidly varying index. To implement this format in FORTRAN, declare an array with dimensions as they appear in this document. To implement the format in C, declare an array with dimensions reversed from their appearance in this document.

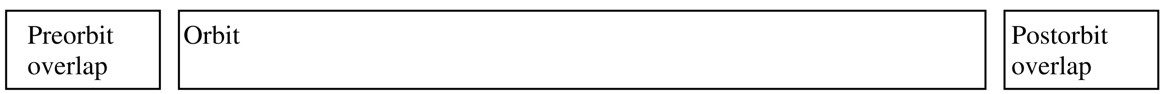
3.5 ORBIT AND GRANULE DEFINITION

The beginning and ending time of an orbit is defined as the time when the sub-satellite track reaches its southernmost latitude. This time is determined from the definitive ephemeris data. A scan is included in an orbit when its Scan Time is greater than or equal to the Orbit Start Time and less than the Orbit End Time. The average orbit is 91.5 minutes or 5490 seconds before August 7, 2001 and 92.5 minutes or 5550s after August 24, 2001 The first partial orbit after launch will be orbit 1, so the first full orbit will be orbit 2.

A granule is defined as one orbit for the VIRS and PR instruments. For the TMI instrument, a granule is defined as one orbit plus an overlap before the orbit, known as the Preorbit Overlap, plus an overlap after the orbit, known as the Postorbit Overlap. The overlap size is fixed at exactly 50 scans. Since there are two overlap periods per granule, each granule will contain 100 overlap scans. Thus the last 100 scans of any granule are duplicated by the first 100 scans of the next granule. See Figure 3.5-1

Overlaps are used to allow algorithm 2B-31 to open only one input granule in order to output one granule. The overlap is needed because 2B-31 requires both TMI and PR measurements at the same location. Since PR points at nadir and TMI points at a 49^{o} angle off of nadir, the colocated measurements will occur around a minute apart.

Single granule:



Multiple granules:

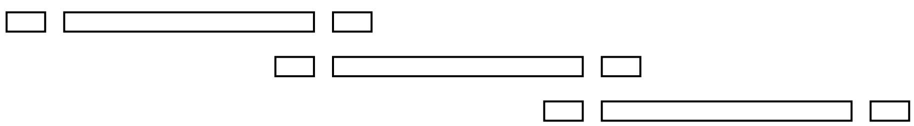


Figure 3.5-1
Granule Structure
Time Increases Toward the Right

The formats in this document for products with overlap (1A-11, 1B-11, and 2A-12) follow the assumption that uniformity within one granule is preferable to uniformity for the same pixel across granules. Therefore one ephemeris file and one UTCF are used in one granule. In a similar vein, the calibration is started at the beginning of the granule and reaches satisfactory values within 10 scans. The advantage of granule uniformity is that there are no discontinuities within a granule and processing has only to input one granule in order to output one granule. The disadvantage is that a pixel in one granule may have a different value, location, and time from the same pixel in another granule. When such a difference occurs, the pixel is in an overlap region in one of the granules. According to the TRMM requirements, the location and time differences will be less than 1 km and 1 ms, respectively.

In Level-1A, extra (usually one) ACS and instrument housekeeping packets are added to ensure that each science packet has an ACS and instrument housekeeping packet before and after the science packet.

3.6 SCANS IN A GRANULE

The number of scans in a granule is shown in the structure diagrams and array dimensions as nscan. For VIRS and PR, the average nscan is calculated from the average number of seconds in an orbit as follows:

$$AVNSCAN = SS \times SO.$$

For TMI, the average nscan is calculated from the average number of seconds in an orbit as follows:

$$AVNSCAN = SS \times SO + 100, \text{ where}$$

		Before August 7, 2001		After August 24, 2001	
Instrument	Scans / Second (SS)	Seconds / Orbit (SO)	AVNSCAN	Seconds / Orbit (SO)	AVNSCAN
TMI	31.600 / 60	5490	2991	5550	3023
VIRS	2 * 98.5 / 60	5490	18026	5550	18223
PR	1 / 0.6	5490	9150	5550	9250

3.7 TIME

Scan Times and Orbit Start Times are stored in the Level-1A headers, the metadata, and in the object named “Scan Time”. The Orbit Start Time is determined from ephemeris data and the definition of the orbit start -- it is independent of any scans. In contrast, a Scan Time is a time associated with a scan of a particular instrument. The Scan Time is the time tag stamped on each science telemetry packet. In particular, the Orbit First Scan Time is the Scan Time of the first scan in an orbit, which occurs at or later than the Orbit Start Time. The Level-1A header stores the Universal Time Correlation Factor (UTCF) derived from the first ACS packet in the orbit. This UTCF is used to translate the Orbit Start Time from UTC to spacecraft clock time. In normal processing, the UTCF, the Scan Times in UTC, and the Scan Times in spacecraft clock time are repeated exactly in Level-1B and higher levels. In the unusual circumstance that the UTCF is found to be incorrect, a corrected UTCF will be stored in Level-1B and higher data products and a flag set to indicate that a corrected UTCF was used. When a corrected UTCF is applied, the UTC Scan Times will be different between (1) Level-1A and (2) Level-1B and higher levels, although the spacecraft clock Scan Times will be the same in Level-1A and

Level-1B and higher levels. Another flag in Level-1B and higher levels shows whether a leap second occurred in the granule.

Times are expressed in five formats:

(1) UTC times in Core or PS metadata or a Level-1A header are written in three words: Date, Time, and Milliseconds. For the Begin and End Times in Core metadata, milliseconds is omitted.

Date is a 10 character string with the following characters:

YYYY/MM/DD, where
YYYY = year,
MM = month number,
DD = day of month, and
"/" is a literal.

Time is an 8 character string with the following characters:

HH:MM:SS, where
HH = hour,
MM = minute,
SS = second, and
":" is a literal.

Milliseconds is a 3 character string with the following characters:

MMM, where
MMM = the number of milliseconds later than the last whole second.

(2) In 2A-52, UTC time is stored as in (1) except "/" is replaced by "-".

(3) In 1B-11 and 2A-12, UTC time is stored in separate words for year, month, day of month, hour, minute, and second.

(4) UTC Scan Time in the body of the data is in seconds of the day. The UTC date and time in the metadata can be combined with the Scan Time to get a complete date and time for every scan.

(5) Spacecraft clock time and UTCF have the same format, which is specified in the **TRMM Telemetry and Command Handbook,** Section 3.3.2.

Spacecraft clock time is the accumulated time count since the power-up of the clock card in the TRMM Spacecraft Data System onboard the satellite. Spacecraft time is correlated to UTC time by the UTCF. The sum of the UTCF and Spacecraft time results in a time that represents the total number of seconds since January 1, 1993 at 00:00:00 (UTC) if one assumes that each day has exactly 86400 seconds, even days with leap seconds. This total number of seconds allows easy computation of days since Janulary 1, 1993. However, to accurately compute time differences one must use more complicated methods, which account for leap seconds. For a more thorough discussion of Spacecraft time and UTCF, see the **TRMM Telemetry and Command Handbook,** Section 3.3.2.

Scan Time is a time associated with each satellite science data scan. It is the time tag written in each science telemetry packet. There is one scan per science telemetry packet. The relationship of Scan Time to the time at each IFOV varies by instrument. A description of the relationship between Scan Time and measurement time for each of the three satellite instruments follows. In each description, T is the beginning sample time and i is the IFOV number:

(1) For TMI, the equations shown in Table 3.7-1 were obtained by personal communication with the instrument scientist.

Table 3.7-1
TMI Equations

CHANNEL	Relationship	Indices	Sample Time
1,2 (10 GHz)	T = Scan Time + 59.185 ms + (i - 1) * 6.600 ms	i = 1 to 104	6.304 ms
3,4,5 (19 , 21, GHz)	T = Scan Time + 125.544 ms + (i - 1) * 6.600 ms	i = 1 to 104	6.266 ms
6, 7 (37 GHz)	T = Scan Time + 125.544 ms + (i - 1) * 6.600 ms	i = 1 to 104	6.304 ms
8, 9 (85 GHz)	T = Scan Time + 125.544 ms + 1.650 ms + (i - 1) * 3.300 ms	i = 1 to 208	3.004 ms

(2) For VIRS, the following equation was derived from a viewgraph produced at Hughes and presented by Bruce Love on January 20, 1995:

T = Scan Time + 107.6 ms + (OFFSET + (i - 1)) * Sample Time,

where i = 1, 261,
Sample Time = 0.29157 ms,
and OFFSET values are shown in Table 3.7-2.

Table 3.7-2
OFFSET Values

CHANNEL	OFFSET
1	0
4	2
5	4
3	6
2	8

The value of Sample Time was derived from the viewgraph using the time of the starting and ending channel 1 science data as follows:

Sample Time = (183.7 ms - 107.6 ms) / 261

(3) For PR, the information was obtained by personal communication with a representative of NASDA.

T = Scan Time + 3.41 ms + (i - 1) * 11.768 ms,
where i = 1 to 49

3.8 QAC ERROR TYPE

This 1 byte of error information is produced at SDPF only for each packet for which an anomaly is detected. This byte contains 8 fields, shown if Table 3.8-1, each of which is a flag.

Table 3.8-1
Error Fields

Bit	Error Type
0	Not used
1	RS header errors
2	Data unit length code wrong
3	RS frame errors
4	CRC frame errors
5	Data unit sequence count error/discontinuity
6	Detected frame errors during the generation of this data unit
7	Data unit contains fill data

A complete description is found in the **Interface Control Document Between the SDPF and the TRMM Consumers.**

3.9 SATELLITE COORDINATES AND FLIGHT MODES

The TRMM satellite structural axes are defined so that +Z is the side where PR is mounted and is the direction normally pointed toward the nadir(straight down toward the Earth). +X is the side toward which the TMI and VIRS instruments are mounted, and the side toward which the TMI instruments takes measurements. Solar arrays are mounted on the + and - Y sides, and the +Y axis is such that the +X, +Y and +Z complete a right-hand system.

The two common flight modes for TRMM are +X forward and -X forward. With +X forward, the +X axis of the spacecraft is pointed along the velocity direction (i.e., in the direction the spacecraft is moving toward), +Y is pointed opposite the orbit normal (orbit spin axis), and +Z is toward the nadir. With -X forward the +X axis is opposite the velocity (i.e., in the direction the spacecraft is moving away from), +Y is along orbit normal, and +Z is still toward the nadir. The spacecraft spends about half it's time in each of these two positions. It switches between +X and -X Forward every two to four weeks with a yaw maneuver taking about 20 minutes. This is done in order to keep the sun always in the -Y Hemisphere, as orbit precession and seasonal changes move the sun slowly above and below the orbit plane. (This maintains passive cooling and power design constraints). The flight mode for each scan is written in all Level 1B, 1C, 2A, and 2B satellite products in Scan Status, Current Spacecraft Orientation.

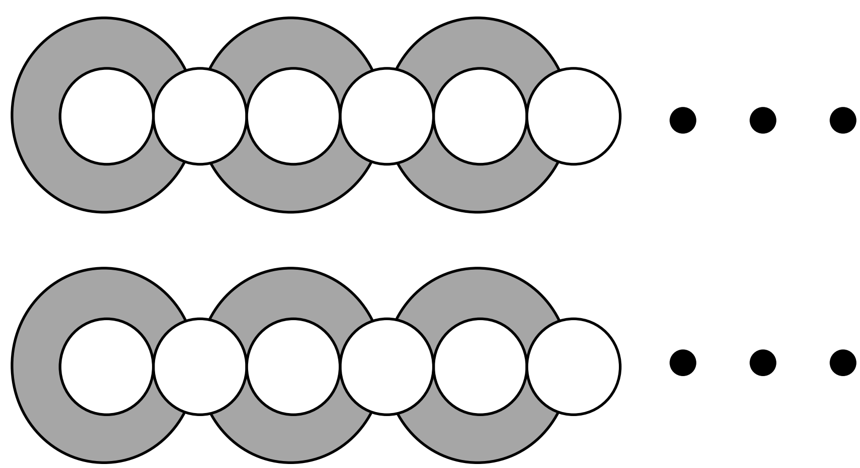
As discussed in the instrument scan geometry sections, the scan directions relative to the flight path change as the mode changes. For TMI, scans are always left to right in the +X spacecraft direction as the microwave antenna rotates about the +Z axis. Thus TMI scans are left to right looking forward along the ground track in the +X forward mode, and are right to left of the ground track in the -X forward mode. For VIRS, scans are right to left of the ground track direction in the +X forward mode, and left to right of the ground track direction in the -X forward mode. PR scans electronically the same direction as VIRS : right to left with +X forward and left to right of the flight path direction with -X forward.

4. TRMM MICROWAVE IMAGER (TMI)

4.1 INSTRUMENT AND SCAN GEOMETRY

The TRMM Microwave Imager (TMI) is one of 5 instruments flown on the TRMM satellite. TMI is similar to the SSM/I instrument flown on the DMSP satellites with several key differences: (1) the addition of vertically and horizontally polarized 10 GHz channels, (2) the scan geometry is the same for every scan instead of alternating between an A scan and a B scan, and (3) there are about twice as many pixels per scan.

The TMI is a 9 channel, 5 frequency, linearly polarized, passive microwave radiometric system. The instrument measures atmospheric and surface brightness temperatures at 10.7, 19.4, 21.3, 37.0, and 85.5 GHz. Each frequency has one vertically (V) and one horizontally (H) polarized channel, except for the 21.3 GHz frequency, which has only vertical polarization. The 10.7, 19.4, 21.3, and 37.0 GHz channels are considered low resolution and the 85.5 GHz channels are considered high resolution. TMI has a conical scanning geometry, rotating continuously about a vertical axis, receiving upwelling radiation from 49˚ off nadir. Scene radiation is recorded from left to right looking in the +x direction. (See Section 3.9) over an annular sector of 130˚ about the sub-satellite track. The swath width is 758.5 km, covered by 104 low resolution pixels or 208 high resolution pixels. A complete description of the TMI instrument is available in the **TMI Technical Description Document**. Figure 4.1-1 shows a simplified version of the scan geometry for two scans. The centers of pixels 1, 3, 5, ... of the high resolution channels (unshaded circles) are collocated with the centers of pixels 1, 2, 3, ... of the low resolution channels (shaded circles).



Low resolution channels appear as shaded circles. High resolution channels appear as open circles in front of the shaded circles. The dots indicate continuation.

Figure 4.1-1

TMI Scan Geometry

4.2 DESIGN CONSIDERATIONS

The TMI formats for the Level-1A and Level-1B products were designed in consultation with Dr. James Shiue (the TMI instrument scientist), Dr. Christian Kummerow (a TMI algorithm scientist), and Mr. Ted Meyer, Mr. Doug Ilg and Dr. Brand Fortner (of EOSDIS). The Level-1A format was designed to minimize processing time and storage volume and to clearly demonstrate reversibility to Level-0. For a discussion of reversibility, see Appendix A. The Level-1A product is a simple concatenation of Level-0 data with a Header Record, which could easily be reversed back to Level-0. Level-1A remains in a binary format and is not in HDF. A detailed description of the Level-1A components is provided in Section 4.3.

The Level-1B format groups like data together. For example, high resolution channel data are in one object rather than, for example, channel, geolocation, and calibration data being interleaved in one object. The Level-1B format includes navigation and calibration information, which was requested by the instrument scientist for purposes of checking the calibration and navigation. Topographic data are not included in Level-1B design at the request of Dr. Kummerow to save disk space. A topographic data base will be provided which users of TSDIS may access. The Surface Type is also not included at the request of Dr. Kummerow since users would have different definitions of Surface Type. The Spacecraft Position and Velocity data are represented in 4-byte floating point precision. Spacecraft Geocentric Position should be represented to 10m accuracy, which equates to 6 significant digits since the earth's radius is about 6,370,000 m. Satellite Local Zenith angle is given for every twentieth high resolution pixel to save disk space. Considerations were given to two existing formats, the "Wentz" format and the MSFC format, both currently used for SSM/I data. The TMI Level-1B format is presented in a Swath Structure and formatted in HDF.

Wentz vs TSDIS format

The Level-1B format is based on the Wentz format, which is described in **User's Manual SSM/I Antenna Temperature Tapes** by Frank J. Wentz of Remote Sensing Systems, published in 1988. Since the Wentz format packs most elements, the scales and biases are listed in the **User's Manual**. The TSDIS format only packs a few elements, whose scales are included in the description of the element. Table 4.2-1 provides a mapping between the Wentz format and the corresponding elements in the TSDIS Level-1B format. Some of the differences in format are due to the difference in scanning geometry between SSM/I and TMI: SSM/I alternates between an A-scan and B-scan, but TMI has only one type of scan. Any references to B-scan by the Wentz format are omitted in the TSDIS format.

MSFC Data

The Pathfinder Daily Antenna Temperature Files archived at MSFC were examined as a possible model for the TSDIS format but not used because their format does not use EOSDIS metadata, and has an unusual way to pack orbits into arrays. Row one of an array contains scan one for the orbit one, then a delimiter, then scan one for orbit two, then a delimiter, and so on for all the orbits in a day. Succeeding rows each contain one particular scan for all of the orbits.

Table 4.2-1

Comparison of Wentz with TSDIS Format

Wentz Element	TSDIS Element
integer time for scan from beginning of 1987	Scan Time
orbit number	Fractional Orbit Number (in Scan Status). The orbit start is defined in Section 3 and is different from the orbit start used in the Wentz format.
time of spacecraft ephemeris	(omitted since ephemeris will be interpolated to the Scan Time)
geodetic latitude of spacecraft ephemeris	Spacecraft Geodetic Position (in Navigation)
fractional time for scan from beginning of 1987	Scan Time
east longitude of spacecraft ephemeris	Spacecraft Geodetic Position (in Navigation)
altitude of spacecraft ephemeris	Spacecraft Geodetic Position (in Navigation)
hot load temperature sensors	Hot Load Temperature (in Calibration)
reference voltages	Hot Load Bridge Reference (in Calibration)
r.f. mixer temperature sensor	(omitted, after discussing with the instrument scientist, Dr. James Shiue, who knows of no algorithm using this information.)
forward radiator temperature sensor	(omitted, after discussing with the instrument scientist, Dr. James Shiue, who knows of no algorithm using this information)
automatic gain control readings for A-scan	Automatic Gain Control (in Calibration)
counts-to-T_A conversion coefficients	Calibration Coefficients (in Calibration)
cold counts for A-scan	Cold Counts (in Calibration Counts)
hot counts for A-scan	Hot Counts (in Calibration Counts)
automatic gain control readings for B-scan	(omitted since there is no B-scan)
cold counts for B-scan	(omitted since there is no B-scan)
hot counts for B-scan	(omitted since there is no B-scan)
geodetic latitudes for A-scan	Geolocation
east longitudes for A-scan	Geolocation
B-scan minus A-scan latitude/longitude differences	(omitted since there is no B-scan)
19, 22, 37 Ghz T_A's and surface-type	Low Resolution Channels (for the T_A's) (surface-type is omitted, after discussion with the algorithm scientist Dr. Christian Kummerow, under the assumptions that the user will use the geolocation information and a surface type data base if surface type is desired and radiometrically derived surface type such as ice are beyond the scope of Level 1B processing)
85 Ghz T_A	High Resolution Channels

4.3 LEVEL-1A

The Level-1A product consists of two files: the Level-1A Product file and the SFDU header file. The Level-1A Product file, "1A-11," is a concatenation of Header record, Spacecraft Attitude packets, TMI Housekeeping packets, TMI Science Data packets, QACs and an MDUL. The SFDU header is a separate file whose format is specified in the **Interface Control Document Between EOSDIS Core System (ECS) and TRMM Science Data and Information System (TSDIS) for the ECS Project.** The data granule size is discussed in section 3. Sizing parameters used are:

> nsec = the number of seconds in an average granule (includes the seconds in an orbit plus the seconds for 100 scans of overlap). See Sections 3-5 and 3-6. Table 4.3-1 describes 1A-11 and Table 4.3-2 is a description of the 1A-11 Header.

Please note that prior to June 1, 2008 all PR, TMI and VIRS binary 1A products were produced on an SGI (big-endian). PPS is currently producing the TMI and VIRS products on the Linux (little-endian) platform. The TMI and VIRS 1A file formats remain the same. The endian order of the data in the headers is written in NATIVE endian (little-endian) format. The CCSDS packets contained in the 1A files remain unchanged.

4.4 INSTRUMENT ANALYSIS PRODUCTS

Instrument Analysis Data and Instrument Analysis Report are intermediate products that are by-products of the Level-1B processing. These products will be made available only to the instrument scientist to assess the health of the TMI. Since these products are not sent to EOSDIS, the format is not specified in this document.

Table 4.3-1
Description of 1A-11

Name	Size	Description
Header	184 bytes	The Header contains information about the size of components of Level-1A file. A description of Header is provided in Table 4.3-2.
Spacecraft Attitude Packets	70 bytes * nsec / 0.5	The Spacecraft Attitude is contained in the ACS Ancillary Packet (APID # 45), whose packet size is 70 bytes and is recorded every 0.5s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of the Spacecraft Attitude Packet.
ACS QAC	0 - (5 bytes * nsec / 0.5)	Quality and Accounting Capsules for the ACS Ancillary Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 3 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3 3. Granule Packet Counter (2 bytes)
TMI Housekeeping Packets	80 bytes * nsec / 18.9873	The TMI Housekeeping (APID # 47) packet size is 80 bytes and is recorded every 18.9873s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of the TMI Housekeeping Packet.
HK QAC	0 - (5 bytes * nsec / 18.9873)	Quality and Accounting Capsules for the TMI Housekeeping Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 3 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3 3. Granule Packet Counter (2 bytes)
TMI Science Data Packets	2006 bytes * nsec / 1.89873	The TMI Science Data (APID # 52) Packet size is 2006 bytes and is recorded every 1.89873s. The TMI Science Data Packet contains calibration and scene data. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of the TMI Science Data Packet.
Science QAC	0 - (5 bytes * nsec / 1.89873)	Quality and Accounting Capsules for the TMI Science Data Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 3 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3 3. Granule Packet Counter (2 bytes)
Science Packets MDUL	0 - (0.5 * 6 byte * nsec / 1.89873)	Missing Data Unit List. The expected number of missing data units is zero. MDUL is only supplied with science data. There are 3 subfields in the MDUL: 1. The Source Data Unit Sequence Count of the first missing packet in a sequence of missing packets (2 bytes). 2. The Source Data Unit Sequence Count of the last missing packet in a sequence of missing packets (2 bytes). 3. The Granule Packet Counter of the last valid packet before the sequence of missing packets (2 bytes).

Table 4.3-2
Description of 1A-11 Header

Number of bytes	Type	Description
4	Character	"TMI "
4	Integer	Orbit number
12	Character	TSDIS descriptor for the ephemeris file. The format is EPHEM.YYMMDD, where YY is year, MM is month, and DD is day of the month.
10	Character	Orbit Start UTC Date in the format described in section 3
8	Character	Orbit Start UTC Time in the format described in section 3
3	Character	Orbit Start UTC Milliseconds in the format described in section 3
8	**	Orbit Start Spacecraft Time
10	Character	Orbit End UTC Date in the format described in section 3
8	Character	Orbit End UTC Time in the format described in section 3
3	Character	Orbit End UTC Milliseconds in the format described in section 3
8	**	Orbit End Spacecraft Time
10	Character	Orbit First Scan UTC Date in the format described in section 3
8	Character	Orbit First Scan UTC Time in the format described in section 3
3	Character	Orbit First Scan UTC Milliseconds in the format described in section 3
8	**	Orbit First Scan Spacecraft Time
10	Character	Orbit Last Scan UTC Date in the format described in section 3
8	Character	Orbit Last Scan UTC Time in the format described in section 3
3	Character	Orbit Last Scan UTC Milliseconds in the format described in section 3
8	**	Orbit Last Scan Spacecraft Time
8	**	UTCF from the first ACS ancillary packet after Orbit Start Time
4	Integer	Number of scans in the Preorbit overlap
4	Integer	Number of scans in the Orbit
4	Integer	Number of scans in the Postorbit overlap
4	Integer	Number of bytes of Spacecraft Attitude
4	Integer	Number of bytes of ACS QAC
4	Integer	Number of bytes of TMI Housekeeping
4	Integer	Number of bytes of HK QAC
4	Integer	Number of bytes of TMI Science Data
4	Integer	Number of bytes of Science QAC
4	Integer	Number of bytes of Science MDUL

** Spacecraft Time format described in the **TRMM Telemetry and Command Handbook,** section 3.3.2

4.5 LEVEL-1B

The TMI Level 1B Product, 1B-11, "TMI Brightness Temperatures," is formatted in HDF. The following sizing parameter is used in describing these formats:

- nscan = the number of scans within one granule. See Sections 3-5 and 3-6.

4.5.1 <u>Structure</u>

Figure 4.5.1-1 shows the structure of the TMI Level-1B product in terms of the component objects and their sizes. The TMI Level-1B product is stored as a swath structure. See Section 3.

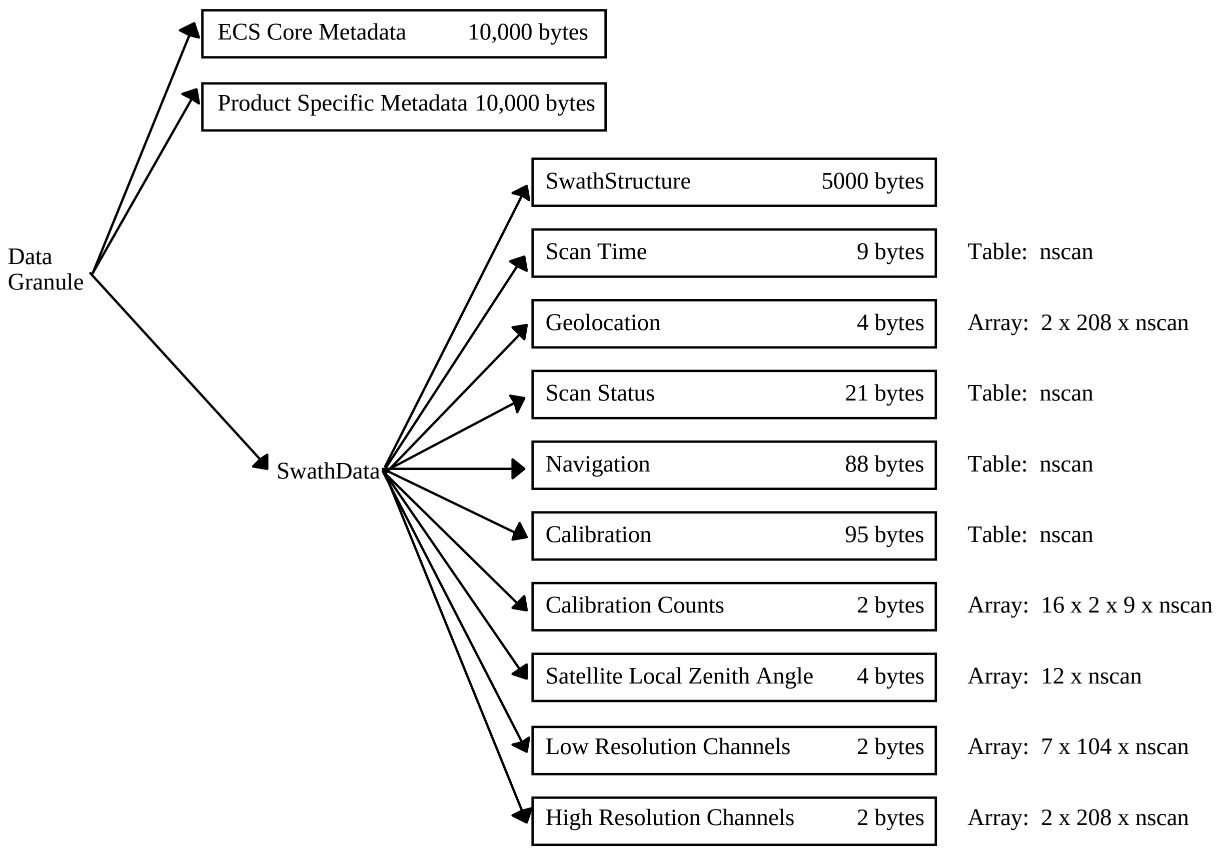


Figure 4.5.1-1
TMI Level-1B Structure

4.5.2 Contents

ECS Core Metadata (Attribute, 10,000-byte character):
ECS Core Metadata are those metadata defined by ECS as Core metadata.
See ICS Volume 6.

PS Metadata (Attribute, 10,000-byte character):
Product Specific Metadata are metadata defined by and specific to TSDIS.
See ICS Volume 6.

SwathStructure (Attribute, 5,000-byte character):
SwathStructure gives the specification of the swath geometry. See Section 2.

Scan Time (Vdata Table, record size 9 bytes, nscan records):
See the following, Table 4.5.2-1.

Table 4.5.2-1
Scan Time
(Vdata Table, record size 9 bytes, nscan records)

Name	Format	Description
Year	2-byte integer	4-digit year, e.g., 1998
Month	1-byte integer	The month of the Year
Day of Month	1-byte integer	The day of the Month
Hour	1-byte integer	The hour (UTC) of the Day
Minute	1-byte integer	The minute of the Hour
Second	1-byte integer	The second of the Minute
Day of Year	2-byte integer	The day of the Year

Geolocation (SDS, array size 2 x 208 x nscan, 4-byte float):
The earth location of the center of the IFOV of the high resolution (85 GHz) channels (channels 8 and 9) at the altitude of the earth ellipsoid. The first dimension is latitude and longitude, in that order. The next dimensions are high resolution pixel and scan. Values are represented as floating point decimal degrees. Off-earth is represented as less than or equal to -9999.9 Latitude is positive north, negative south. Longitude is positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.

Scan Status (Vdata, record size 21 bytes, nscan records):
The status of each scan is represented in terms of quality, platform and instrument control data, and fractional orbit number are shown in Table 4.5.2-2.

Navigation (Vdata, record size 88 bytes, nscan records):
See Appendix B.

Calibration (Vdata Table, record size 95 bytes, nscan records):
See the following, Table 4.5.2-3.

Table 4.5.2-2
Scan Status
(Vdata, record size 21 bytes, nscan records)

Name	Format	Description
Missing	1-byte integer	Missing indicates whether information is contained in the scan data. The values are: 0 Scan data elements contain information 1 Scan was missing in the telemetry data 2 Scan data contains no elements with rain
Validity	1-byte integer	Validity is a summary of status modes. If all status modes are routine, all bits in Validity = 0. Routine means that scan data has been measured in the normal operational situation as far as the status modes are concerned. Validity does not assess data or geolocation quality. Validity is broken into 8 bit flags. Each bit = 0 if the status is routine but the bit = 1 if the status is not routine. Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(8-i) - 1). The non-routine situations follow: Bit Meaning if bit = 1 0 Spare (always 0) 1 Non-routine spacecraft orientation (2 or 3) 2 Non-routine ACS mode (other than 4) 3 Non-routine yaw update status (0 or 1) 4 Non-routine TMI instrument status (Bit 0 = 0 or bit 1 = 0) 5 Non-routine QAC (non-zero) 6 Spare (always 0) 7 Spare (always 0)
QAC	1-byte integer	The Quality and Accounting Capsule of the Science packet as it appears in Level-0 data. If no QAC is given in Level-0, which means no decoding errors occurred, QAC in this format has a value of zero.
Geolocation Quality	1-byte integer	Geolocation Quality is broken into 8 one-bit flags. Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(7-i). A value of 0 indicates 'good' quality, and 1 indicates 'bad' quality. Each flag is listed below. Note that ranges indicated will be refined in early-orbit check out. Bit Meaning if bit = 1 0 Grossly bad geolocation results: • Spacecraft position vector magnitude outside range 6720 to 6740 km. • Z component of midpoint of scan outside range -4100 to 4100 km. • Distance from S/C to midpoint of scan outside range 340 to 360 km. 1 Unexpectedly large scan to scan jumps in geolocated positions in along and cross track directions for first, middle, and last pixels in each scan. Allowed duration from nominal jump in along track motion = 0.06 km (first pixel), 0.04 km (middle pixel), and 0.06 km (last pixel). Allowed duration from nominal jump in cross track motion = 0.05 km (first pixel), 0.04 km (middle pixel), and 0.05 km (last pixel). Bit set in normal mode only.

Name	Format	Description
Geolocation Quality (continued)	1-byte integer	2 Scan to scan jumps in yaw, pitch, and roll exceed maximum values. Values are : yaw = 0.0001 radians; pitch = 0.0001 radians; roll = 0.0001 radians. Bit set in normal control mode only. 3 In normal mode, yaw outside range (-0.003, 0.003) radians; pitch outside range (-0.007, 0.007) radians; roll outside range (-0.007, 0.007). 4 Satellite undergoing maneuvers during which geolocation will be less accurate. 5 Questionable ephemeris quality (including use of predicted Ephemeris for quicklook) or questionable UTCF quality. 6 Geolocation calculations failed (fill values inserted in the per pixel geolocation products, but not in metadata). 7 Missing attitude data. ACS data gap larger than 20 seconds.
Data Quality [9]	9 X 1-byte integer	The Quality of Channel Data for a given channel on a given scan line is the percentage of pixels whose values are within the acceptable range listed in the Metadata. Quality is given for each channel in the order of the channel number.
Current Spacecraft Orientation	1-byte integer	Value Meaning 0 +x forward 1 -x forward 2 -y forward 3 Inertial - CERES Calibration 4 Unknown Orientation
Current ACS Mode	1-byte integer	Value Meaning 0 Standby 1 Sun Acquire 2 Earth Acquire 3 Yaw Acquire 4 Nominal 5 Yaw Maneuver 6 Delta-H (Thruster) 7 Delta-V (Thruster) 8 CERES Calibration
Yaw Update Status	1-byte integer	Value Meaning 0 Inaccurate 1 Indeterminate 2 Accurate
TMI Instrument Status	1-byte integer	Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(8-i) - 1). Bit Meaning 00 Receiver Status (1=ON, 0=OFF) 01 Spin-up Status (1=ON, 0=OFF) 02 Spare Command 1 Status 03 Spare Command 2 Status 04 1 Hz Clock Select (1=A, 0=B) 05 21 GHz Cold Count Flag 06 Spare Command 4 Status 07 Spare Command 5 Status
Fractional Orbit Number	4-byte float	The orbit number and fractional part of the orbit at Scan Time. The orbit number will be counted from the beginning of the mission. The fractional part is calculated as: (Time - Orbit Start Time) / (Orbit End Time - Orbit Start Time)

Table 4.5.2-3
Calibration
(Vdata Table, record size 95 bytes, nscan records)

Name	Format	Description
Hot Load Temperature [3]	3 X 2-byte integer	The physical temperatures, in degrees Kelvin, for the 3 temperature sensors attached to the hot load. This temperature is reduced by 80K, multiplied by 100, and stored in the file as a 2-byte integer. Stored value = (T - 80K) * 100. Range: 0 to 400 K.
Hot Load Bridge Reference Positive Bridge Voltage	2-byte integer	The positive bridge voltage of the hot load bridge reference. Range: 0 to 4095.
Hot Load Bridge Reference Near Zero Voltage	2-byte integer	The near zero voltage of the hot load bridge reference. Range: 0 to 4095.
85.5 GHz Receiver Temperature	2-byte integer	The receiver shelf temperature of the 85.5 GHz channel. This temperature is increased by 200, multiplied by 100, and stored in the file as a 2-byte integer. Range: -273.15 to 126.85 C
Top Radiator Temperature	2-byte integer	The temperature of the top of the radiator channel. This temperature is increased by 200, multiplied by 100, and stored in the file as a 2-byte integer. Range: -273.15 to 126.85 C
Automatic Gain Control [9]	9 X 1-byte integer	Automatic gain control for the 9 channels in counts. Range: 0 to 15.
Calibration Coefficient A [9]	9 X 4-byte float	Calibration coefficient A (degrees Kelvin / counts) for the 9 channels. Coefficient A for each channel is used in the following equation to convert counts, C, to antenna temperature, T_A: $T_A = A C + B$
Calibration Coefficient B [9]	9 X 4-byte float	Calibration coefficient B (degrees Kelvin) for the 9 channels. Coefficient B for each channel is used in the following equation to convert counts, C, to antenna temperature, T_A: $T_A = A C + B$

Calibration Counts (SDS, array size 16 x 2 x 9 x nscan, 2-byte integer):
Calibration measurements, in counts. The dimensions are: samples, load, channel, and scan. The sample dimension has a maximum of 16. The load dimension has first hot load and then cold sky. The low resolution channels (1-7) have 8 samples (the remaining 8 elements in the array are not used for each low resolution channel) and the high resolution channels (8 - 9) have 16 samples.

Satellite Local Zenith Angle (SDS, array size 12 x nscan, 4-byte float):
The angle, in degrees, between the local pixel geodetic zenith and the direction to the satellite. This angle is given for every twentieth high resolution pixel along a scan: pixel 1, 21, 41, ... , 201, 208. For the pixel dimension, Offset = 0 and Increment = -20.

Low Resolution Channels (SDS, array size 7 x 104 x nscan, 2-byte integer):
Brightness temperature (K) reduced by 100 K, multiplied by 100, and stored as a 2-byte integer, i.e.

Stored value = (T - 100 K) * 100

The dimensions are: channel, pixel, scan. The pixel dimension has Offset = 0 and Increment = -2. The data range for each channel is listed in the two metadata elements: Minimum valid value of channel and Maximum valid value of channel. The channels shown in Table 4.5.2-4 are included.

Table 4.5.2-4
Low Resolution Channels
(SDS, array size 7 x 104 x nscan, 2-byte integer)

Channel	Frequency	Polarization
1	10 GHz	Vertical
2	10 GHz	Horizontal
3	19 GHz	Vertical
4	19 GHz	Horizontal
5	21 GHz	Vertical
6	37 GHz	Vertical
7	37 GHz	Horizontal

High Resolution Channels (SDS, array size 2 x 208 x nscan, 2-byte integer):
Brightness temperature (K) reduced by 100 K, multiplied by 100, and stored as a 2-byte integer, i.e.

Stored value = (T - 100 K) * 100

The dimensions are: channel, pixel, scan. The data range for each channel is listed in the two metadata elements: Minimum valid value of channel and Maximum valid value of channel. The following channels are included:

Table 4.5.2-5
High Resolution Channels
(SDS, array size 2 x 208 x nscan, 2-byte integer)

Channel	Frequency	Polarization
8	85 GHz	Vertical
9	85 GHz	Horizontal

5. VISIBLE AND INFRARED SCANNER (VIRS)

5.1 INSTRUMENT AND SCAN GEOMETRY

The Visible and Infrared Scanner (VIRS) sensor is one of the five instruments on the TRMM satellite. The VIRS instrument has a swath width of 720 km and a horizontal resolution of 2 km at nadir. VIRS is similar to the Advanced Very High Resolution Radiometer (AVHRR) now in operation on polar-orbital environmental satellites.

The VIRS measures radiance values in the channels shown in the Table 5.1-1. All five Channels will be in operation during daytime, but only Channels 3, 4 and 5 are in operation during nighttime. The VIRS is a cross-track scanning system and records scene radiation from right to left looking in the +x direction (See Section 3.9) over a scan angle of +/- 45^0 from the nadir (subpoint view). The swath width of 720 km is covered by 261 pixels and every scan has the same geometry. The Level-1B product stores radiance for every pixel measured.

Table 5.1-1
Channels where VIRS Measures Radiance Values

Channel	Spectral Region	Wavelength (μm)
1	Visible	0.63
2	Near Infrared	1.6
3	Near Infrared	3.75
4	Infrared	10.8
5	Infrared	12.0

5.2 DESIGN CONSIDERATIONS

The VIRS formats for the Level-1A and Level-1B products were designed in consultation with Dr. William Barnes (VIRS Instrument Scientist), Mr. Ted Meyer, Mr. Doug Ilg and Dr. Brand Fortner (of EOSDIS). The Level-1A format was designed to minimize processing time and storage volume and to clearly demonstrate reversibility to Level-0. The Level-1A product is a simple concatenation of Level-0 data with a Header, which could easily be reversed back to Level-0. For a discussion of reversibility, see Appendix A. Level-1A remains in a binary format and is not in HDF. A detailed description of the Level-1A components is provided in Section 5.3.

The Level-1B format groups like data together. For example, channel data are in one object rather than, for example, channel, geolocation, and calibration data being interleaved in one object. The Level-1B format includes navigation and calibration information, which was requested by Dr. Barnes. The Satellite and Solar Local Direction are supplied for every tenth pixel in a scan line to save space. Spacecraft Position and Velocity data are represented in 4-byte floating point precision. Spacecraft Geocentric Position is represented to 10m accuracy, which equates to 6 significant digits since the earth's radius is about 6,370,000 m. Data elements are based on the NOAA AVHRR format. The VIRS Level-1B format is are presented in a Swath Structure and formatted in HDF

5.3 LEVEL-1A

The Level-1A product consists of two files: the Level-1A Product file and the SFDU header file. The Level-1A Product file, "1A-01," is a concatenation of Header record, Spacecraft Attitude packets, VIRS Housekeeping Data packets, VIRS Science Data packets, QACs, and an MDUL. The SFDU header is a separate file whose format is specified in the Interface Control Document Between EOSDIS Core System (ECS) and TRMM Science Data and Information System (TSDIS) for the ECS Project. The data granule size is discussed in section 3. Sizing parameters used are:

nsec = the number of seconds in a granule. See Section 3-6. Tables 5.3-1 and 5.3-2 describe 1A-01.

Table 5.3-1
Description of 1A-01

Name	**Size**	**Description**
Header	204 bytes	The Header contains Information about the components of Level-1A file. A description of Header is described in Table 5.3-2.
Spacecraft Attitude Packets	70 bytes * nsec / 0.5	The Spacecraft Attitude is contained in the ACS Ancillary Packet (APID # 45), whose packet size is 70 bytes and is recorded every 0.5s. Refer to the TRMM Telemetry and Command Handbook for a detailed description of the Spacecraft Attitude Packet.
ACS QAC	0 - (5 bytes * nsec / 0.5)	Quality and Accounting Capsules for the ACS Ancillary Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 3 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3 3. Granule Packet Counter (2 bytes)
VIRS Housekeepin g Packets	110 bytes * nsec / 10	The VIRS Housekeeping (APID # 46) packet size is 110 bytes and is recorded every 10.00s. Refer to the TRMM Telemetry and Command Handbook for a detailed description of the VIRS Housekeeping Packet.
HK QAC	0 - (5 bytes * nsec / 10)	Quality and Accounting Capsules for the VIRS Housekeeping Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 3 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3 3. Granule Packet Counter (2 bytes)

VIRS Science Data Packets	[1892 bytes * (91.5-15) / 91.5 + 1110 bytes * 15/91.5] * nsec / 0.3045685	The VIRS Science Data Packet (APID # 51) contains calibration, scene, and housekeeping information and is recorded every 0.3045685s. The daytime mode packet size is 1892 bytes and the nighttime mode packet size is 1110 bytes. On the average, VIRS would spend 15 minutes out of 91.5 minutes per orbit in the nighttime mode. However, the fraction of packets that are nighttime is determined by the instrument scientist and may change. The packets in a single orbit may divide into 2, 3, or 4 sections, with each section containing a continuous sequence of packets with only one mode. Most orbits will divide into 2 sections, but some orbits will divide into 3 or even 4 sections. The header in Table 5.3-2 stores the sizes of each section separately for easier access to the data. Refer to the TRMM Telemetry and Command Handbook for a detailed description of the VIRS Science Packets.
Science QAC	0 - (5 bytes * nsec / 0.3045685)	Quality and Accounting Capsules for the VIRS Science Data Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 3 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3 3. Granule Packet Counter (2 bytes)
Science Packets MDUL	0 - (0.5 * 6 byte * nsec / 0.3045685)	Missing Data Unit List. The expected number of missing data units is zero. MDUL is only supplied with science data. There are 3 subfields in the MDUL: 1. The Source Data Unit Sequence Count of the first missing packet in a sequence of missing packets (2 bytes). 2. The Source Data Unit Sequence Count of the last missing packet in a sequence of missing packets (2 bytes). 3. The Granule Packet Counter of the last valid packet before the sequence of missing packets (2 bytes).

Table 5.3-2
Description of 1A-01 Header

Number of bytes	Type	Description
4	Character	“VIRS”
4	Integer	Orbit number
12	Character	TSDIS descriptor for the ephemeris file. The format is EPHEM.YYMMDD, where YY is year, MM is month, and DD is day of the month.
10	Character	Orbit Start UTC Date in the format described in section 3
8	Character	Orbit Start UTC Time in the format described in section 3
3	Character	Orbit Start UTC Milliseconds in the format described in section 3
8	**	Orbit Start Spacecraft Time
10	Character	Orbit End UTC Date in the format described in section 3
8	Character	Orbit End UTC Time in the format described in section 3
3	Character	Orbit End UTC Milliseconds in the format described in section 3
8	**	Orbit End Spacecraft Time
10	Character	Orbit First Scan UTC Date in the format described in section 3
8	Character	Orbit First Scan UTC Time in the format described in section 3
3	Character	Orbit First Scan UTC Milliseconds in the format described in section 3
8	**	Orbit First Scan Spacecraft Time
10	Character	Orbit Last Scan UTC Date in the format described in section 3
8	Character	Orbit Last Scan UTC Time in the format described in section 3

3	Character	Orbit Last Scan UTC Milliseconds in the format described in section 3
8	**	Orbit Last Scan Spacecraft Time
8	**	UTCF from the first ACS ancillary packet after Orbit Start Time
4	Integer	Number of scans in the Orbit
4	Integer	Number of bytes of Spacecraft Attitude
4	Integer	Number of bytes of ACS QAC
4	Integer	Number of bytes of VIRS Housekeeping
4	Integer	Number of bytes of HK QAC
4	Integer	Number of bytes of Science Data-Section 1
4	Integer	Type of Science Data-Section 1 0 = no data 1 = daytime mode 2 = nighttime mode
4	Integer	Number of bytes of Science Data-Section 2
4	Integer	Type of Science Data-Section 2
4	Integer	Number of bytes of Science Data-Section 3
4	Integer	Type of Science Data-Section 3
4	Integer	Number of bytes of Science Data-Section 4
4	Integer	Type of Science Data-Section 4
4	Integer	Number of bytes of Science QAC
4	Integer	Number of bytes of Science MDUL

** Spacecraft Time format described in the **TRMM Telemetry and Command Handbook,** Section 3.3.2

Please note that prior to June 1, 2008 all PR, TMI and VIRS binary 1A products were produced on an SGI (big-endian). PPS is currently producing the TMI and VIRS products on the Linux (little-endian) platform. The TMI and VIRS 1A file formats remain the same. The endian order of the data in the headers is written in NATIVE endian (little-endian) format. The CCSDS packets contained in the 1A files remain unchanged.

5.4 INSTRUMENT ANALYSIS PRODUCTS

Instrument Analysis Data and Instrument Analysis Report are intermediate products that are by-products of the Level-1B processing. These products will be made available only to the instrument scientist to assess the health of the VIRS. Since these products are not sent to EOSDIS, the format is not specified in this document.

5.5 LEVEL-1B

The VIRS Level-1B Product, 1B-01, "VIRS Radiance," is written in HDF. The following sizing parameter is used in describing these formats:

- nscan = the number of scans within one granule. See Section 3-6.

5.5.1 Structure

Figure 5.5.1-1 shows the structure of the VIRS Level-1B product in terms of the component objects and their sizes. The VIRS Level-1B product is stored as a swath structure (see Section 3).

5.5.2 Contents

ECS Core Metadata (Attribute, 10,000-byte character):
ECS Core Metadata are those metadata defined by ECS as Core metadata.
See ICS Volume 6.

PS Metadata (Attribute, 10,000-byte character):
Product Specific Metadata are metadata defined by and specific to TSDIS. See ICS Volume 6.

SwathStructure (Attribute, 5,000-byte character):
SwathStructure gives the specification of the swath geometry. See Section 2.

Scan Time (Vdata Table, record size 8 bytes, nscan records):
See the following, Table 5.5.2-1.

Geolocation (SDS, array size 2 x 261 x nscan, 4-byte float):
The earth location of the center of the IFOV at the altitude of the earth ellipsoid. The first dimension is latitude and longitude, in that order. The next dimensions are pixel and scan. Values are represented as floating point decimal degrees. Off-earth is represented as less than or equal to -9999.9. Latitude is positive north, negative south. Longitude is positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.

Scan Status (Vdata, record size 19 bytes, nscan records):
The status of each scan is represented in terms of quality, platform and instrument control data, and fractional orbit number as shown in Table 5.5.2-2.

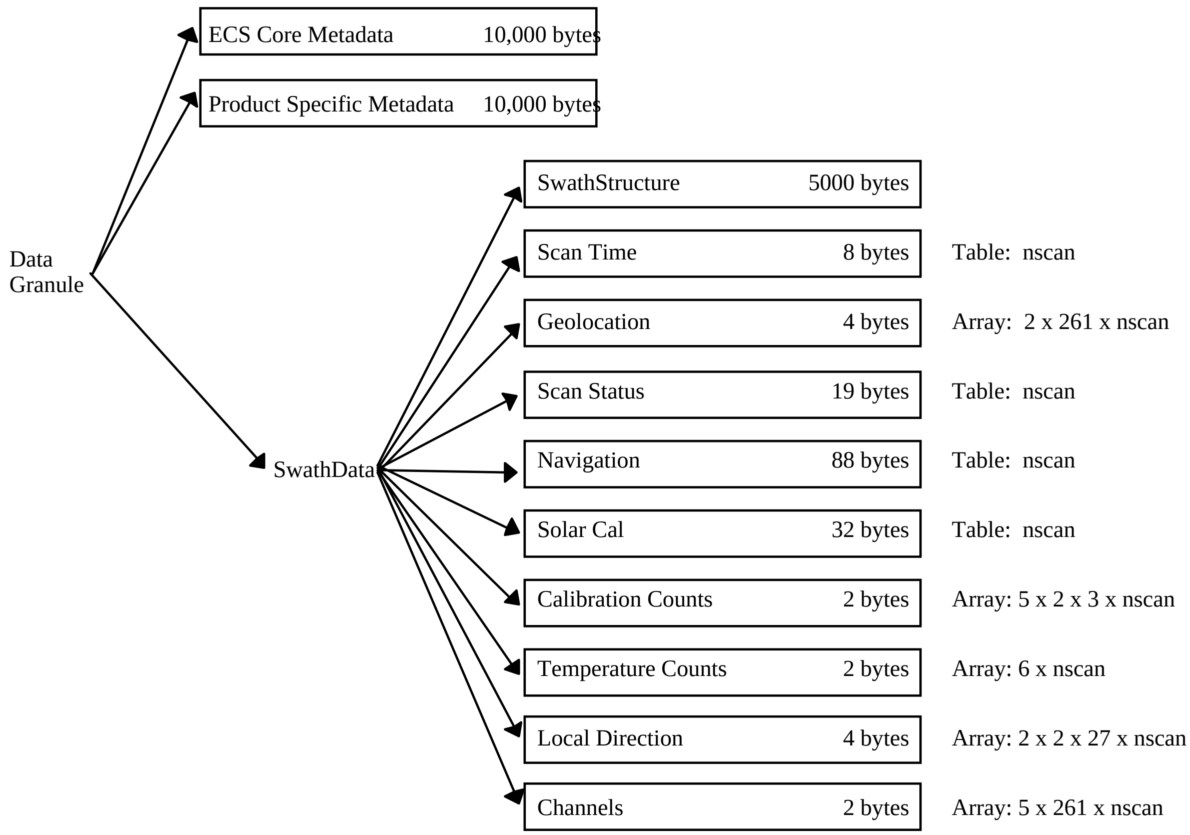


Figure 5.5.1-1
VIRS Level-1B Structure

Table 5.5.2-1
Scan Time
(Vdata Table, record size 8 bytes, nscan records)

Name	Format	Description
Scan Time	8-byte float	A time associated with the scan. The exact relationship between Scan Time and the time of each IFOV is described in Section 3. Scan Time is expressed as the UTC seconds of the day.

Table 5.5.2-2
Scan Status
(Vdata, record size 19 bytes, nscan records)

Name	Format	Description
Missing	1-byte integer	Missing indicates whether information is contained in the scan data. The values are: 0 Scan data elements contain information 1 Scan was missing in the telemetry data 2 Scan data contains no elements with rain
Validity	1-byte integer	Validity is a summary of status modes. If all status modes are routine, all bits in Validity = 0. Routine means that scan data has been measured in the normal operational situation as far as the status modes are concerned. Validity does not assess data or geolocation quality. Validity is broken into 8 bit flags. Each bit = 0 if the status is routine but the bit = 1 if the status is not routine. Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(8-i) - 1). The non-routine situations follow: Bit Meaning if bit = 1 0 Spare (always 0) 1 Non-routine spacecraft orientation (2 or 3) 2 Non-routine ACS mode (other than 4) 3 Non-routine yaw update status (0 or 1) 4 Non-routine instrument status (2) 5 Non-routine QAC (non-zero) 6 VIRS in non-mission mode (non-zero) 7 VIRS condition is abnormal (non-zero)
QAC	1-byte integer	The Quality and Accounting Capsule of the Science packet as it appears in Level-0 data. If no QAC is given in Level-0, which means no decoding errors occurred, QAC in this format has a value of zero.
Geolocation Quality	1-byte integer	Geolocation Quality is broken into 8 one-bit flags. A value of 0 indicates 'good' quality, and 1 indicates 'bad' quality. Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(7-i). Each flag is listed below. Note that ranges indicated will be refined in early-orbit check out. Bit Meaning if bit = 1 0 Grossly bad geolocation results: • Spacecraft position vector magnitude outside range 6720 to 6740 km. • Z component of midpoint of scan outside range -4100 to 4100 km. • Distance from S/C to midpoint of scan outside range 340 to 360 km. 1 Unexpectedly large scan to scan jumps in geolocated positions in along and cross track directions for first, middle, and last pixels in each scan. Allowed duration from nominal jump in along track motion = 0.06 km (first pixel), 0.04 km (middle pixel), and 0.06 km (last pixel). Allowed duration from nominal jump in cross track motion = 0.05 km (first pixel), 0.04 km (middle pixel), and 0.05 km (last pixel). Bit set in normal mode only. 2 Scan to scan jumps in yaw, pitch, and roll exceed maximum values. Values are : yaw = 0.0001 radians; pitch = 0.0001 radians; roll = 0.0001 radians. Bit set in normal control mode only.

Table 5.5.2-2 (continued)
Scan Status
(Vdata, record size 19 bytes, nscan records)

Name	Format	Description
Geolocation Quality (Continued)	1-byte integer	3 In normal mode, yaw outside range (-0.003, 0.003) radians; pitch outside range (-0.007, 0.007) radians; roll outside range (-0.007, 0.007). 4 Satellite undergoing maneuvers during which geolocation will be less accurate. 5 Questionable ephemeris quality (including use of predicted Ephemeris for quicklook) or questionable UTCF quality. 6 Geolocation calculations failed (fill values inserted in the per pixel geolocation products, but not in metadata). 7 Missing attitude data. ACS data gap larger than 20 seconds.
Data Quality [5]	5 X 1-byte integer	The Quality of Channel Data for a given channel on a given scan line is the percentage of pixels whose values are within the acceptable range listed in the Metadata. Quality is listed for each channel in order of the channel number.
Fractional Orbit Number	4-byte float	The orbit number and fractional part of the orbit at Scan Time. The orbit number will be counted from the beginning of the mission. The fractional part is calculated as: (Time - Orbit Start Time) / (Orbit End Time - Orbit Start Time)
Current Spacecraft Orientation	1-byte integer	Value Meaning 0 +x forward 1 -x forward 2 -y forward 3 Inertial - CERES Calibration 4 Unknown Orientation
Current ACS Mode	1-byte integer	Value Meaning 0 Standby 1 Sun Acquire 2 Earth Acquire 3 Yaw Acquire 4 Nominal 5 Yaw Maneuver 6 Delta-H (Thruster) 7 Delta-V (Thruster) 8 CERES Calibration
Yaw Update Status	1-byte integer	Value Meaning 0 Inaccurate 1 Indeterminate 2 Accurate
VIRS Instrument Status	1-byte integer	Value Meaning 0 Day (no calibration occurring) 1 Night 2 Monitor Scan Stability 3 Day with Calibration

Table 5.5.2-2 (continued)
Scan Status
(Vdata, record size 19 bytes, nscan records)

Name	Format	Description
VIRS mode	1-byte integer	Value Meaning 0 mission mode 1 safehold mode 2 outgas mode 3 activation mode
VIRS Abnormal Conditions	1-byte integer	Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(8-i) - 1). Bit Value Meaning 0 0 normal 1 scan phase error 1 0 normal 1 selftest error 2 0 normal 1 thermal data missing 3 0 normal 1 moon in space view 4 0 normal 1 H/K data drop-out suspected 5 0 normal 1 SV counts for channel 4 or 5 greater than L1B01_MIN_DNSV 6 0 not used 7 0 not used

Navigation (Vdata, record size 88 bytes, nscan records):
See Appendix B.

Solar Cal (Vdata, record size 32 bytes, nscan records):
The three components of the solar unit vector in Geocentric Inertial Coordinates, and the Sun-Earth distance in meters as shown in Table 5.5.2-3.

Table 5.5.2-3
Solar Cal (Vdata, record size 32, nscan records)

Name	Format	Description
Solar Position [3]	3x8-byte float	Sun Unit Vector (X-component) Sun Unit Vector (Y-component) Sun Unit Vector (Z-component) (Geocentric Inertial Coord)
Distance	8-byte float	Sun-Earth Distance (m)

Calibration Counts (SDS, array size 5 x 2 x 3 x nscan, 2-byte integer):
Raw calibration counts are given in four dimensions. The first dimension is the channel number, the second dimension is the data word, the third dimension is blackbody, space view and solar diffuser, in that order, and the fourth dimension is the number of scans.

Temperature Counts (SDS, array size 6 x nscan, 2-byte integer):
Temperatures of the black body, primary and redundant, the radiant cooler temperatures, primary and redundant, the mirror temperature, and the electronics module temperature. All quantities have units of counts, and have minimum values of 0, and maximum values of 4095.

Local Direction (SDS, array size 2 x 2 x 27 x nscan, 4-byte float):
Angles (degrees) to the satellite and sun from the IFOV pixel position on the earth are given in 4 dimensions. The first dimension is zenith and azimuth angles, in that order. The zenith angle is measured between the local pixel geodetic zenith and the direction to the satellite. The azimuth angle is measured clockwise from the local North direction around toward the local East direction. The second dimension is the object to which the directions point, namely the satellite and the sun, in that order. The third dimension is the pixel number. Angles are given only for every tenth pixel along a scan: pixel 1, 11, 21, ..., and 261. For the pixel dimension, Offset = 0 and Increment = -10. The fourth dimension is the scan number.

Channels (SDS, array size 5 x 261 x nscan, 2-byte integer):
Scene data for the five channels, measured in Radiance (mW cm^{-2} μm^{-1} sr^{-1}) multiplied by a scale factor and stored as 2-byte integers. sr means steradian. The scale factors are 500, 1000, 100000, 10000, and 10000 for channels 1, 2, 3, 4, and 5, respectively. The three dimensions are channel, pixel, and scan. The range and accuracy for each channel is shown is Figure 5.2.2-4.

Table 5.5.2-4
VIRS Range and Accuracy

Channel	**Minimum (mW cm^{-2} μm^{-1} sr^{-1})**	**Maximum (mW cm^{-2} μm^{-1} sr^{-1})**	**Accuracy**
1	0	55.84	10%
2	0	8.9	10%
3	0	0.111	2%
4	0	1.371	2%
5	0	1.15	2%

6. PRECIPITATION RADAR

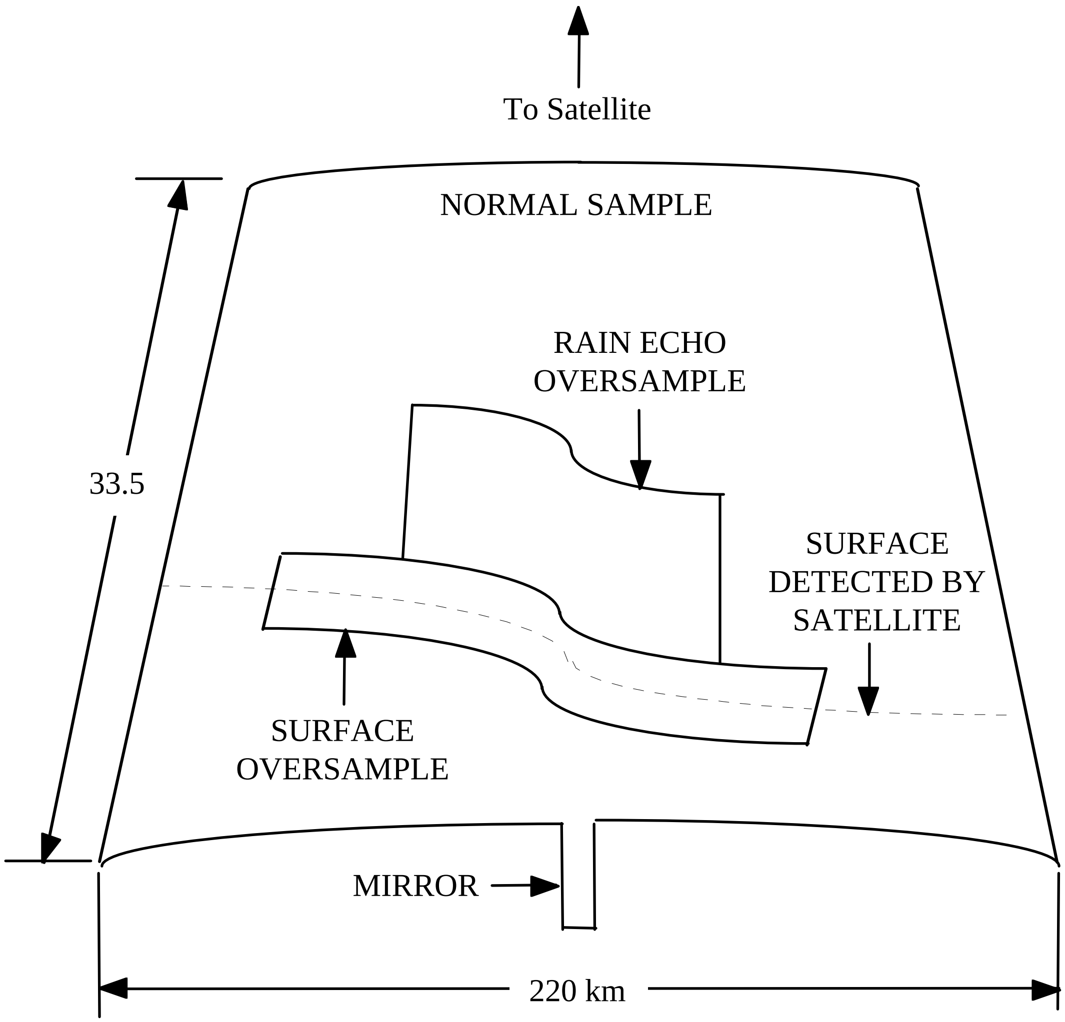
6.1 INSTRUMENT AND SCAN GEOMETRY

The Precipitation Radar (PR) is one of five instruments on the TRMM satellite. The PR is an active 13.8 GHz radar, recording energy reflected from atmospheric and surface targets. The PR electronically scans right to left looking in the +x direction (see Section 3.9) of the satellite every 0.6 s with a swath width of 215 km before August 7, 2001 and 247 km after August 24, 2001.

The complex scan geometry is represented in Figure 6.1-1. Each scan contains 49 rays sampled over an angular sector of 34°. For a given ray, the satellite begins recording samples at a fixed distance from the satellite and records a certain number of samples every 125 m along the ray. The starting distance and the number of samples are different for each ray. Assuming the satellite altitude is 350 km, the sampling begins about 23 km above mean sea level and extends for a certain distance along the ray. This distance along the ray is 33.5 km at the two rays farthest from nadir, monotonically declining to 30.25 km at the two rays adjacent to nadir, and jumping to 34.75 km at the single nadir ray. The extra data in the nadir ray is known as “the mirror,” because it records energy reflected not once from a target, but three times (ground to target to ground). Rays other than the nadir ray also sample “below” the surface. The purpose of this extension is “to see” below the surface to clearly detect the location of the surface.

The satellite saves data in three samples. Every other data point in the vertical is saved in the “normal sample,” shown in Figure 6.1-2. Thus the normal sample has a spacing of 250 m along the ray. The mirror is contained in the normal sample. A subset of the remaining data points is saved in two oversamples: the “surface oversample” and the “rain echo oversample.” Both oversamples have a spacing of 250 m along a ray, but a region with both normal sample and oversample has a spacing of 125 m. The PR determines which levels to save in the oversamples based on its on board determination of the surface bin. No data are saved as oversample in rays 1-10 and 40-49. Five levels are saved from rays 11-39 in the surface oversample. If the PR detects the surface in an oversample bin, the surface oversample is centered on the detected surface. If, on the other hand, the PR detects the surface in a normal sample bin, 3 oversample bins are above and 2 oversample bins are below the detected surface. In addition, 28 levels (immediately above the surface oversample) are saved from rays 20-30 in the rain echo oversample.

NASDA defines a range bin number, which is related to distance from the satellite along the ray. It starts at 1 roughly 327 km (381 km after August 24, 2001) from the satellite, increments by 1 roughly every 125 m, and increases to a maximum of 400 at roughly 377 km (431 km after August 24, 2001) from the satellite. The exact value for the starting distance is written in the 1B21 and 1C21 files in Ray Header, Starting Bin Distance for the nadir ray. Twice the exact value for the increment is written in the 1B21 and 1C21 files in Ray Header, Range Bin Size for any ray.



The outer outline encloses the normal sample. The rain echo oversample and the surface oversample occupy subsets of the normal sample region. Both oversamples are vertically located with respect to the surface level detected by the satellite.

Figure 6.1-1
PR Scan Geometry

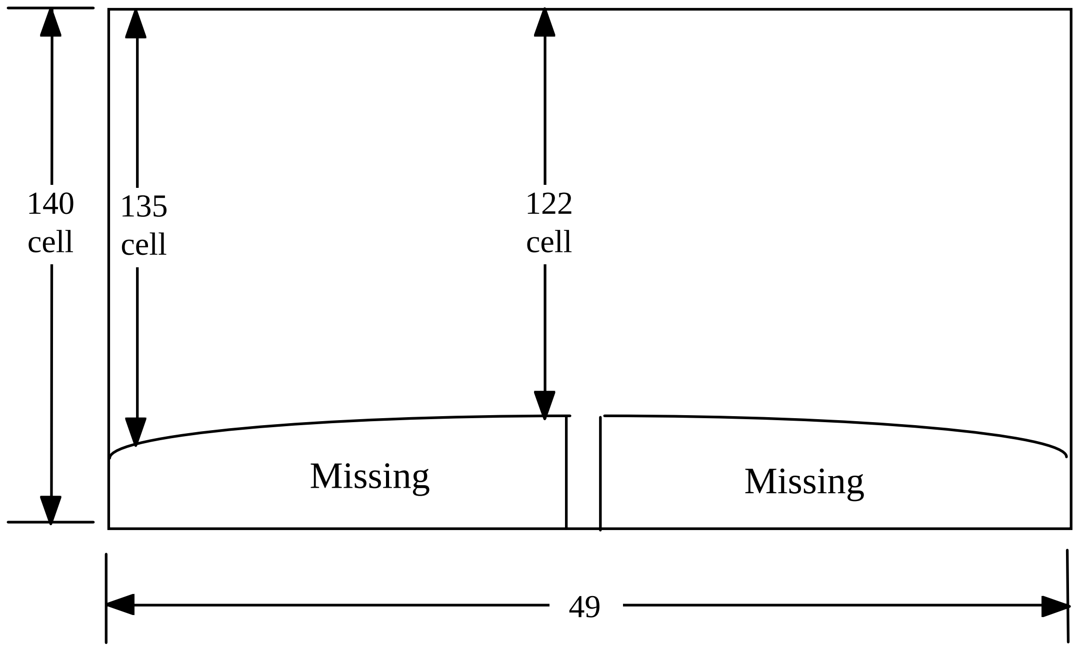


Figure 6.1-2
Normal Sample Data Array

6.2 DESIGN CONSIDERATIONS

The Precipitation Radar (PR) formats for the Level-1A, Level-1B, and Level-1C products were designed in consultation with NASDA, CRL, Dr. Robert Meneghini (a PR algorithm scientist) and Mr. Ted Meyer, Mr. Doug Ilg and Dr. Brand Fortner (EOSDIS).

TSDIS, with guidance from Dr. Meneghini, created a PR synthetic data set in a binary format. The TSDIS Level-1B and Level-1C formats consist of the binary format augmented by satellite information and modified by information from NASDA. The TSDIS Level-1B and Level-1C formats are presented in a Swath Structure and formatted in HDF.

The satellite information includes navigation and calibration information, which was requested by the scientists. The Spacecraft Position and Velocity data are represented in 4-byte floating point precision. Spacecraft Geocentric Position is represented to 10m accuracy, which equates to 6 significant digits since the earth's radius is about 6,370,000 m.

6.3 LEVEL-1A

The Level-1A Product file, "1A-21," is a concatenation of a TSDIS Header, Spacecraft Attitude packets, PR Housekeeping Data packets, PR Science Data packets, Calibration Coefficients, QACs, and a Missing Data Units List (MDUL). Tables 6.3-1, Table 6.3-2, and Table 6.3-3 describe 1A-21. There is an additional file: a detached SFDU header. The SFDU header is described in the **Interface Control Document Between EOSDIS Core System (ECS) and TRMM Science Data and Information System (TSDIS) for the ECS Project**. The sizing parameters used are:

nsec = the number of seconds in a granule. See Section 3-6.

Table 6.3-1
Description of 1A-21

Name	Size	Description
Header	236 bytes	The Header contains information about the size of components of Level-1A file. A description of Header is provided in Table 6.3-2.
Spacecraft Attitude Packets	70 bytes * nsec / 0.5	The Spacecraft Attitude is contained in the ACS Ancillary Packet (APID # 45), whose packet size is 70 bytes and is recorded every 0.5s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of the Spacecraft Attitude Packet.
ACS QAC	0 - (3 bytes * nsec / 0.5)	QACs for the ACS Ancillary Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
PR Housekeeping Packets	126 bytes * nsec / 10.0	The PR Housekeeping (APID # 48) Packet size is 126 bytes and is recorded every 10.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of the PR Housekeeping Packet
Modified PR Housekeeping Packets	198 bytes * nsec / 10.0	The Modified PR Housekeeping Packet size is 198 bytes and is recorded every 10.00s. This packet is an exact copy of the PR Housekeeping Packet except 24 fields are replaced by engineering variables. Since these fields expanded from a 1 byte field to a 4 byte engineering field, the packet size increases by 3 * 24 bytes from the PR Housekeeping Packet size. The modified fields are: 4 fcif_a_temp, 4 fcif_b_temp, 12 panel_temp, and 4 antenna_temp fields.
HK QAC	0 - (3 bytes * nsec / 10.0)	QACs for the PR Housekeeping Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
PR Science Data Packets	6988 bytes * nsec / 0.6	The PR Science Data (APID # 53) Packet size is 6988 bytes and is recorded every 0.6s. Refer to Table 6.3-3 for a detailed description of the PR Science Data Packet.
Science QAC	0 - (3 bytes * nsec / 0.6)	QACs for the PR Science Data Packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
Science Packets MDUL	0 - (0.5 * 4 byte * nsec / 0.6)	Missing Data Unit List. Each entry in the list is a pair of 2-byte integer Source Data Unit Sequence Counts. The pair are the Source Data Unit Sequence Counts of the first and last missing packets in a sequence of missing packets. The expected number of missing data units is zero. MDUL is only supplied with science data.
Calibration Coefficients	76 bytes	The Calibration Coefficients consists of 4 tables: Calibration Coefficient Version, 4 bytes Transmission coefficient, 4 bytes Reception coefficient, 4 bytes

		FCIF I/O Characteristics, 64 bytes Definition of the tables is **TBD** by NASDA.
IPSDU High Rate Side A Packets	40 bytes * nsec / 1.0	The IPSDU High Rate Side A (APID # 196) Packet size is 40 bytes and is recorded every 1.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of this packet.

Table 6.3-1 (continued) Description of 1A-21

Name	Size	Description
IPSDU High Rate Side A QAC	0 - (3 bytes * nsec / 1.0)	QACs for these packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
IPSDU High Rate Side B Packets	40 bytes * nsec / 1.0	The IPSDU High Rate Side B (APID # 197) Packet size is 40 bytes and is recorded every 1.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of this packet.
IPSDU High Rate Side B QAC	0 - (3 bytes * nsec / 1.0)	QACs for these packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
IPSDU Medium Rate Side A Packets	116 bytes * nsec / 8.0	The IPSDU Medium Rate Side A (APID # 198) Packet size is 116 bytes and is recorded every 8.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of this packet.
IPSDU Medium Rate Side A QAC	0 - (3 bytes * nsec / 8.0)	QACs for these packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
IPSDU Medium Rate Side B Packets	116 bytes * nsec / 8.0	The IPSDU Medium Rate Side B (APID # 199) Packet size is 116 bytes and is recorded every 8.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of this packet.
IPSDU Medium Rate Side B QAC	0 - (3 bytes * nsec / 8.0)	QACs for these packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
IPSDU Low Rate Side A Packets	182 bytes * nsec / 32.0	The IPSDU Medium Rate Side A (APID # 200) Packet size is 182 bytes and is recorded every 32.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of this packet.
IPSDU Low Rate Side A QAC	0 - (3 bytes * nsec / 32.0)	QACs for these packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC: 1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
IPSDU Low Rate Side B Packets	182 bytes * nsec / 32.0	The IPSDU Medium Rate Side B (APID # 201) Packet size is 182 bytes and is recorded every 32.00s. Refer to the **TRMM Telemetry and Command Handbook** for a detailed description of this packet.
IPSDU Low Rate Side B QAC	0 - (3 bytes * nsec / 32.0)	QACs for these packets. QACs will only be present when some anomaly is detected in the decoding of the packet. Therefore the expected number of QACs is near zero. There are 2 subfields in the QAC:

		1. Data Unit Sequence Count (2 bytes) 2. QAC Error Type (1 byte) defined in section 3
Modified IPSDU elements	72 bytes * nsec (estimate)	18 fields of engineering units derived from the IPSDU packets. All fields are 4-byte floats. Details are **TBD** by NASDA.

Table 6.3-2
Description of 1A-21 Header

# of bytes	Type	Description
4	Character	"PR "
4	Integer	Orbit number
12	Character	TSDIS descriptor for the ephemeris file. The format is EPHEM.YYMMDD, where YY is year, MM is month, and DD is day of the month.
10	Character	Orbit Start UTC Date in the format described in section 3
8	Character	Orbit Start UTC Time in the format described in section 3
3	Character	Orbit Start UTC Milliseconds in the format described in section 3
8	**	Orbit Start Spacecraft Time
10	Character	Orbit End UTC Date in the format described in section 3
8	Character	Orbit End UTC Time in the format described in section 3
3	Character	Orbit End UTC Milliseconds in the format described in section 3
8	**	Orbit End Spacecraft Time
10	Character	Orbit First Scan UTC Date in the format described in section 3
8	Character	Orbit First Scan UTC Time in the format described in section 3
3	Character	Orbit First Scan UTC Milliseconds in the format described in section 3
8	**	Orbit First Scan Spacecraft Time
10	Character	Orbit Last Scan UTC Date in the format described in section 3
8	Character	Orbit Last Scan UTC Time in the format described in section 3
3	Character	Orbit Last Scan UTC Milliseconds in the format described in section 3
8	**	Orbit Last Scan Spacecraft Time
8	**	UTCF from the first ACS ancillary packet after Orbit Start Time
4	Integer	Number of scans in the Orbit
4	Integer	Number of bytes of Spacecraft Attitude
4	Integer	Number of bytes of ACS QAC
4	Integer	Number of bytes of PR Housekeeping
4	Integer	Number of bytes of Modified PR Housekeeping
4	Integer	Number of bytes of HK QAC
4	Integer	Number of bytes of PR Science Data
4	Integer	Number of bytes of Science QAC
4	Integer	Number of bytes of Science MDUL
4	Integer	Number of bytes of PR Calibration Coefficients
4	Integer	Number of bytes of IPSDU High Rate Side A
4	Integer	Number of bytes of IPSDU High Rate Side A QAC
4	Integer	Number of bytes of IPSDU High Rate Side B
4	Integer	Number of bytes of IPSDU High Rate Side B QAC
4	Integer	Number of bytes of IPSDU Medium Rate Side A
4	Integer	Number of bytes of IPSDU Medium Rate Side A QAC
4	Integer	Number of bytes of IPSDU Medium Rate Side B
4	Integer	Number of bytes of IPSDU Medium Rate Side B QAC
4	Integer	Number of bytes of IPSDU Low Rate Side A

4	Integer	Number of bytes of IPSDU Low Rate Side A QAC
4	Integer	Number of bytes of IPSDU Low Rate Side B
4	Integer	Number of bytes of IPSDU Low Rate Side B QAC
4	Integer	Number of bytes of Modified IPSDU Elements

** Spacecraft Time format described in the **TRMM Telemetry and Command Handbook,** section 3.3.2

Table 6.3-3
Description of the Modified PR Science Data Packet (APID # 53)

Byte Position	# of Bytes	Description
1 - 6	6	CCSDS Primary Header. Refer to **TRMM Telemetry and Command Handbook** for a description
7 - 14	8	CCSDS Secondary Header. Refer to **TRMM Telemetry and Command Handbook** for a description
15	1	PR mode status: 1= Observation 2= External Calibration (limited scan) 3= External Calibration (fixed scan) 4= Internal Calibration 5= Analysis 7= Stand-By
16 - 23	8	8 (out of 128) contiguous Solid State Power Amplifier (SSPA) transmitted powers
24	1	The SSPA number of the first SSPA power above. SSPA numbers would be 1, 9, 17,..., 121
25	1	Bias of logarithmic amplifier
26	1	Selected value of attenuation frequency converter
27 - 222	196	4 System noise values for each of Observation angle bins No. 1 - 49.
223 - 530	308	28 rain echo oversample data values for the Observation angle bin No. 20 - 30.
531 - 733	203	1 Range bin number of the Peak surface echo (2 bytes) and 5 Surface echo oversample data values for Observation angle bins #11 - 39.
734 - 6979	6246	Rain echo data
6980 - 6988	9	Spare

6.4 INSTRUMENT ANALYSIS PRODUCTS

Since NASDA will monitor the PR instrument and instrument analysis products will not be created in TSDIS, TSDIS will not supply a format for PR instrument analysis products.

6.5 LEVEL-1B

The PR Level-1B product, 1B-21, “PR Power,” is written as a Swath Structure. See Section 2 in HDF. The following sections describe the structure and contents of the format.

6.5.1 Structure

Figure 6.5.1-1 shows the structure of the PR Level-1B product in terms of its component objects and their sizes.

The following sizing parameters are used in describing the format:

- nray = the number of rays = 49
- nscan = the number of scans within one granule. See Section 3-6.

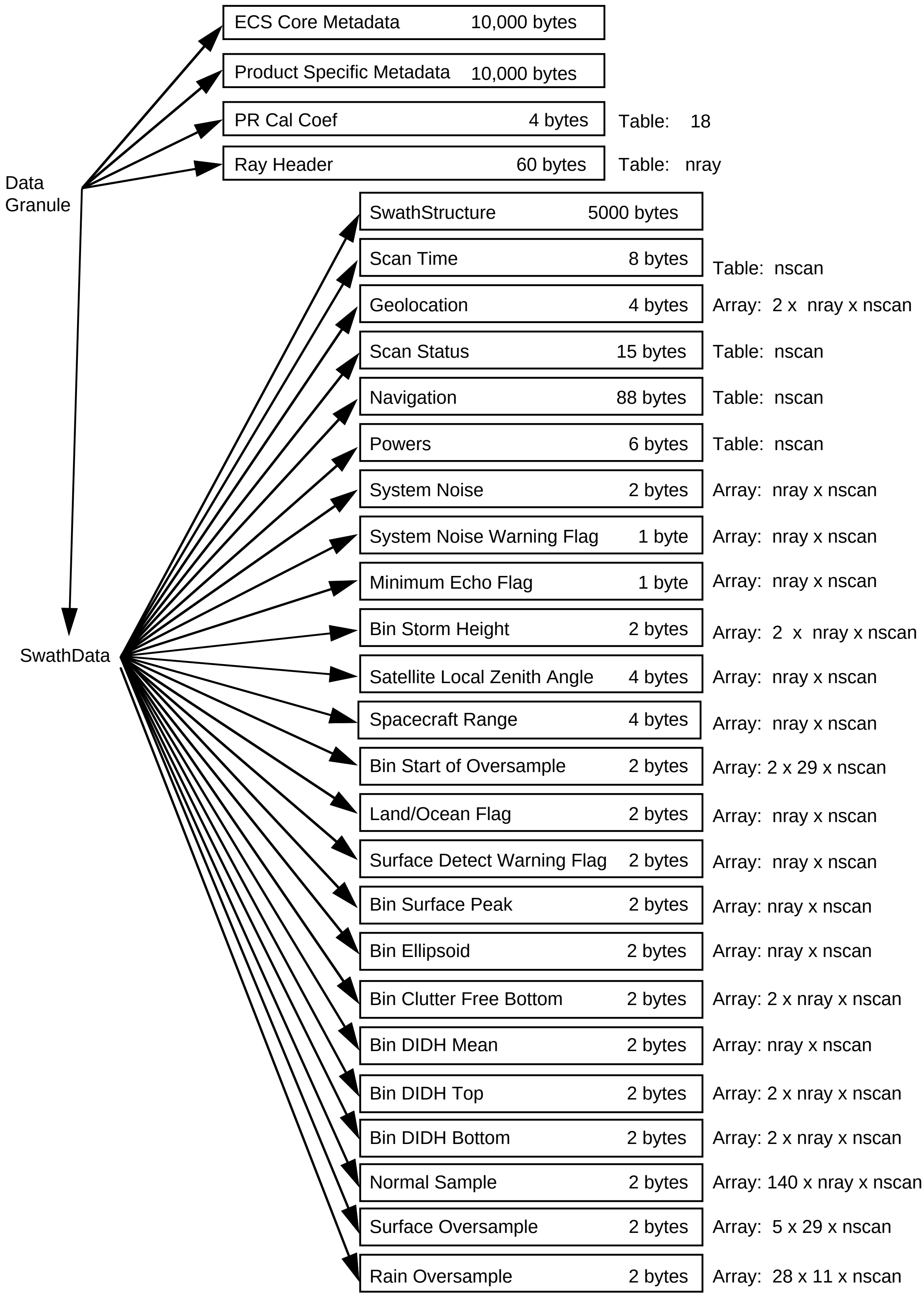

ECS Core Metadata 10,000 bytes
Product Specific Metadata 10,000 bytes
PR Cal Coef 4 bytes
Table: 18
Ray Header 60 bytes
Table: nray
Data Granule
SwathStructure 5000 bytes
Scan Time 8 bytes
Table: nscan
Geolocation 4 bytes
Array: 2 x nray x nscan
Scan Status 15 bytes
Table: nscan
Navigation 88 bytes
Table: nscan
Powers 6 bytes
Table: nscan
System Noise 2 bytes
Array: nray x nscan
System Noise Warning Flag 1 byte
Array: nray x nscan
Minimum Echo Flag 1 byte
Array: nray x nscan
Bin Storm Height 2 bytes
Array: 2 x nray x nscan
SwathData
Satellite Local Zenith Angle 4 bytes
Array: nray x nscan
Spacecraft Range 4 bytes
Array: nray x nscan
Bin Start of Oversample 2 bytes
Array: 2 x 29 x nscan
Land/Ocean Flag 2 bytes
Array: nray x nscan
Surface Detect Warning Flag 2 bytes
Array: nray x nscan
Bin Surface Peak 2 bytes
Array: nray x nscan
Bin Ellipsoid 2 bytes
Array: nray x nscan
Bin Clutter Free Bottom 2 bytes
Array: 2 x nray x nscan
Bin DIDH Mean 2 bytes
Array: nray x nscan
Bin DIDH Top 2 bytes
Array: 2 x nray x nscan
Bin DIDH Bottom 2 bytes
Array: 2 x nray x nscan
Normal Sample 2 bytes
Array: 140 x nray x nscan
Surface Oversample 2 bytes
Array: 5 x 29 x nscan
Rain Oversample 2 bytes
Array: 28 x 11 x nscan

Figure 6.5.1-1 PR Level-1B Structure (previous page)

6.5.2 Contents

ECS Core Metadata (Attribute, 10,000-byte character):
ECS Core Metadata are those metadata defined by ECS as Core metadata.
See ICS Volume 6.

PS Metadata (Attribute, 10,000-byte character):
Product Specific Metadata are metadata defined by and specific to TSDIS.
See ICS Volume 6.

PR Cal Coef (Vdata Table, record size 4 bytes, 18 records):
Calibration coefficients for the PR. The records consist of:
Transmission coefficient (unitless, 1 record),
Reception coefficient (unitless, 1 record), and
FCIF I/O Characteristics (unitless, 16 records).
Descriptions are **TBD** by NASDA.

Ray Header (Vdata Table, record size 60 bytes, 49 records):
Information about each ray (angle bin) that is constant for every scan. The record number represents the angle bin number. Each record describes one ray and is defined in Table 6.5.2-1.

SwathStructure (Attribute, 5,000-byte character):
SwathStructure gives the specification of the swath geometry. See Section 2.

Scan Time (Vdata Table, record size 8 bytes, nscan records):
See Table 6.5.2-2.

Geolocation (SDS, array size 2 x 49 x nscan, 4-byte float):
The earth location of the center of the IFOV at the altitude of the earth ellipsoid. The first dimension is latitude and longitude, in that order. The next dimensions are pixel and scan. Values are represented as floating point decimal degrees. Off-earth is represented as less than or equal to -9999.9 Latitude is positive north, negative south. Longitude is positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.

Scan Status (Vdata Table, record size 15 bytes, nscan records):
The status of each scan is represented in terms of quality, platform and instrument control data, and fractional orbit number as shown in Table 6.5.2-3.

Navigation (Vdata Table, record size 88 bytes, nscan records):
See Appendix B.

Powers (Vdata Table, record size 6 bytes, nscan records):
See the following, Table 6.5.2-4.

Table 6.5.2-1
Ray Header
(Vdata Table, record size 60 bytes, 49 records)

Name	Format	Description
Ray Start	2-byte integer	Starting range bin number of Normal sample
Ray Size	2-byte integer	Number of Normal samples in the ray
Angle	4-byte float	Angle (degrees) of the ray from nadir. The sign of the angle is consistent with the sensor y-axis, i.e., the angle is positive to the right of the direction of travel if the spacecraft is in normal mode.
Starting Bin Distance	4-byte float	Distance (m) between the satellite and the starting bin number of the Normal sample for the ray
Rain Threshold 1	4-byte float	Threshold used in minimum echo test (unitless). Value set by NASDA
Rain Threshold 2	4-byte float	Threshold used in minimum echo test (unitless). Value set by NASDA
Transmitter Antenna Gain	4-byte float	Transmitted radar antenna effectiveness (dB)
Receiver Antenna Gain	4-byte float	Received radar antenna effectiveness (dB)
One-way 3dB Along-track Beamwidth	4-byte float	Radar beamwidth (radians) at the point transmitted power reaches one half of peak power in the along-track direction.
One-way 3dB Cross-track Beamwidth	4-byte float	Radar beamwidth (radians) at the point transmitted power reaches one half of peak power along the cross-track.
Equivalent wavelength	4-byte float	Equivalent wavelength (m).
Radar Constant	4-byte float	Radar constant dC (units are dB), which relates Received Power to Radar Reflectivity. dC depends on angle. dC = 10 logC = $10 \log \left[\pi^3 \frac{\mid K \mid^2}{2^{10} \ln 2} 10^{-18} \cos(angle) \right]$ where $K = (\varepsilon - 1)/(\varepsilon + 2)$ ε is the dielectric constant of water $\mid K \mid^2 = 0.9255$
PR Internal delayed time	4-byte float	The time (seconds) between when echo returns at antenna and when echo is recorded in onboard processor.
Range Bin Size	4-byte float	The vertical resolution of Normal sample bin (250 m).
Logarithmic Averaging Offset	4-byte float	The offset value (dB) between logarithmic average and normal average (+2.507dB).
Mainlobe Clutter Edge	1-byte integer	Absolute value of the difference in Range Bin Numbers between the detected surface and the edge of the clutter from the mainlobe.
Sidelobe Clutter Range [3]	3 X 1-byte integer	Absolute value of the difference in Range Bin Numbers between the detected surface and the clutter psition from the sidelobe. A zero means no clutter indicated in this field since less than 3 bins contained significant clutter.

Table 6.5.2-2
Scan Time
(Vdata Table, record size 8 bytes, nscan records)

Name	Format	Description
Scan Time	8-byte float	A time associated with the scan. The exact relationship between Scan Time and the time of each IFOV is described in Section 3. Scan Time is expressed as the UTC seconds of the day.

Table 6.5.2-3
Scan Status
(Vdata Table, record size 15 bytes, nscan records)

Name	Format	Description
Missing	1-byte integer	Missing indicates whether information is contained in the scan data. The values are: 0 Scan data elements contain information 1 Scan was missing in the telemetry data 2 Scan data contains no elements with rain
Validity	1-byte integer	Validity is a summary of status modes. If all status modes are routine, all bits in Validity = 0. Routine means that scan data has been measured in the normal operational situation as far as the status modes are concerned. Validity does not assess data or geolocation quality. Validity is broken into 8 bit flags. Each bit = 0 if the status is routine but the bit = 1 if the status is not routine. Bit 0 is the least significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**i). The non-routine situations follow: Bit Meaning if bit = 1 0 Spare (always 0) 1 Non-routine spacecraft orientation (2 or 3) 2 Non-routine ACS mode (other than 4) 3 Non-routine yaw update status (0 or 1) 4 Non-routine instrument status (other than 1) 5 Non-routine QAC (non-zero) 6 Spare (always 0) 7 Spare (always 0)
QAC	1-byte integer	The Quality and Accounting Capsule of the Science packet as it appears in Level-0 data. If no QAC is given in Level-0, which means no decoding errors occurred, QAC in this format has a value of zero.

Name	Format	Description
Geolocation Quality	1-byte integer	Geolocation quality is a summary of geolocation quality in the scan. A zero integer value indicates 'good' geolocation. A non-zero value broken down into the following bit flags indicates the following, where bit 0 is the least significant bit (i.e., if bit i = 1 and other bits = 0 the unsigned integer value is 2**i): Bit Meaning if bit = 1 0 latitude limit error 1 geolocation discontinuity 2 attitude change rate limit error 3 attitude limit error 4 satellite undergoing maneuvers 5 using predictive orbit data 6 geolocation calculation error 7 not used

Table 6.5.2-3 (continued)
Scan Status
(Vdata Table, record size 15 bytes, nscan records)

Name	Format	Description
Data Quality	1-byte integer	Data quality is a summary of data quality in the scan. Unless this is 0 (normal), the scan data is meaningless to higher processing. Bit 0 is the least significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**i). Bit Meaning if bit = 1 0 missing 5 Geolocation Quality is not normal 6 Validity is not normal
Current Spacecraft Orientation	1-byte integer	Value Meaning 0 +x forward 1 -x forward 2 -y forward 3 Inertial - CERES Calibration 4 Unknown Orientation
Current ACS Mode	1-byte integer	Value Meaning 0 Standby 1 Sun Acquire 2 Earth Acquire 3 Yaw Acquire 4 Nominal 5 Yaw Maneuver 6 Delta-H (Thruster) 7 Delta-V (Thruster) 8 CERES Calibration
Yaw Update Status	1-byte integer	Value Meaning 0 Inaccurate 1 Indeterminate 2 Accurate
PR Mode	1-byte integer	Value Meaning 1 = Observation Mode 2 = Other Mode
PR Status 1	1-byte integer	This status is a warning for scan data. Unless this is 0, the scan data may include a little questionable value though it is not a problem (such as break of caution limit). This field is used only for NASDA's data analysis.
PR Status 2	1-byte integer	Initialization in Onboard Surface Search Algorithm 0 Not initialized 1 Initialized
Fractional Orbit Number	4-byte float	The orbit number and fractional part of the orbit at Scan Time. The orbit number will be counted from the beginning of the mission. The fractional part is calculated as: (Time - Orbit Start Time) / (Orbit End Time - Orbit Start Time)

Table 6.5.2-4
Powers
(Vdata Table, record size 6 bytes, nscan records)

Name	Format	Description
Radar Transmission Power	2-byte integer	The total (sum) power of 128 SSPA elements corrected with SSPA temperature in orbit, based on temperature test data of SSPA transmission power. The units are dBm * 100. For this variable, the TSDIS Toolkit does not provide scaling.
Transmitted Pulse Width	4-byte float	Transmitted pulse width (s) corrected with FCIF temperature in orbit, based on temperature test data of FCIF.

System Noise (SDS, array size nray x nscan, 2-byte integer):
System Noise (dBm) is an average of the 4 measured system noise values, multiplied by 100 and stored as a 2-byte integer. The range is -120 dBm to -20 dBm with an accuracy of 0.9 dBm. Missing data are given the value of -32,734.

System Noise Warning Flag (SDS, array size nray x nscan, 1-byte integer):
System Noise Warning Flag indicates possible contamination of lower window noise by high towers of rain. 1 means possible contamination; 0 means no possible contamination.

Minimum Echo Flag (SDS, array size nray x nscan, 1 byte-integer):
Flag to indicate the presence of rain in the ray (angle bin). The values of the flag are:
0 = no rain
10 = rain possible
11 = rain possible (Echo greater than rain threshold #1 in clutter range)
12 = rain possible (Echo greater than rain threshold #2 in clutter range)
13 = rain possible but probably sidelobe clutter
20 = rain certain

Bin Storm Height (SDS, array size 2 x nray x nscan, 2 byte-integer):
Range Bin Number of the storm top. The first dimension is threshold, with values of possible rain threshold and certain rain threshold in that order. The Bin Storm Heights are generated in the procedure to determine the Minimum Echo Flag. The Bin Storm Height is the top range bin of the portion of consecutive range bins that flagged the ray as rain possible or rain certain. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

Satellite Local Zenith Angle (SDS, array size nray x nscan, 4-byte float):
The angle, in degrees, between the local zenith and the beam's center line. The local (geodetic) zenith at the intersection of the ray and the earth ellipsoid is used.

Spacecraft Range (SDS, array size nray x nscan, 4-byte float):

Distance (m) between the spacecraft and the center of the footprint of the beam on the earth ellipsoid.

Bin Start of Oversample (SDS, array size 2 x 29 x nscan, 2 byte-integer):
The first dimension is the Bin Start of Oversample and Surface Tracker Status. The second dimension is the ray. The number of rays is 29 because this information only applies to the rays that have oversample data (rays #11 to #39). The third dimension is the scan. The Bin Start of Oversample is the starting range bin number of the oversample (either surface or rain) data, counting from the top down. The Surface Tracker Status has the value of 0 (Lock) or 1 (Unlock),
where Lock means that (1) the on board surface detection detected the surface and (2) the surface detected later by processing on the ground fell within the oversample bins. Unlock means that Lock was not achieved. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

Land/Ocean Flag (SDS, array size nray x nscan, 2-byte integer):
Land or ocean information. The values of the flag are:

0 = Water
1 = Land
2 = Coast
3 = Water (w/ large attenuation)
4 = Land/Coast (w/ large attenuation)

Surface Detect Warning Flag (SDS, array size nray x nscan, 2-byte integer):
Definition **TBD** by NASDA.

Bin Surface Peak (SDS, array size nray x nscan, 2 byte-integer):
The range bin number of the peak surface echo. This peak is determined by the post observation ground processing, not by the on board surface detection. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

Bin Ellipsoid (SDS, array size nray x nscan, 2-byte float):
The range bin number of the earth ellipsoid. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

This field will not be used until product version #4 products are available. Until that time this field contains zero (0) and should be ignored.

Bin Clutter Free Bottom (SDS, array size 2 x nray x nscan, 2-byte integer):
The range bin number of the lowest clutter free bin. Clutter free bin numbers are given for clutter free certain and possible, respectively. The clutter free certain bin is always less than or equal to the clutter free possible bin number.

This field will not be used until product version #4 products are available. Until that time this field contains zero (0) and should be ignored.

Bin DID Average (SDS, array size nray x nscan, 2-byte integer):
The mean range bin number of the DID surface elevation in a 5 km x 5 km box centered on the IFOV. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

This field will not be used until product version #4 products are available. Until that time this field contains zero (0) and should be ignored.

Bin DID Top (SDS, array size 2 x nray x nscan, 2-byte integer):
The range bin number of the maximum DID surface elevation in a box centered on the IFOV. The first dimension is the box size, with sizes of 5 km x 5 km and 11 km x 11km. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

This field will not be used until product version #4 products are available. Until that time this field contains zero (0) and should be ignored.

Bin DID Bottom (SDS, array size 2 x nray x nscan, 2-byte integer):
The range bin number of the minimum DID surface elevation in a box centered on the IFOV. The first dimension is the box size, with sizes of 5 km x 5 km and 11 km x 11km. The range bin number is defined in this volume in the section on Precipitation Radar, Instrument and Scan Geometry.

This field will not be used until product version #4 products are available. Until that time this field contains zero (0) and should be ignored.

Normal Sample (SDS , array size 140 x nray x nscan, 2 byte-integer):
Return power (dBm) of the normal sample, multiplied by 100 and stored as a 2-byte integer. Since each ray has a different size, the elements after the end of each ray are filled with a value of -32767. Other bins where data is not written due to a transmission, calibration, or other problem, including an entire scan of missing bins, have the value of -32734. See Figure 6.1-2. The size of each ray is specified in Ray Header. The range is -120 dBm to -20 dBm.

Surface Oversample (SDS, array size 5 x 29 x nscan, 2 byte-integer):
Return power (dBm) of the surface echo oversample for the central 29 rays (rays #11-39), multiplied by 100 and stored as a 2-byte integer. The range is -120 dBm to -20 dBm. Bins where data is not written due to a transmission, calibration, or other problem, including an entire scan of missing bins, have the value of -32734.

Rain Oversample (SDS, array size 28 x 11 x nscan, 2 byte-integer):
Return power (dBm) of the rain echo oversample for the central 11 rays (rays #20-30), multiplied by 100 and stored as a 2-byte integer. The range is -120 dBm to -20 dBm. Bins where data is not written due to a transmission, calibration, or other problem, including an entire scan of missing bins, have the value of –32734.

6.6 LEVEL-1C

The PR Level-1C product, 1C-21, "PR Reflectivities," has the same format as 1B-21, with 3 changes: The variable in the Normal Sample, Surface Oversample, and Rain Oversample is reflectivity (dBz) in 1C-21. In these 3 objects, the data ranges from -20 dBZ to 80 dBZ with an accuracy of 1.0 dBZ. If a cell (range bin) is determined to have no rain, the reflectivity is set to -32700.

6.7 METADATA FOR PR

ECS Core Metadata Format (Attribute, maximum 10,000-byte character): ECS Core Metadata are those metadata defined by ECS as Core metadata. A description of each ECS Core metadata element is listed in Table 6.6-1. The size column refers to the size of the name plus value. The actual element would take up an additional 100 bytes due to metadata implementation overhead. In other words, the true size is the listed size plus 100 bytes. Note that "All" or "L1" in the "Products Using Element" column includes Level 1B and Level 1C, but not Level 1A.

Table 6.6-1
ECS Core Metadata Elements for PR Level 1

ECS Metadata Element	Size (bytes)	Description	Products Using Element
ID of ECS Data Object (collection)	100	The unique identifier of an ECS collection to which this granule belongs. (i.e. "Total Power, Noise")	All
Size MB ECS Data Object	50	The size attribute will indicate the volume of data contained in the granule.	All
Spatial Coverage Type	50	This attribute denotes whether the locality/coverage requires horizontal, vertical or both spatial domain and coordinate system definitions.	All
Ellipsoid Name	50	Name of the ellipsoid.	L1 & L2 Satellite Products
Equatorial Radius	50	Equatorial radius of the earth ellipsoid (meters).	L1 & L2 Satellite Products

ECS Metadata Element	Size (bytes)	Description	Products Using Element
Denominator of Flattening Ratio	50	The reciprical of the flattening ratio, f, where $f = 1 - b / a$, a = Equatorial radius of the earth ellipsoid and b = Polar radius of the earth ellipsoid	L1 & L2 Satellite Products
Orbit Model Name	100	The reference name to the orbital model to be used to calculate the geolocation of this data to determine global spatial extent.	L1 & L2 Satellite Products
Orbit Number	50	The orbit number to be used in calculating the spatial extent of this data.	L1 & L2 Satellite Products
Semi Major Axis	50	Half of the long axis of the orbit ellipse (meters).	L1 & L2 Satellite Products
Mean Anomaly	50	Angle around the orbit at the Epoch Time about the Ellipse center from the ascending node (radians).	L1 & L2 Satellite Products
Right Ascension of Ascending Node	50	Right Ascension in Geocentric Inertial Coordinates of the north bound equator crossing (radians).	L1 & L2 Satellite Products
Argument of Perigee	50	Angle from the ascending node to perigee (radians).	L1 & L2 Satellite
Eccentricity	50	Eccentricity of ellipse (unit less).	L1 & L2 Satellite
Inclination	50	Angle between Orbit plane and Earth Equatorial plane (radians).	L1 & L2 Satellite
Epoch date	50	Reference date for orbital elements	L1 & L2 Satellite
Epoch time	50	Reference time for orbital elements	L1 & L2 Satellite
Epoch milliseconds	50	Reference milliseconds for orbital elements	L1 & L2 Satellite

Table 6.6-1 (continued)
ECS Core Metadata Elements for PR Level 1

ECS Metadata Element	Size (bytes)	Description	Products Using Element
West Bounding Coordinate	50	The degree value for the west longitude of boundary.	All
East Bounding Coordinate	50	The degree value for the east longitude of boundary.	All
North Bounding Coordinate	50	The degree value for the north latitude of boundary.	All
South Bounding Coordinate	50	The degree value for the south latitude of boundary.	All
Temporal Range Type	50	This tells the system how temporal coverage is specified for the granule.	All
Beginning Date	50	The date when the granule coverage began. Granule coverage is defined as the orbit for Level-1 and Level-2 satellite data, as the hour of the granule for Level-1 and Level-2 ground validation data, as the day of the granule for rain gauge and disdrometer data, and as the pentad or month of the granule for Level-3 data.	All
Beginning Time	50	The time when the granule coverage began. See beginning date.	All
Ending Date	50	The date when the granule coverage ended. See beginning date.	All
Ending Time	50	The time when the granule coverage ended. See beginning date.	All
QA Parameter Name	50	"ScienceQualityFlag"	All
QA Parameter Value	100	A post processing indication of quality by the algorithm developer. The Quality Indicator takes the form of 4 possible ASCII strings: "NOT BEING INVESTIGATED", "BEING INVESTIGATED", "FAILED", or "PASSED".	All
Reprocessing Status	50	This attribute identifies the intent of the product author to reprocess the data (i.e. data gaps, geolocation accuracy, scientist review quality flags).	All
Browse Package Reference	100	This attribute will contain a system-resolvable reference to an HDF package containing a collection of browse granules.	All
Contact Name	100	The name of the algorithm developer related to this granule. The contact name supplied here must exist in the ECS contact database.	All

PS Metadata (Attribute, maximum 10,000-byte character): Product Specific Metadata are metadata defined by TSDIS. The size column refers to the size of the name plus value. The actual element would take up an additional 100 bytes due to metadata implementation overhead. In other words, the true size is the listed size plus 100 bytes. Note that “All” or “L1” in the “Products Using Element” column includes Level 1B and Level 1C, but not Level 1A. A description of each PS metadata element follows in Table 6.6-2.

Table 6.6-2
PS Metadata Elements for PR Level 1

PS Metadata Element	Estimated Size (bytes)	Description	Products Using Element
Granule ID	100	TSDIS granule ID	All
Algorithm ID	50	Name of the algorithm (i.e. 1B21)	All
Algorithm Version	50	The version of the science algorithm is written as “M.m”, where M is an integer corresponding to major revisions of the code. Major revisions are changes in the science algorithm which do affect the science, are delivered to TSDIS in an official delivery package, and require reprocessing. “m” is an integer corresponding to minor revisions or corrections. Minor revisions or corrections are made so the science algorithm will function properly in TSDIS, do not affect the science, are not delivered to TSDIS in an official delivery package, and do not require reprocessing. “M” is written without leading zeroes, with a range from 1 to 99. “m” is written with leading zeroes, with a range from 00 to 99. At launch, the version of all science algorithms is “1.00”.	All
Product Version Number	50	A single integer indicating the version of the product. The first Product Version Number is 1. The Product Version Number is incremented every time the product is reprocessed due to the fact that the algorithm creating it changes or the algorithms creating the input to the algorithm change.	All
Toolkit Version	50	Version of Toolkit used to create thisgranule	All
Calibration Coefficient Version	50	Version of the calibration coefficients. (i.e. 1, 2, 3, etc.)	All PR
Anomaly Flag	100	This flag indicates if and why a granule is empty. The possible values are:	All

PS Metadata Element	Estimated Size (bytes)	Description	Products Using Element
		"EMPTY: GENERATED AFTER SOFTWARE ERROR" * "EMPTY: NO DATA DUE TO NO RAIN" "EMPTY: NO DATA RECORDED" "EMPTY: DATA RECORDED BUT STILL MISSING" "EMPTY: REASON UNKNOWN" * "NOT EMPTY: POSSIBLE PROBLEM" "NOT EMPTY" * It is expected that satellite data would use only the three values followed by an asterisk. GV data is expected to use all seven values.	
Missing Data	50	Number of missing scans in the orbit (satellite data) or missing rays (ground radar data).	L1 and L2 data

Table 6.6-2 (continued)
PS Metadata Elements for PR Level 1

PS Metadata Element	Estimated Size (bytes)	Description	Products Using Element
Percentage of bad or missing pixels	100	List by channel of the percentage of bad or missing pixels in the orbit (satellite data) or granule (GV data).	L1 and L2 data
Number of Data Gaps	50	The number of data gaps in the data in the orbit (satellite data) or granule (GV data).	L1 and L2 data
Data Gaps Duration	50	The sum of the durations of the data gaps in seconds in the orbit (satellite data) or granule (GV data).	L1 and L2 data
Data Accuracy	50	List by channel of the accuracies of the data.	L1 data
Maximum valid value of channel	100	List by channel of the maximum valid value (value specified by the instrument scientist).	L1 data
Minimum valid value of channel	100	List by channel of the minimum valid value (value specified by the instrument scientist).	L1 data
Min Max Units	50	Units of the Minimum and Maximum valid values.	L1 data
Input Ids	300	List of input granule IDs.	L1 and L2
Date of Generation of input files	100	List of the generation dates of the input files. For ingested files, this is the date TSDIS received the file.	L1 and L2
Data center source of input files	100	List of the data centers generating the input files, e.g., TSDIS, NMC	L1 and L2
Generation date	50	Date the dataset was generated	All
Longitude of Maximum Latitude	50	Longitude of the northernmost extent of the satellite orbit. Decimal degrees with 6 figures precision after the decimal point. Positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.	L1 and L2 Satellite
Mean Motion	50	Number of orbits per day, including fractions of orbits.	L1 and L2 Satellite
Orbit Adjust Flag	50	Orbit Adjust Flag. Values are as follows: 0 = no orbit adjust activity during this orbit. 1 = orbit adjustment control modes occurred during this orbit.	L1 and L2 Satellite
Attitude Mode Flag	50	Attitude Mode Flag. Values are as follows: 0 = forward mode (+X forward) throughout this orbit 1 = backward mode (-X forward) throughout this orbit 2 = yaw maneuver during this orbit	L1 and L2 Satellite
Solar beta angle at beginning of granule	50	Elevation of sun in the orbit plane at the orbit start (degrees).	L1 and L2 Satellite
Solar beta angle at end of the granule	50	Elevation of sun in the orbit plane at the orbit end (degrees).	L1 and L2 Satellite
Sensor Alignment	100	Euler Sequence (3 integers) and Euler angles for rotation from spacecraft coordinates to sensor coordinates in degrees. (These are to be provided by the science team)	L1 and L2 Satellite

Table 6.6-2 (continued)
PS Metadata Elements for PR Level 1

PS Metadata Element	Estimated Size (bytes)	Description	Products Using Element
Sensor Alignment Channel Offsets	50 x number of channels	Euler Sequence (3 integers) and Euler angles for rotation from sensor coordinates to Channel coordinates with angles separately for each channel in degrees. (These are to be provided by the science team if needed, but they are not nominally used in TSDIS processing since geolocation is not done per channel)	L1 and L2 Satellite
Scan Path Model	100	Parameters describing the scan path as used for pixel geolocation. For a (nominal) conical scan model the following parameters are used: Axis of Scan (+/- 1,2,or 3). Reference Axis for zero rotation angle (+/- 1,2,or 3), and Scan cone angular radius in degrees. Starting rotation angle relative to the scan axis in degrees, Total rotation angle spanned in degrees, Active scan duration time in seconds (between first and last pixel), and Time Offset between spacecraft time of the sensor data packet and the first pixel time, in seconds.	L1 and L2 Satellite
Scan Path Parameters Per Channel	50	Parameters describing the scan path separately for each channel in degrees. (These are to be provided by the science team if needed, but they are not nominally used in TSDIS processing since geolocation is not done per channel)	L1 and L2 Satellite
Ephemeris File Descriptor	50	TSDIS granule ID for the ephemeris file. The format is EPHEM.YYMMDD.nn, where YY is year, MM is month, DD is day of the month, and nn is the version number.	L1 and L2 Satellite
Orbit Size	50	Number of scans in Orbit. If the granule is empty, Orbit Size = 0.	L1 and L2 Satellite
Orbit First Scan UTC Date	50	Orbit First Scan UTC Date in the format described in Section 3. If the granule is empty, the value is '0/0/0'.	L1 and L2 Satellite
Orbit First Scan UTC Time	50	Orbit First Scan UTC Time in the format described in Section 3. If the granule is empty, the value is '0:0:0'.	L1 and L2 Satellite
Orbit First Scan UTC Milliseconds	50	Orbit First Scan UTC Milliseconds in the format described in Section 3	L1 and L2 Satellite
Orbit First scan time - Spacecraft clock - seconds	50	The seconds field of the spacecraft clock time of the first scan in the orbit	L1 and L2 Satellite
Orbit First scan time - Spacecraft clock - subseconds	50	The subseconds field of the spacecraft clock time of the first scan in the orbit	L1 and L2 Satellite
Orbit Last Scan UTC Date	50	Orbit Last Scan UTC Date in the format described in Section 3. If the granule is empty, the value is '0/0/0'.	L1 and L2 Satellite

Table 6.6-2 (continued)
PS Metadata Elements for PR Level 1

PS Metadata Element	Estimated Size (bytes)	Description	Products Using Element
Orbit Last Scan UTC Time	50	Orbit Last Scan UTC Time in the format described in Section 3. If the granule is empty, the value is ‘0:0:0’.	L1 and L2 Satellite
Orbit Last Scan UTC Milliseconds	50	Orbit Last Scan UTC Milliseconds in the format described in section 3	L1 and L2 Satellite
Orbit Last scan time - Spacecraft clock - seconds	50	The seconds field of the spacecraft clock time of the last scan in the orbit	L1 and L2 Satellite
Orbit Last scan time - Spacecraft clock - subseconds	50	The subseconds field of the spacecraft clock time of the last scan in the orbit	L1 and L2 Satellite
UTCF seconds	50	The seconds field of the UTCF for the granule.	L1 and L2 Satellite
UTCF subseconds	50	The subseconds field of the UTCF for the granule.	L1 and L2 Satellite
UTCF flag	50	Flag that indicates the origin of the UTCF. 0 = UTCF was derived from the first ACS packet in the orbit. 1 = a corrected UTCF was used.	L1 and L2 Satellite
Leap second flag	50	Flag that indicates if a leap second or UTCF update occurred within the granule. 0 = none; 1 = leap second; 2 = UTCF change; 3 = both leap second and UTCF change	All
Radar wavelength	50	Wavelength of the radar (meters).	L1 PR & GV
Software Version	50	Version of the software	All PR
Data base Version	50	Version of PR Database in the PR L1 software	All PR
Total Quality Code	50	Total quality of the PR L1 product. Range is ‘G’, ‘F’, or ‘P’	All PR
Longitude on the Equator	50	Longitude on the equator from the ascending node. Range is -180.000 to 179.999	L1 PR & L2 PR
UTC Date on the Equator	50	UTC date on the equator.	L1 PR & L2 PR
UTC Time on the Equator	50	UTC time on the equator.	L1 PR & L2 PR
UTC Milliseconds on the Equator	50	UTC Milliseconds on the Equator.	L1 PR & L2 PR
Orbit Center Scan UTC Date	50	UTC date at orbit center scan.	L1 PR & L2 PR
Orbit Center Scan UTC Time	50	UTC time at orbit center scan.	L1 PR & L2 PR

Table 6.6-2 (continued)
PS Metadata Elements for PR Level 1

PS Metadata Element	Estimated Size (bytes)	Description	Products Using Element
Orbit Center Scan UTC Milliseconds	50	UTC milliseconds at orbit center scan.	L1 PR & L2 PR
Orbit First Scan Latitude	50	Latitude of orbit first scan. Range is -40.000 to 40.000	L1 PR & L2 PR
Orbit First Scan Longitude	50	Longitude of orbit first scan. Range is -180.000 to 179.999	L1 PR & L2 PR
Orbit Last Scan Latitude	50	Latitude of orbit last scan. Range is -40.000 to 40.000	L1 PR & L2 PR
Orbit Last Scan Longitude	50	Longitude of orbit last scan. Range is -180.000 to 179.999	L1 PR & L2 PR
Number of Rain Scans	50	The number of rain scans.	L1 PR & L2 PR

7. GROUND VALIDATION RADAR

7.1 INSTRUMENT AND SCAN GEOMETRY

The purpose of the Ground Validation (GV) activities of TRMM is to provide reliable comparative data during the TRMM mission for space/time averaged rainfall, which will allow the validity of the TRMM satellite measurements to be established within specified limits. The TRMM GV network will consist of 4 Primary and 6 Special Climatology sites. In addition, there will be two sites that consist of multiple radars and are considered Special Climatology-Multiple Radar sites. Table 7.1-1 lists the currently selected sites along with the type and number of radars.

The GV radars consist of simple radars, Doppler radars and a single dual polarization Doppler radar. Operated at the radio frequencies sensitive to precipitation, simple radars measure the returned power from the precipitation signal. This power is converted to reflectivity (Z) and estimates of rainfall are inferred from it. In addition to reflectivity, Doppler radars have the ability to estimate the mean radial velocity (V) of targets by measuring Doppler shifts in the returned signal. At a site with multiple Doppler radars with overlapping coverage it is possible to map the 2D wind field. The United States National Weather Service's WSR-88D radars, also known as Next Generation Radar (NEXRAD) systems, are examples of Doppler radars. Polarimetric radars are capable of transmitting microwaves of different polarization. Measuring the power or reflectivity in the returned signals at each polarization (differential reflectivity, ZDR) can yield an estimate of hydrometeor asymmetry. Table 7.1-2 shows typical ranges for some characteristics of ground-based radars.

As stated above, some parameters that radars measure are; reflectivity (Z), mean radial velocity (V) and, for a polarimetric radar, differential reflectivity (ZDR). In addition to these parameters, Doppler radars can measure spectral width (SW), a measure of the fluctuations in radial velocity. This can provide information on local turbulence. Polarimetric radars (e.g. the Darwin radar) can measure a host of other parameters including reflectivity at both polarizations (ZH, ZV), linear depolarization ratio (LDR), cross correlation coefficient between two polarizations (ρHV) and propagation differential phase shift (KDP). These parameters can be used to obtain more detailed microphysical information about the hydrometeors. While TRMM GV algorithms will not use these additional parameters they may appear in the raw data tapes. Table 7.1-3 lists the parameters for each radar along with specific range information for the parameters that impact TRMM GV algorithms. Note the values denoted with * are estimates derived from specifications provided by the TRMM Office. These estimated values will most likely need revision when more information is available.

A radar transmits a series of pulses and measures the power in the returned signal as a function of time delay. The time delay is then converted to distance from the radar and the measurements are presented in a number of discrete bins. Figure 7.1-1 shows the geometry of a single radar bin. The position of a bin relative to the radar is defined by two angles (the position of the radar antenna) and a slant range distance. The elevation angle is defined from the local horizontal and the azimuth angle is defined from some prescribed direction (geographic north). The data collected from a specific elevation and azimuth angle is called a ray. By changing the elevation and azimuth, various scanning strategies can be implemented.

TSDIS will receive GV data for volume scan (VOS) mode only. A volume scan consists of a base scan, during which the radar is set at the lowest elevation angle, making a complete 360° sweep in the azimuth direction. The radar antenna is then moved up to a higher elevation angle and another full sweep of azimuth is performed. After the radar antenna has completed a full sweep at the highest elevation angle the VOS is complete. The antenna is moved back to its original position at the lowest elevation level to begin a new VOS. The number of sweeps (elevation angles) and rays in a sweep vary from radar to radar. Table 7.1-3 lists the characteristics of a VOS for the GV radars.

Table 7.1-1
Ground Validation Radar Sites

Site Name	Site Type	Number of Radars	Radar Type
Darwin	Primary	1	C band dual-polarized Doppler
Melbourne,FL	Primary	1	NEXRAD
Kwajalein	Primary	1	NEXRAD
Houston, TX	Primary	1	NEXRAD
Florida	Special Cl. Multiple	4	All NEXRAD
Texas	Special Cl. Multiple	4	All NEXRAD
Guam	Special Cl.	1	NEXRAD
Taiwan	Special Cl.	1	S band Doppler
Sao Paolo, Brazil	Special Cl.	1	S band simple
Jerusalem, Israel	Special Cl.	1	S band simple
Chiang Mai,Thailand	Special Cl.	1	S band Doppler
Hawaii	Special Cl.	1	NEXRAD

Table 7.1-2
Characteristics of Ground Based Radars

Antenna	Representative Values
Antenna Diameter	3 to 9 meters
Beam Width	.96 to 1.1 degrees
Gain	39 to 45 dB
Azimuth speed	up to 36 deg/s
Elevation speed	up to 18 deg/s
Transmitter	**Representative Values**
Wavelength	5.30 to 10.77 cm
Peak Power	250 to 1000 kW

Pulse Width	.5 to several μs
Polarization	Horizontal, Vertical, Left/Right Circular
Doppler Capability	yes/no
PRF	Variable: 250 to 1500 Hz
Noise Figure	1 to 4 dB

Table 7.1-3
Volume Scan Characteristics

Site / Type	Parameters	VOS per hour	Number of Elevation Angles	Number of Azimuth Angles	Z Range Interval (m)	Z Number of bins	V Range Interval (m)	V Number of bins
Darwin	Z_H,Z_V,V,SW, Z_{DR},LDR, KDP,ρ_{HV}	6	15	360	300	600	150*	600*
NEXRAD	Z,V,SW	10	14/9	375	1000	475	500	460
Thailand	Z,V,SW	12	16	360	1000	250	1000	250
Israel	Z	12	16	360	1000	295	-	-
Brazil	Z	6	16	360	1000	295	-	-
Taiwan	Z,V,SW	6	15	360	1000	295	500*	295*

* These are estimates since this information is not currently available.

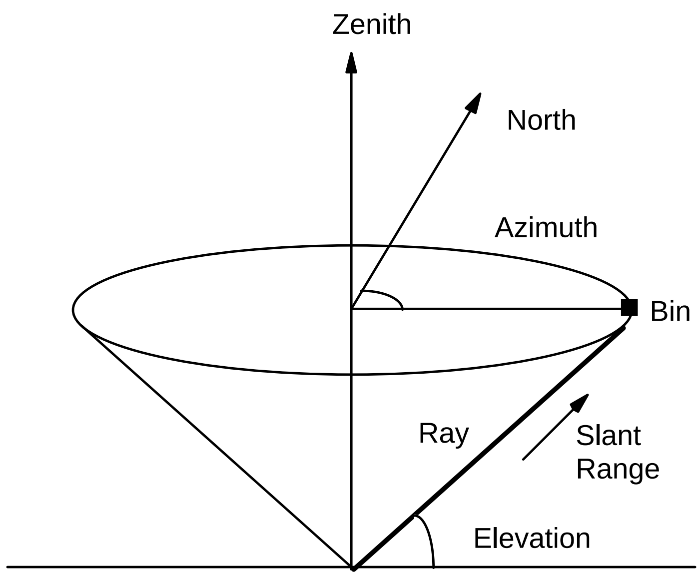


Figure 7.1-1
Schematic Showing the Geometry of a Radar Bin.

7.2 DESIGN CONSIDERATIONS

This section describes the design considerations that were taken into account while constructing the Level-1B and Level-1C formats. These formats for ground validation products were designed in consultation with Dr. Robert Houze (the GV Team Leader) and Mr. David Wolff of the TRMM Office. Following direction from these sources, the Doppler Radar Data Exchange (DORADE) format developed by the National Center for Atmospheric Research (NCAR) has been used as a model. The DORADE fields used to develop this file format are outlined in the

DORADE specifications dated October 1994, available from NCAR. While the data fields in this file format have been obtained from the DORADE conventions, the file format itself is HDF. This has lead to a small number of unavoidable deviations from the DORADE convention, which is primarily a tape format. This section points out and explains these deviations and illustrates the motivations behind them.

The goal was to accommodate the HDF format while adhering to DORADE conventions whenever possible. Ideally each DORADE block would be mapped to a single HDF object. However one of the constraints of the HDF format is that performance suffers when the number of objects in the HDF file is large. Therefore, the number of HDF objects has been minimized. Table 7.2-1 gives an overview of DORADE block names and their HDF counterparts along with the type of structure used for each. Note that due to the constraints on the type of variables in SDS arrays the Ray Info Block has been separated into two HDF objects. This reduces the total number of HDF objects since the ray information for all rays in a VOS are consolidated into two SDS arrays.

DORADE contains two fields at the beginning of each block, a code identifier which denotes the beginning of a block and a field for the length of a block. This is desirable when the data are read sequentially from tape. However, this is not needed in HDF and if included, would increase the number of objects since the tags and lengths are of different data types. Therefore, the first two entries of every DORADE block do not appear in the HDF structures. All other fields in the HDF objects appear as they do in the appropriate DORADE block. Since the size of many objects is variable, the Toolkit will provide a routine to get information on the sizes of objects in the HDF file.

Table 7.2-1
Names of DORADE Blocks and Corresponding HDF Objects

DORADE Block	**DORADE-TRMM_GV HDF Object** Code identifier and block length not included	**Structure**
Comment Block	Comment	Vdata Table
Volume Descriptor	Volume Descriptor	Vdata Table
Radar Descriptor	Radar Descriptor	Vdata Table
Correction Factor Descriptor	Correction Factor Descriptor	Vdata Table
Cell Range Vector	Cell Range Vector	Vdata Table
Sweep Info Block	Sweep Info	Vdata Table
Platform Info Block	Platform Info	SDS Array
Ray Info Block	Ray Info_Integer	SDS Array
	Ray Info_Float	SDS Array
Parameter Descriptor	Parameter Descriptor	Vdata Table
Parameter Data Block	Parameter Data	SDS Array

7.3 LEVEL 1B AND 1C

This section describes the file format which is valid for both Level-1B and Level-1C products. Level-1B contains raw radar data while Level-1C contains range truncated reflectivity and differential reflectivity and quality control masks for both. The only difference between Level-1B and Level-1C formats is the number and type of parameters. Level-1B parameters will include reflectivity (thresholded at -15dBZ), mean velocity and differential reflectivity when available. Level-1C will include reflectivity and differential reflectivity from Level-1B with the addition of a Quality Control Mask for each parameter. Data will be truncated at 230km (slant range) for Level-1B and 200km (slant range) for Level-1C. The Level-1C Quality Control Mask will consist of values from -99 to 99, with -99 indicating a deletion and 99 indicating that the point needs no correction. Values from -10 to +10 in the Quality Control Mask are corrections to the data and should be mathematically added to the corresponding data value. No other values are valid.

Table 7.3-1 lists the names, descriptions, units and data size for each parameter in Level-1 GV products. These parameter names will be entered in the Parameter Name field of the Parameter Descriptor. Additional information can be given in the Parameter Description field (e.g., “Reflectivity” for Z).

Table 7.3-1
Parameters in GV Level-1 Products

Description	Name	Units	Data Size	Product Level
Reflectivity (Z)	Z	dBZ	2-bytes	1B, 1C
Differential Reflectivity (Z_{DR})	ZDR	dB	2-bytes	1B, 1C
Mean Velocity (V)	V	m/s	2-bytes	1B
Quality Control Mask for Z	QCMZ	dBZ	1-bytes	1C
Quality Control Mask for Z_{DR}	QCMZDR	dB	1-bytes	1C

7.3.1 Structure

Figure 7.3.1-1 shows the structure of the GV Level-1B and Level-1C products in terms of the component objects and their sizes. Note that the Vgroups are repeated; e.g. VOS is repeated nvos times per granule, Sensor is repeated nsensor times per VOS and Parameter is repeated nparm times per Sensor.

The GV granule size for Level-1 is 1 hour. Level-1B products contain all VOSs from the raw radar tape. The number of VOSs in a granule at Level-1B depends on the radar type (see Table 7.1-3). At Level-1C, volume scans will be kept every 30 minutes, for 2 VOS per granule, except when the satellite passes over a GV site. Every VOS within +/- 30 minutes of a satellite overpass with be retained at Level-1C. Therefore, the number of VOSs in a granule at Level-1C can range from 2 to 12. The former number applies if no satellite overpass occurs and the latter if there is an overpass of the Israeli radar in the middle of a granule.

The relevant variables which contain sizing information can be found at the locations specified below.

- nvos - Number of volume scans in granule. Provided in PS Metadata.
- nsensor - Number of sensors in a volume scan. Provided in Volume Descriptor.
- nparm - Number of parameters in a volume scan. Provided in Radar Descriptor.
- nsweep - Number of sweeps in a volume scan. Obtained from dimensions of Sweep Info
- nray - Number of rays in a sweep. Provided in Sweep Info.
- ncell - Number of cells in a ray. Obtained from Cell Range Vector.

Typical values of these variables at Level-1B for a NEXRAD system are:

nvos = 10
nsensor = 1
nparm = 2
nsweep = 14
nray = 375
ncell = 230

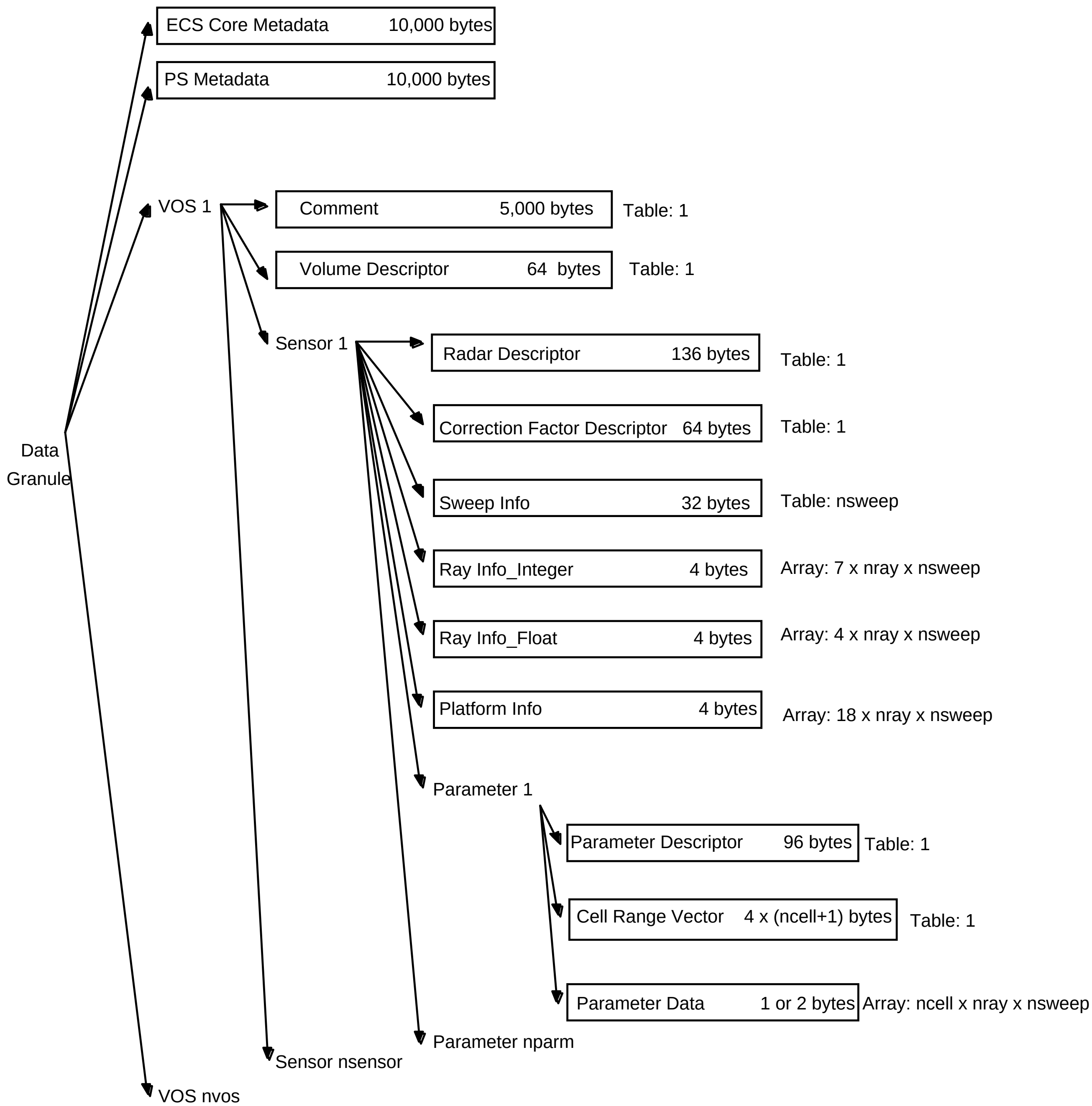


Figure 7.3.1-1
Ground Validation Level-1 Structure

At Level-1C, typical values for a NEXRAD system (no satellite overpass) are:

nvos = 2
nsensor = 1
nparm = 2
nsweep = 14
nray = 375
ncell = 200

Note that these values vary with the radar and will also vary in time for a given radar.

7.3.2 Contents

ECS Core Metadata (Attribute, 10,000 byte character):
ECS Core Metadata are those metadata defined by ECS.
See ICS Volume 6.

PS Metadata (Attribute, 10,000 byte character):
Product Specific (PS) Metadata are metadata defined by and specific to TSDIS.
See ICS Volume 6.

Comment (Vdata Table, 5,000 bytes character):
This can contain any information which is specific to the current volume scan. This information can include, for example, descriptions of staggered pulse repetition rates, unconventional scan strategies or detailed antenna polarization information.

Volume Descriptor (Vdata Table, record size 64 bytes, 1 record):
This contains information on when the data for this volume scan was obtained and when this file was produced. The following table lists the fields contained in the Volume Descriptor.

Name	Format	Description
Version Number	2-byte integer	Version number of DORADE specifications used. Currently 1.0
Volume Number	2-byte integer	Number of this volume scan in granule
Size of Data Record	4-byte integer	The maximum size of a DORADE data record in this VOS: 2bytes x max(ncell).
Project Name	20-byte char	Project name: 20 ASCII characters e.g. TRMM_GV
Date -- Year	2-byte integer	Year of the beginning of this volume scan. (UTC) e.g. 1995
Date -- Month	2-byte integer	Month of the beginning of this volume scan. (UTC) e.g. 8
Date -- Day	2-byte integer	Day of the beginning of this volume scan. (UTC) e.g. 23
Time -- Hour	2-byte integer	Hour of the beginning of this volume scan. (UTC) e.g. 16
Time -- Minute	2-byte integer	Minute of the beginning of this volume scan. (UTC) e.g. 35
Time -- Second	2-byte integer	Second of the beginning of this volume scan. (UTC) e.g. 20
Flight Number for Airborne Radar or IOP Number for Ground Radars	8-byte char	Flight number or IOP (Intense Observation Period) number. 8 ASCII characters.

Generation Facility Name	8-byte char	Name of the data processing facility that generated this volume. 8 ASCII characters e.g. TSDIS.
Generation date -- Year	2-byte integer	Year when this volume was generated. (UTC)
Generation date -- Month	2-byte integer	Month when this volume was generated. (UTC)
Generation date -- Day	2-byte integer	Day when this volume was generated. (UTC)
Number of Sensor Descriptors	2-byte integer	Number of sensor descriptors that are in this particular volume scan.

Radar Descriptor (Vdata Table, record size 136 bytes, 1 record):
Entries in this object include radar/antenna parameters such as radar name, scan mode, frequency and antenna gain. The following table defines all entries in the Radar Descriptor.

Name	Format	Description
Radar Name	8-byte character	Radar name, 8 ASCII characters
Radar Constant	4-byte float	Radar constant (dB). Used in radar equation to convert received power (P) to reflectivity (Z) for a given range (r). Defined here as $Z = P*C*r^2$ (linear)
Nominal Peak Power	4-byte float	Nominal peak power of transmitter (kW)
Nominal Noise Power	4-byte float	Nominal noise power (dBm)
Receiver Gain	4-byte float	Receiver gain (dB)
Antenna Gain	4-byte float	Antenna gain (dB). Ratio of power per unit area along beam axis to that of isotropic radiator at same point.
Radar System Gain	4-byte float	Radar system gain (dB)
Horizontal Beam Width	4-byte float	3 dB one-way beam width along horizontal axis (deg)
Vertical Beam Width	4-byte float	3 dB one-way beam width along vertical axis (deg)
Radar Type	2-byte integer	Radar type: 0 - Ground 1 - Airborne fore 2 - Airborne aft 3 - Airborne tail 4 - Airborne lower fuselage 5 - Shipborne 6 - Not defined 7 - Satellite
Scan Mode	2-byte integer	Scan Mode of the Radar: 0 -- Calibration 1 -- PPI (Constant Elevation) 2 -- Coplane 3 -- RHI (Constant Azimuth) 4 -- Vertical pointing 5 -- Target (Stationary) 6 -- Manual 7 -- Idle (out of control) 8 -- Surveillance 9 -- Vertical sweep (Aircraft only, rotation axis parallels the fuselage)
Nominal Scan Rate	4-byte float	Nominal scan rate (deg/sec). The meaning of this and the following two angles depends on the scan mode specified above

Name	Format	Description
Nominal start angle	4-byte float	Nominal start angle (deg)
Nominal stop angle	4-byte float	Nominal stop angle (deg)
Number of Parameter Descriptors	2-byte integer	Total number of parameter descriptors for this particular radar.
Number of Descriptors	2-byte integer	Total number of descriptors, including parameter descriptors for this radar.
Data Compression	2-byte integer	Data compression in use: 0 - No compression 1 - Data compressed Should always be 0, compression handled by HDF.
Data Reduction Algorithm	2-byte integer	Data reduction algorithm in use: 0 -- No Reduction 1 -- Data recorded between two rotation angles 2 -- Data recorded between two concentric circles 3 -- Data recorded between two altitudes 4 -- Other type of data reduction
Data Reduction Specific Parameter #1	4-byte float	Data reduction specific parameter #1: 1 -- Smallest Positive Angle (deg) 2 -- Inner Circle Diameter (km) 3 -- Minimum Altitude (km) 4 -- **TBD** if type defined
Data Reduction Specific Parameter #2	4-byte float	Data reduction specific parameter #2: 1 -- Largest Positive Angle (deg) 2 -- Outer Circle Diameter (km) 3 -- Maximum Altitude (km) 4 -- **TBD** if type defined
Radar Longitude	4-byte float	Radar longitude (deg). For airborne radar only this should be airport longitude.
Radar Latitude	4-byte float	Radar latitude (deg). For airborne radar only this should be airport latitude.
Radar altitude above mean sea level	4-byte float	Radar altitude above mean sea level (km). For airborne radar only this should be airport altitude.
Effective unambiguous velocity	4-byte float	Effective unambiguous velocity (m/s). Determined by inter-pulse period and frequency
Effective unambiguous range	4-byte float	Effective unambiguous range (km). Determined by inter-pulse period and frequency
Number of Transmitted Frequencies	2-byte integer	Number of different frequencies transmitted.
Number of Inter-Pulse Periods Transmitted	2-byte integer	Number of different inter-pulse periods (IPP) transmitted.
Frequency #1	4-byte float	Frequency #1 (GHz) Frequency of transmitted microwave radiation. Determines wavelength.
Frequency #2	4-byte float	Frequency #2 (GHz). See Frequency #1
Frequency #3	4-byte float	Frequency #3 (GHz). See Frequency #1
Frequency #4	4-byte float	Frequency #4 (GHz). See Frequency #1
Frequency #5	4-byte float	Frequency #5 (GHz). See Frequency #1
Inter-Pulse Period #1	4-byte float	Inter-pulse period #1 (msec). Period between successive transmitted pulses, inverse of pulse repetition frequency
Inter-Pulse Period #2	4-byte float	Inter-pulse period #2 (msec). See Inter-pulse period #1
Inter-Pulse Period #3	4-byte float	Inter-pulse period #3 (msec). See Inter-pulse period #1

Name	Format	Description
Inter-Pulse Period #4	4-byte float	Inter-pulse period #4 (msec). See Inter-pulse period #1
Inter-Pulse Period #5	4-byte float	Inter-pulse period #5 (msec). See Inter-pulse period #1

Correction Factor Descriptor (Vdata Table, record size 64 bytes, 1 record):
This object contains correction information that is to be mathematically added to the appropriate field. The following table lists the fields found in the Correction object.

Name	Format	Description
Correction for Azimuth	4-byte float	Correction for azimuth. This number is added to the azimuth angle (deg)
Correction for Elevation	4-byte float	Correction for elevation. This number is added to the elevation angle. (deg)
Correction for Range Delay	4-byte float	Correction for range delay. This number is added to the range delay. (m)
Correction for Radar Longitude	4-byte float	Correction for radar longitude. This number is added to the radar longitude. (deg)
Correction for Radar Latitude	4-byte float	Correction for radar latitude. This number is added to the radar latitude. (deg)
Correction for Radar Pressure Altitude	4-byte float	Correction for radar altitude pressure, msl. This number is added to the radar altitude pressure. (km)
Correction for Radar Altitude Above Ground Level	4-byte float	Correction for radar altitude above ground level, agl. This number is added to the radar altitude. (km)
Correction for Radar Platform Ground Speed East-West	4-byte float	Correction for radar platform ground speed East-West. This number is added to the radar platform ground speed East-West. (m/s)
Correction for Radar Platform Ground Speed North-South	4-byte float	Correction for radar platform ground speed North-South. This number is added to the radar platform ground speed North-South. (m/s)
Correction for Radar Platform Vertical Velocity	4-byte float	Correction for radar platform vertical velocity. This number is added to radar platform vertical velocity. (m/s)
Correction for Radar Platform Heading	4-byte float	Correction for radar platform heading. This number is added to the radar platform heading. (deg)
Correction for Radar Platform Roll	4-byte float	Correction for radar platform roll. This number is added to the radar platform roll. (deg)
Correction for Radar Platform Pitch	4-byte float	Correction for radar platform pitch. This number is added to the radar platform pitch. (deg)
Correction for Radar Platform Drift	4-byte float	Correction for radar platform drift. This number is added to the radar platform drift. (deg)
Correction for Radar Rotation Angle	4-byte float	Correction for radar rotation angle. This number is added to the radar rotation angle. (deg)
Correction for Radar Tilt Angle	4-byte float	Correction for radar tilt angle. This number is added to the radar tilt angle. (deg)

Sweep Info (Vdata Table, record size 32 bytes, nsweep records):
This object contains information specific to a sweep. The record is repeated nsweep times in a VOS. The table below lists all fields in the Sweep Info object.

Name	Format	Description
Radar Name	8-byte character	Name of radar. 8 ASCII characters. Note: as in DORADE, this field is repeated here.
Sweep Number	4-byte integer	Sweep number of this volume scan. The first sweep in volume scan is sweep 1.
Number of Rays in Sweep	4-byte integer	Number of rays in this sweep.
True Start Angle	4-byte float	Angle of instantaneous field of view at start of sweep (deg).
True Stop Angle	4-byte float	Angle of instantaneous field of view at end of sweep (deg).
Fixed Angle	4-byte float	The constant angle of this sweep (deg). PPI: angle is elevation. RHI: angle is azimuth. etc.
Filter Flag	4-byte integer	Filter flag: 0 -- No filtering 1 -- Filter in use (description of filter placed in comment block)

Ray Info_Integer (SDS, array size 7 x nray x nsweep, 4-byte integers):
This array contains information on the current ray which can be represented as integer.
The structure of the first vector is repeated for each ray in the sweep. The following table lists each unique entry in the array.

Entry	Name	Description
1	Ray Sweep Number	Number of the sweep that contains this ray.
2	Julian Day	Julian Day for this ray.
3	Hour	Hour of the day for this ray. UTC
4	Minute	Minutes for this ray.
5	Second	Seconds for this ray.
6	Millisecond	Milliseconds for this ray.
7	Ray Status	Status of current ray: 0 -- Normal 1 -- Transition (antenna repositioning) 2 -- Bad 3 -- Questionable

Ray Info_Float (SDS, array size 4 x nray x nsweep, 4-byte float):
This array contains information on the current ray which can be represented as floating point. The structure of the first vector is repeated for each ray in the sweep. The following table lists each unique entry in the array. Figures referenced appear in the DORADE specifications document dated Oct. 1994.

Entry	Name	Description
1	Azimuth Angle	Azimuth angle for this ray (deg). See DORADE specification Figure 9 for definition when platform is moving.
2	Elevation Angle	Elevation angle for this ray (deg). See DORADE specification Figure 9 for definition when platform is moving.

3	Peak Transmitted Power	Average peak transmitted power for this ray (kw).
4	Radar True Scan Rate	True scan rate of radar for this ray (deg/s)

Platform Info (SDS, array size 18 x nray x nsweep, 4-byte float):
One complete vector of entries represents the platform information for one ray. This structure is repeated for each ray in a sweep. Each vector has a one to one correspondence with a vector in the Ray Info objects. Figures referenced below are included at the end of this section. The figures are taken from the DORADE specifications document dated Oct. 1994. Note that TSDIS Ground Validation products will not use this object, since products are generated for stationary radars only. The table below lists all entries in the Platform Info block.

Entry	Name	Description
1	Radar Longitude	Radar longitude (deg). East is positive. West is negative. -180 to +180
2	Radar Latitude	Radar latitude (deg). North is positive. South is negative. -90 to +90
3	Radar Pressure Altitude	Radar pressure altitude, msl (km)
4	Radar Altitude Above Ground Level	Radar altitude above ground level, agl (km)
5	Platform Ground Speed (East-West)	Platform ground speed along East - West (m/s)
6	Platform Ground Speed (North-South)	Platform ground speed along North - South (m/s)
7	Platform Vertical Velocity	Platform vertical velocity (m/s) Positive is up, Negative is down
8	Platform Heading	Platform heading (deg) See Figure 7.3.2-3.
9	Platform Roll	Platform roll (deg) See Figure 7.3.2-1.
10	Platform Pitch	Platform pitch (deg) See Figure 7.3.2-2.
11	Platform Drift	Platform drift (deg) See Figure 7.3.2-3.
12	Radar Rotation Angle	Radar rotation angle (deg) See Figure 7.3.2-4
13	Radar Tilt Angle	Radar tilt angle (deg) See Figure 7.3.2-5
14	Horizontal Wind Speed at Radar (East-West)	Horizontal wind speed at radar along East-West (m/s)
15	Horizontal Wind Speed at Radar (North-South)	Horizontal wind speed at radar along North-South (m/s)
16	Vertical Wind Speed at Radar	Vertical wind speed at radar (m/s) Positive is up, Negative is down
17	Heading Change Rate	Heading change rate (deg/s)
18	Pitch Change Rate	Pitch change rate (deg/s)

Parameter Descriptor (Vdata Table, record size 96 bytes, 1 record):
This Vdata table contains information unique to a given parameter. This object is repeated for each parameter in this volume scan. Each parameter name can be described in 8 ASCII characters. The following table lists the entries in the Parameter Descriptor.

Name	Format	Description
Name of Parameter	8-byte char	Name of this parameter. 8 ASCII characters.
Description of Parameter	40-byte char	A description of this parameter. 40 ASCII characters.
Units of Parameter	8-byte char	Units for this parameter. 8 ASCII characters.
Inter-Pulse Periods Used	2-byte integer	Bit 0 set to 1 indicates IPP #1 was used. Bit 1 set to 1 indicates IPP #2 was used. Bit 2 set to 1 indicates IPP #3 was used. Bit 3 set to 1 indicates IPP #4 was used. Bit 4 set to 1 indicates IPP #5 was used.
Transmitted Frequencies Used	2-byte integer	Bit 0 set to 1 indicates frequency #1 was used. Bit 1 set to 1 indicates frequency #2 was used. Bit 2 set to 1 indicates frequency #3 was used. Bit 3 set to 1 indicates frequency #4 was used. Bit 4 set to 1 indicates frequency #5 was used.
Receiver Bandwidth	4-byte float	Receiver bandwidth (MHz)
Pulse Width	2-byte integer	Pulse width (length) of transmitted wave (m)
Polarization of Transmitted Wave(s)	2-byte integer	Polarization of transmitting antenna(s) used for this parameter: 0 -- Horizontal 1 -- Vertical 2 -- Circular, Right-handed 3 -- Elliptical (specify in comment block) 4 -- Circular, Left-handed 5 -- Dual Polarization Dual polarization indicates that two transmitted waves of different polarization were used to measure this parameter. The polarizations used should be implicit in the parameter description, e.g. Differential reflectivity (Z_{DR}). Any needed clarifications should appear in the comment block for this VOS.
Number of Samples	2-byte integer	Number of samples used in a single dwell time, e.g. many samples may be averaged to produce an average power for a single cell.
Parameter Data Type	2-byte integer	Data type of parameter: 1 -- 8 bit integer 2 -- 16 bit integer 3 -- 32 bit integer 4 -- floating point
Threshold Field	8-byte char	Name of threshold value. 8 ASCII characters. This is the name of the threshold parameter that was used to threshold these data. Note: This can and often is different from the parameter in this descriptor. For example; velocity can be thresholded by power values.
Threshold Value	4-byte float	Units depend on threshold field above. The value of the parameter was set to the Deleted or Missing Data Flag (below) when the threshold parameter described above takes on the threshold value or below.
Scale Factor	4-byte float	Scale factor to be used in obtaining meteorological value from data, see offset factor.
Offset Factor	4-byte float	Offset factor to be used in obtaining meteorological value from data. meteorological value = (recorded value-offset factor)/scale factor
Deleted or Missing Data Flag	4-byte integer	Flag for missing or deleted data , from TSDIS specs: -99 for 1 byte integer -9999 for 2 byte integer -9999 for 4 byte integer -9999.9 for float

Cell Range Vector (Vdata, record size 4 x (ncell + 1), 1 record):
This contains information on the distance in meters (m) from the radar to the center of a cell for a single parameter. The first entry contains the number of cells in this vector. The remaining entries contain the distance from the radar to cell n. Since the number of cells and the distances to a cell may be different for each parameter, this vector is repeated for each parameter. The table below lists the entries in the Cell Range Vector.

Name	Format	Description
Number of Cells	4-byte integer	Number of cells in this cell vector
Distance to cell 1	4-byte float	Distance from radar to center of cell 1 (m)
.	.	.
Distance to cell n	4-byte float	Distance from radar to center of cell n (m)

Parameter Data (SDS, array size ncell x nray x nsweep, 1-byte or 2-byte integer):
This array contains all the data for a single parameter for a single volume scan. This structure is repeated for each parameter. The type of the parameter is specified in the Parameter Descriptor, i.e. 1-byte integer or 2-byte integer. The possible parameters are listed in Table 7.3-1. Currently the data sizes for GV radar data do not include 4-byte integer or floating point values.

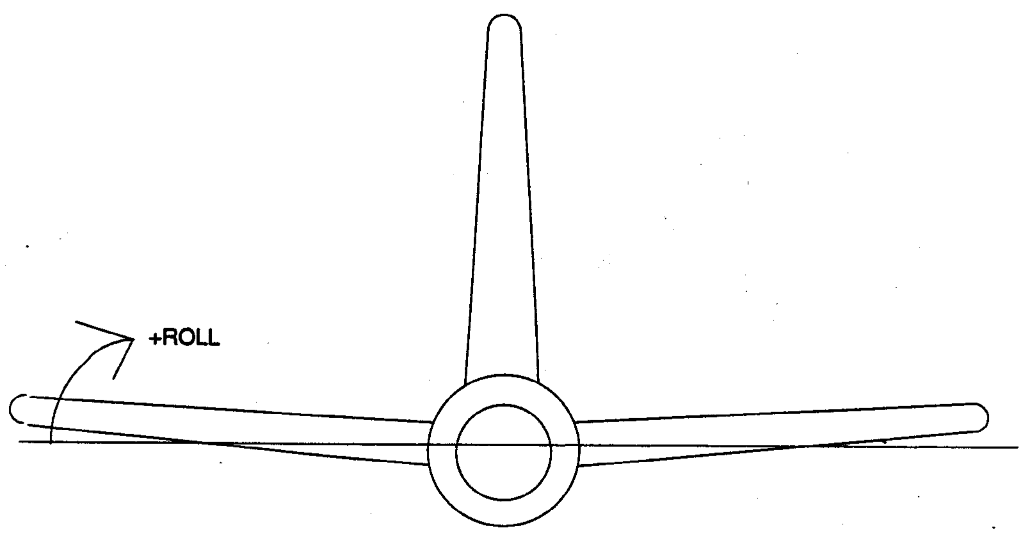


Figure 7.3.2-1
ROLL: Zero is Horizontal, Left Wing Up is Positive Looking Forward
Note: This figure appears as Figure 3 in the DORADE specifications document.

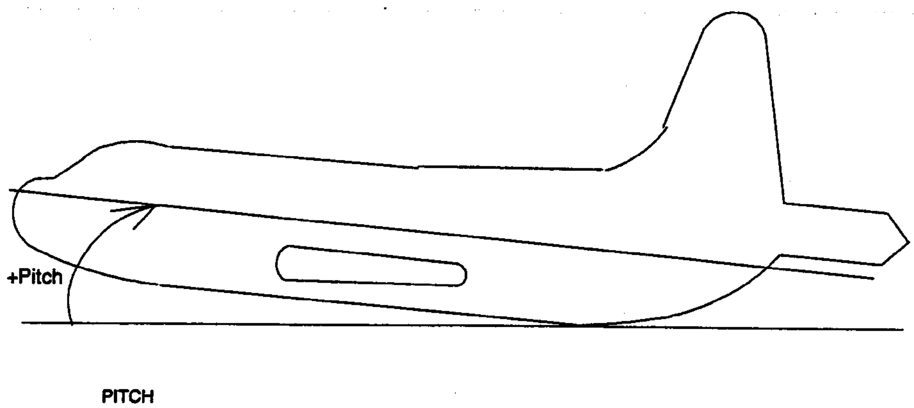


Figure 7.3.2-2
PITCH: Horizontal is Zero, Nose Up is Positive
Note: This figure appears as Figure 4 in the DORADE specifications document.

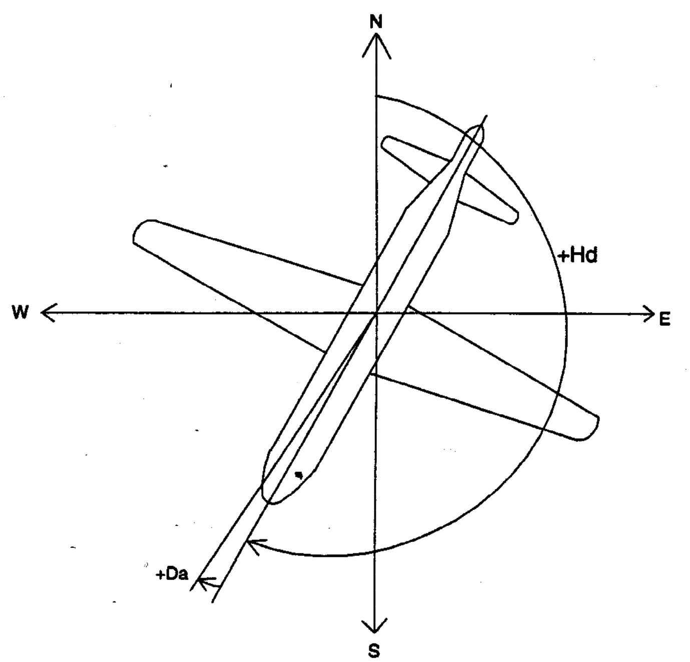


Figure 7.3.2-3

HEADING and DRIFT: Zero heading is True North, Positive is Clockwise While Looking Down. Zero drift is equal to heading, positive drift is aircraft's motion vector more clockwise than heading. Note: This figure appears as Figure 5 in the DORADE specifications document..

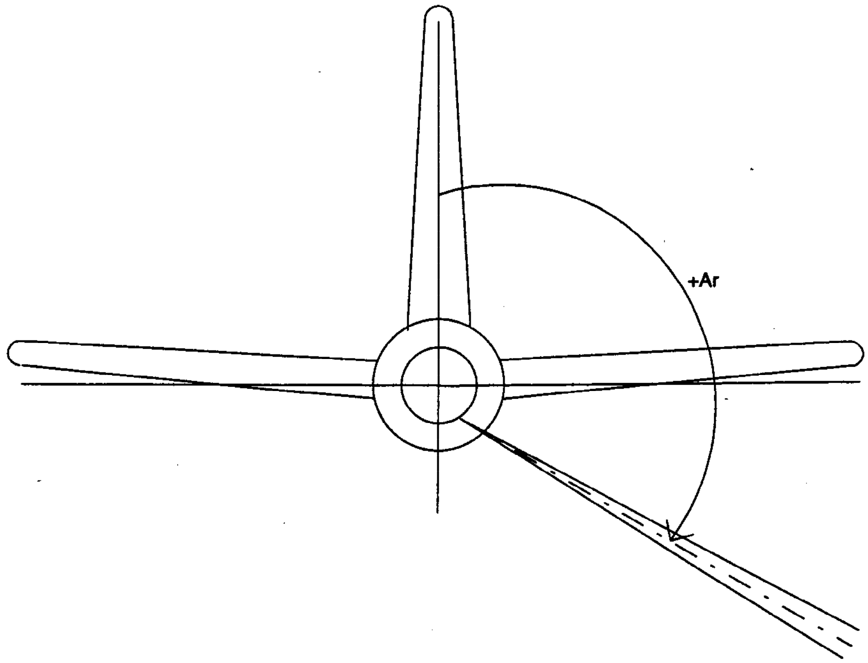


Figure 7.3.2-4
ROTATION ANGLE: Angle Between the Radar Beam and the Vertical Axis of the Aircraft. Zero is along vertical stabilizer, Positive is Clockwise Looking Forward. Note: This figure appears as Figure 7 in the DORADE specifications document..

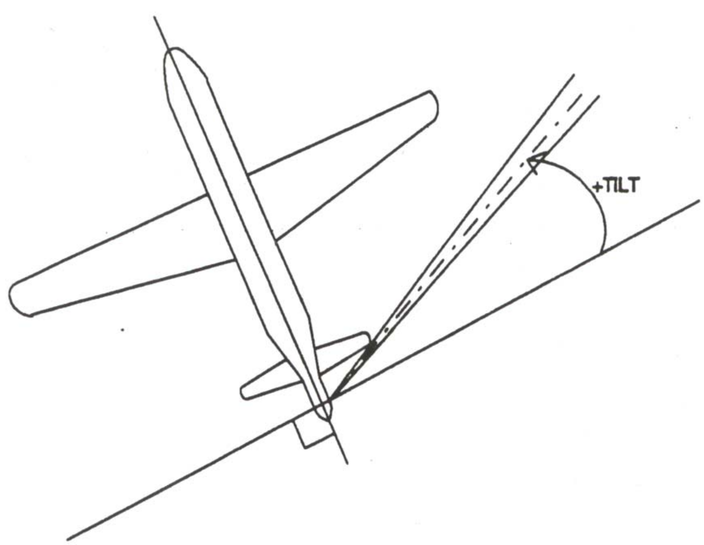


Figure 7.3.2-5
TILT: Angle Between Radar Beam
(When it is In a Plane Containing the Longitudinal Axis of the Aircraft) and a Line Perpendicular to the Longitudinal Axis. Zero is Perpendicular to Longitudinal Axis, Positive is Towards Nose of Aircraft. Note: This figure appears as Figure 8 in the DORADE specifications document.

8. ISSUES

1. Ground Stations / Ground Instruments are not represented in the current ECS Sources object class. The Source Short Name in the list above should be tied to a Ground Instrument for GV granules and there should be an equivalent for Satellite Short Name to indicate the ground site/radar name. ECS now includes elements to represent ground radar and ground platforms. Issue **closed**. TSDIS will provide a list of Satellite Short Names to ECS.

2. Issue **closed**.

3. TSDIS would like to set up pre-defined collections in ECS to contain TRMM granules. The collections would be defined by product type and grouped under higher-level collections identifying the instrument and satellite that produced the data. Given these pre-defined collections, we would prefer not to provide collection information on each granule such as: Discipline Keyword, Geophysical Parameter Keyword, Spatial Keyword, Temporal Keyword, and Vertical Coverage Value. Is this acceptable even though these are listed as required granule metadata in table 4-15? Issue **closed**. These Metadata were moved to Collection Metadata (not in each granule).

4. Are Keplerian elements acceptable as an Orbit Model? Yes. Issue **closed**.

5. TRMM currently produces none of the following ECS quality flags:
   - Geophysical location accuracy
   - Bias
   - Situational Bias
   - Random Error
   - Radiometric Accuracy

   Should they be added? Can we generate values for them? Do they vary on a granule by granule basis or are they constant for a given instrument? Issue **closed**. ECS has changed the quality flag to "Science Quality Flag". TSDIS supplies Science Quality Flag.

6. Reprocessing status is intended to identify future intent to reprocess a granule. What are we going to do with this field? .

7. The TRMM products are not generated by an ECS PGE. What should TRMM products put in the PGE metadata filed? There also does not seem to be any tie in the current granule metadata to indicate which Algorithm Package generated the granule. Should the granule metadata in the files include Algorithm Package Name and Algorithm Version? Issue **closed.** PGE metadata moved to Collection Metadata.

8. There are some TRMM products that are 3D. Should a Dss Altitude System Definition be included in these products to further define the vertical coverage of the data? Issue **closed**. ECS does not require this metadata.

9. The L2-3 GV products do not fit well into the geographic coordinate system which is described in terms of degree x degree resolution. Is there a way to specify km x km resolution of gridded products? Issue **closed**. These will be user defined structures.

10. If using an Orbit Model to represent spacial coverage, what value should be used for Path Number if a granule contains an entire orbit? Issue **closed**. Path Number deleted.

9. ABBREVIATIONS AND ACRONYMS

A

ACS Attitude Control System
APID Application Process ID

C

CCSDS Consultative Committee for Space Data Standards

D

DORADE Doppler Radar Data Exchange

E

ECS EOSDIS Core System
EOSDIS EOS Data and Information System

F

FORTRAN Formula Translation

G

GMT Greenwich Mean Time
GV Ground Validation

H

HDF Hierarchical Data Format

I

ID Identifier
IFOV Instantaneous Field of View
IPSDU Instrument Power Switching and Distribution Unit

M

MDULMissing Data Units List

N

NASDA National Space Development Agency
NCSA National Center for Supercomputing Applications
NEXRAD Next Generation Radar
NMC National Meteorological Center

O

ODL	Object Development Language (defined in the Planetary Data System Standards Reference)

P

PR	Precipitation Radar
PS	Product Specific

Q

QAC	Quality and Accounting Capsule

S

SDS	Scientific Data Set
SFDU	Standard Format Data Unit
SSPA	Solid State Power Amplifier

T

TBD	To Be Determined
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Measuring Mission
TSDIS	TRMM Science Data and Information System

U

UTC	Universal Time Coordinated
UTCF	Universal Time Correlation Factor

V

VIRS	Visible Infrared Scanner
VOS	Volume Scan

10. GLOSSARY

Attribute	A structure for textual information in HDF attached to an SDS or a file.
Earth Ellipsoid	An imaginary surface of the earth in the shape of an ellipsoid that coincides with the average Mean Sea Level.
Eccentricity	A quantity expressing the elliptical shape of an orbit.
Geoid	An imaginary surface of the earth that coincides with Mean Sea Level over oceans and is extended through continents.
Granule	The amount of information contained in one file (e.g., one orbit for Level-1 and Level-2 satellite data or one hour for Level-1 and Level-2 ground validation data).
Housekeeping Data	Satellite data concerning an instrument or platform (e.g., voltages, temperatures, doors open or shut, etc.)
Increment	The data element interval to which each geolocation element applies (i.e., if Stride = 2, each successive geolocation applies to every other data element).
Meridional	North-South
Metadata	Information about a data set (e.g., date recorded, source, or purpose).
Offset	The first data element to which the first geolocation element applies.
Planetary Grid Structure	An EOSDIS defined structure in HDF to store data organized in one of the planetary grids defined by EOSDIS.
Radar Grid Structure	A user defined structure in HDF to store data organized in a grid with constant distance spacing on the surface of the earth.
Radar Structure	A user defined structure in HDF to store data organized in original ground radar spherical geometry.
Scan	A sweep of a sensor on a satellite
Steradian	The unit of solid angle, abbreviated sr. The total solid angle about a point is equal to 4π steradians.
Swath Structure	An EOSDIS defined structure in HDF to store data organized by scans.
Vdata	An HDF object that is a table of records.
Vgroup	An HDF group of objects or other Vgroups.
Zonal	East-West

Appendix A
Reversibility from Level-1A to Level-0

Level-1A data are required to be "reversible to their input formats and values." The Level-1A formats in this document are simple concatenations of Level-0 packets. Figure A-1 maps Level-0 to Level-1A. Note that lines entering Level-1A Attitude cross the lines entering Instrument Housekeeping because Level-0 is sorted by time but Level-1A is sorted by data type. Figure A-1 is simplified. Not shown are elements that occur only for PR (Calibration Coefficients and IPSDU packets), QACs and MDULs, and the Level-1A SFDU header and metadata.

All the sections of the Level-1A File except the Header are copies of Level-0 packets file as well as information about decoding errors (QACs) and missing packets (MDUL). The Header contains information about the structure of the Level-1A file, start and end times, and the UTCF derived from the first ACS packet in the orbit. Since they are straight copies, all the Level-1A data are "reversible to their input formats and values."

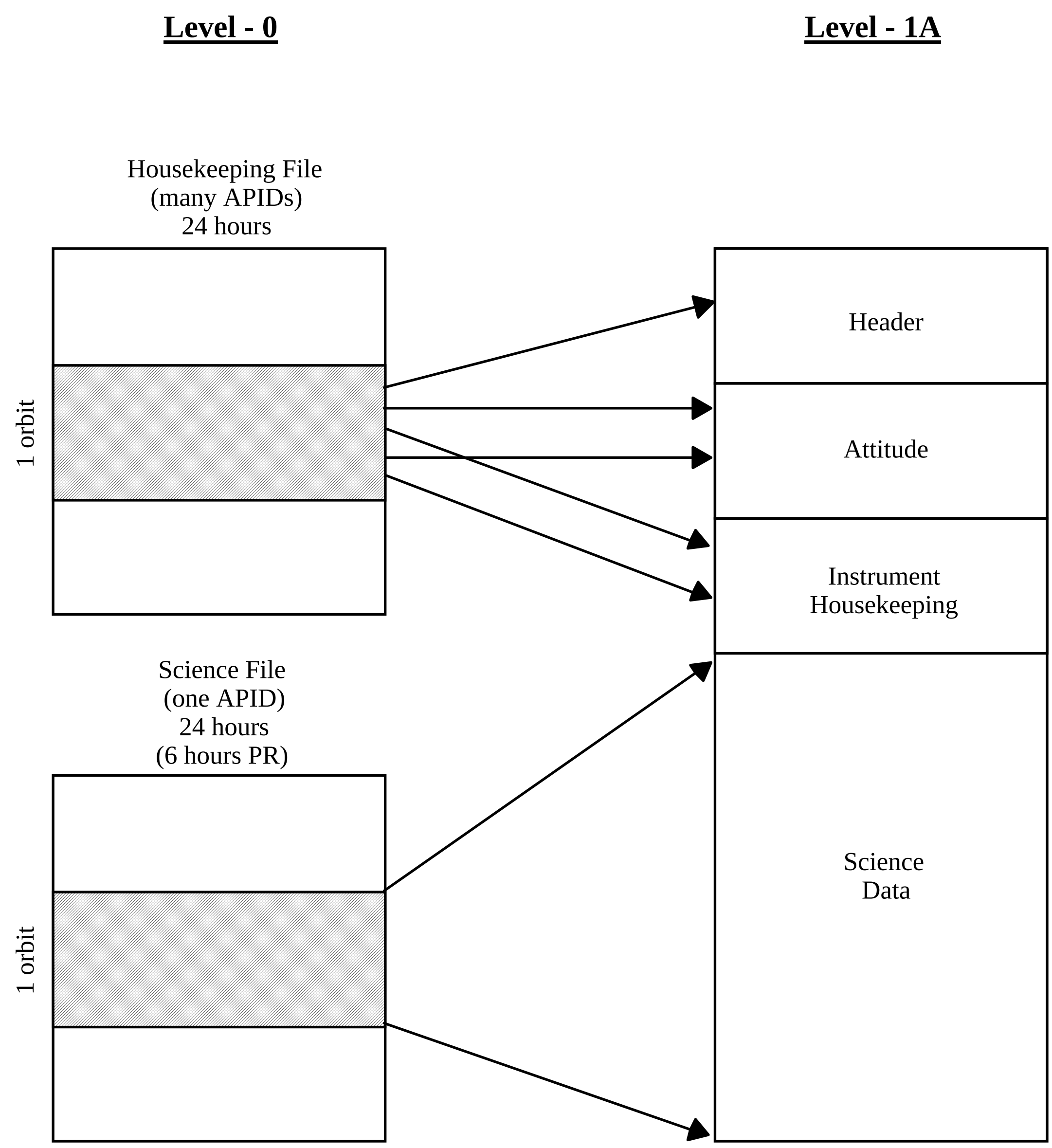


Figure A-1 Level-0 to Level-1A Mapping

Appendix B
Navigation

Navigation (Vdata, record size 88 bytes, nscan records):

Name	Format	Description
Spacecraft Geocentric Position [3]	3 X 4-byte float	The position (m) of the spacecraft in Geocentric Inertial Coordinates at the Scan mid-Time (i.e., time at the middle pixel/IFOV of the active scan period). The order of components is: x, y, and z. Geocentric Inertial Coordinates are also commonly known as Earth Centered Inertial coordinates. These coordinates will be True of Date (rather than Epoch 2000 which are also commonly used), as interpolated from the data in the Flight Dynamics Facility ephemeris files generated for TRMM.
Spacecraft Geocentric Velocity [3]	3 X 4-byte float	The velocity (ms^{-1}) of the spacecraft in Geocentric Inertial Coordinates at the Scan mid-Time. The order of components is: x, y, and z.
Spacecraft Geodetic Latitude	4-byte float	The geodedic latitude (decimal degrees) of the spacecraft at the Scan mid-Time.
Spacecraft Geodetic Longitude	4-byte float	The geodedic longitude (decimal degrees) of the spacecraft at the Scan mid-Time. Range is -180 to 179.999999.
Spacecraft Geodetic Altitude	4-byte float	The altitude (m) of the spacecraft above the Earth Ellipsoid at the Scan mid-Time.
Spacecraft Attitude [3]	3 X 4-byte float	The satellite attitude Euler angles at the Scan mid-Time. The order of the components in the file is roll, pitch, and yaw. However, the angles are computed using a 3-2-1 Euler rotation sequence representing the rotation order yaw, pitch, and roll for the rotation from Orbital Coordinates to the spacecraft body coordinates. Orbital Coordinates represent an orthogonal triad in Geocentric Inertial Coordinates where the Z-axis is toward the geocentric nadir, the Y-axis is perpendicular to the spacecraft velocity opposite the orbit normal direction, and the X-axis is approximately in the velocity direction for a near circular orbit. Note this is geocentric, not geodetic, referenced, so that pitch and roll will have twice orbital frequency components due to the onboard control system following the oblate geodetic Earth horizon. Note also that the yaw value will show an orbital frequency component relative to the Earth fixed ground track due to the Earth rotation relative to inertial coordinates.
Sensor Orientation Matrix [3 X 3]	3 X 3 X 4-byte float	The rotation matrix from the instrument coordinate frame to Geocentric Inertial Coordinates at the Scan mid-Time.
Greenwich Hour Angle	4-byte float	The rotation angle (degrees) from Geocentric Inertial Coordinates to Earth Fixed Coordinates.

Appendix C
Non-Standard Algorithms

This Appendix includes file specification for some products that are not standard TRMM products: 2N-25, 3A-12, and CSH.

C.1 2N-25 - PR Nadir only 2A-25 product

The 2N-25 product is a simple subset of the PR 2A-25 product described in ICS Vol 4. 2N-25 contains the same variables as 2A-25 but only data from the nadir ray of the PR instrument is present. All 2A-25 variables with array indices including 49 (from the 49 PR rays) are reduced to 1. The nadir ray of PR is index 24 in C notation (zero-based) and 25 in FORTRAN. See the 2A-25 documentation for an explanation of all variables.

C.2 3A-12 Monthly TMI Profiling

See Figure C - 2 Data Format Structure for 3A-12, Monthly TMI Profiling (following page)

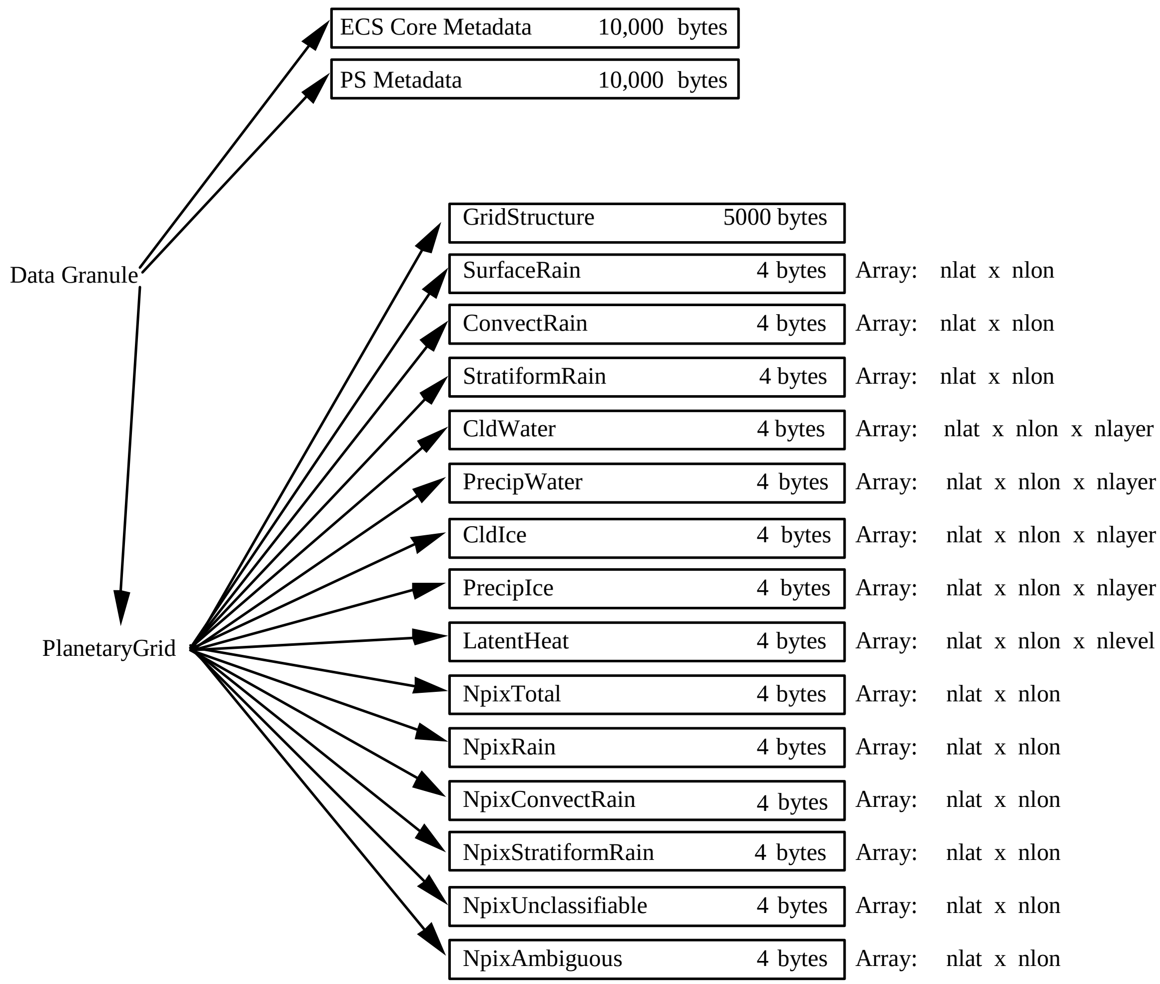


Figure C-2
Data Format Structure for 3A-12, Monthly TMI Profiling

C.2 3A-12 - Monthly TMI Profiling

3A-12, "Monthly TMI Profiling", produces global 0.5° x 0.5° monthly gridded means using 2A-12 data. Vertical hydrometeor profiles and surface rainfall means are computed. Various pixel counts are also reported. The PI is Dr. Christian Kummerow. The granule size is one month. Figure C-2 shows the structure of the 3A-12 product in terms of the component objects and sizes.

The following parameters are used in describing the formats:

nlat: the number of 0.5° grid intervals of latitude from 40° N to 40° S (160).

nlon: the number of 0.5° grid intervals of longitude from 180° W to 180° E (720).

nlayer: the number of profiling layers within one grid (14). The top of each layer is given at 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0, 8.0, 10.0, 14.0 and 18.0 km. above the surface.

nlevel: the number of latent heating levels (14). The 14 levels (different from the hydrometeor levels) are: 0 km, 1 km, 2 km, 3 km, 4 km, 5 km, 6 km, 7 km, 8 km, 9 km, 10 km, 12 km, 14 km, and 16 km..

The grid origin is at the southwest corner of the grid. Longitude indices begin at 180° W and end at 180° E. Latitude indices begin at the southern extreme and end at the northern extreme of the grid.

The contents of objects in the structure are as follows:

ECS Core Metadata (Attribute, 10,000-byte character):
ECS Core Metadata are metadata useful to most products stored at EOSDIS. See Section 1 in Volume 6 of ICS, Metadata for TRMM Products.

PS Metadata (Attribute, 10,000-byte character):
Product Specific Metadata are metadata defined by and specific to TSDIS. See Section 2 in Volume 6 of ICS, Metadata for TRMM Products.

GridStructure (Attribute, 5000-byte character):
GridStructure gives the specification of the geometry of the grids. See Section 2 in Volume 3 of ICS, Level 1 File Specifications

SurfaceRain (SDS, array size nlat x nlon, 4-byte float):
The surfaceRain is the monthly mean of the instantaneous rain rate at the surface for each grid. It ranges from 0.0 to 3000.0 mm/h.

ConvectRain (SDS, array size nlat x nlon, 4-byte float):
The convectRain is the monthly mean of the instantaneous convective rain rate at the surface for each grid. It ranges from 0.0 to 3000.0 mm/h.

StratiformRain (SDS, array size nlat x nlon, 4-byte float):
The stratiformRain is the monthly mean of the instantaneous stratiform rain rate at the surface for each grid. It ranges from 0.0 to 3000.0 mm/h.

CldWater (SDS, array size nlat x nlon x nlayer, 4-byte float):
The cldWater is the monthly mean of the cloud liquid water content for each grid at each vertical layer. It ranges from 0.0 to 10.0 gm^{-3}.

PrecipWater (SDS, array size nlat x nlon x nlayer, 4-byte float):
The precipWater is the monthly mean of the precipitation water content for each grid at each vertical layer. It ranges from 0.0 to 10.0 $gm^{-3.}$

CldIce (SDS, array size nlat x nlon x nlayer, 4-byte float):
The cldIce is the monthly mean of the cloud ice water content for each grid at each vertical layer. It ranges from 0.0 to 10.0 gm^{-3}.

PrecipIce (SDS, array size nlat x nlon x nlayer, 4-byte float):
The precipIce is the monthly mean of the precipitation ice content for each grid at each vertical layer. It ranges from 0.0 to 10.0 gm^{-3}.

LatentHeat (SDS, array size nlat x nlon x nlevel, 4-byte float):
The latentHeat is the monthly mean of the latent heating release for each grid at each vertical level. It ranges from -256.0 deg/hour to 256.0 deg/hour.

NpixTotal (SDS, array size nlat x nlon, 4-byte integer):
The npixTotal is the monthly accumulation of pixels with surface rain greater than or equal to 0.0 (mm/h) for each grid. It is used to compute the monthly means described above. It ranges from 0 to 10,000.

NpixRain (SDS, array size nlat x nlon, 4-byte integer):
The npixRain is the monthly accumulation of pixels with surface rain greater than 0.0 (mm/h) for each grid. It ranges from 0 to 10,000.

NpixConvectRain (SDS, array size nlat x nlon, 4-byte integer):
The npixConvectRain is the monthly accumulation of pixels with surface convective rain greater than 0.0 (mm/h) for each grid. It ranges from 0 to 10,000.

NpixStratiformRain (SDS, array size nlat x nlon, 4-byte integer):
The npixConvectRain is the monthly accumulation of pixels with surface stratiform rain greater than 0.0 (mm/h) for each grid. It ranges from 0 to 10,000.

NpixUnclassifiable (SDS, array size nlat x nlon, 4-byte integer):
The npixUnclassifiable is the monthly accumulation of pixels with surface rain greater than or equal to 0.0 (mm/h) that can not be classified as convective or stratiform for each grid. It ranges from 0 to 10,000.

All the means and pixel counts described above include ambiguous pixels.

NpixAmbiguous (SDS, array size nlat x nlon, 4-byte integer):
The npixAmbiguous is the monthly accumulation of pixels with surface rain greater than or equal to 0.0 (mm/h) and rain flag greater than 0 (indicates ambiguous rain) for each grid. It ranges from 0 to 10,000.

C.3 CSH - Latent Heating

CSH, "Latent Heating", produces 0.5° x 0.5° monthly latent heating profiles from surface convective rainfall rate and surface stratiform rainfall rate. The PI is Dr. Wei-Kuo Tao. The granule size is one month. The following parameters are used in describing the format:

nlath: the number of 0.5° grid intervals from 37° S to 37° N (148)

nlonh: the number of 0.5° grid intervals from 180° W to 180° E (720)

nh: the number of levels at 0.5 km, 1 km, 2 km, ..., 18 km (19)

The grid origin is at the southwest corner of the grid. Longitude indices begin at 180° W and end at 180° E. Latitude indices begin at the southern extreme and end at the northern extreme of the grid.

Figure C-3 (following page) shows the structure of the CSH product in terms of the components objects and sizes.

The contents of objects in the structure are as follows:

ECS Core .Metadata (Attribute, 10,000-byte character):
ECS Core Metadata are those metadata defined by ECS as Core metadata. See ICS Volume 6.

PS metadata.(Attribute, 10,000-byte character):
Product Specific Metadata are metadata defined by and specific to TSDIS. See ICS Volume 6.

GridStructure (Attribute, 5000-byte character):
GridStructure gives the specification of the geometry of the grids. See Section 2 in Volume 3 of ICS, Level 1 File Specifications.

LatentHeating (SDS, array size nlath x nlonh x nlayer, 4-byte float):
The latent, eddy flux and radiative heating. It ranges from -50 deg/hr to +100 deg/hr.

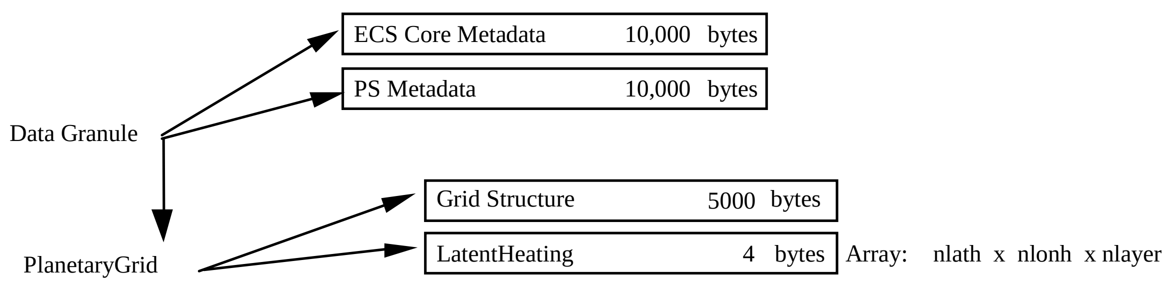


Figure C-3
Data Format Structure for CSH, Latent Heating