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820-013
Deep Space Mission System
External Interface Specification

TLM-3-27

DSN Telemetry Interface with the Advanced Composition Explorer (ACE)

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Section 1
Introduction

1.1 Purpose and Scope

This interface module defines and controls the format of telemetry data blocks that are transmitted from the Deep Space Network (DSN) to the Advanced Composition Explorer (ACE) Mission Operations Center (MOC). These blocks are used to deliver telemetry data acquired by the DSN from the ACE spacecraft. The scope of this module is limited to the format and content of the telemetry data blocks. The communications interfaces and protocols used to effect delivery from the DSN to the MOC are defined and controlled by references [1b] and [1c].

1.1.1 Applicability of This Release

This is the initial release of this module.

1.2 Revision and Control

Revisions or changes to the information herein presented may be initiated according to the procedure specified in the *Introduction* to Document 820-013.

1.3 Reference Documents

The following document are referenced in the text of this module.

1. 820-013	*Deep Space Mission System (DSMS), External Interface Specifications*
1a. OPS-6-21A	*Standard Code Assignments*
1b. GCF-10-1	*DSN CDR Electronic Access for External Users*
1c. GCF-10-21	*DSN Ground Communications System and GSFC Multi-Mission Interface for Transmission of 4800 Bit Blocks using IP Datagrams*
2. 820-019	*Interface Design Standards*
2a. DFL-1-1	*Network-Level Data Flow Standard*
3. D-5325	JPL Standard Formatted Data Unit (SFDU) Usage and Description (Issue 5, March 7, 1988)
4. GSFC-410-ACE-017	*Advanced Composition Explorer Detailed Mission Requirements* (13 July 1995)
5. 101.0-B-2	*CCSDS Recommendation for Space Data System Standards: Telemetry Channel Coding* (Issue 2, January 1987)

6. 102.0-B-2 *CCSDS Recommendation for Space Data System Standards: Packet Telemetry* (Issue 2, January 1987)

7. 620.0-B-2 *CCSDS Recommendation for Space Data System Standards: Standard Formatted Data Units—Structure and Construction Rules* (Issue 2, May 1992

8. T-49-12 *ANSI/IEEE STD 754-1985, IEEE Standard for Binary*

1.4 Terminology and Conventions

1.4.1 Terminology

Many of the terms used in this module are taken from the literature describing the Standard Formatted Data Unit (SFDU) concept (e.g., references [3] and [7]). The SFDU concept was developed by the Consultative Committee for Space Data Systems (CCSDS) to provide a standardized and internationally recognized methodology for information interchange. Because the SFDU concept evolved over time, the meaning of some terms also has evolved. The definitions provided here are intended to clarify the use of certain terms as they apply to this module:

a) A *label-value-object* (LVO) is a data structure that is comprised of a *label field* and a *value field*. The label field provides for the data structure to be self-identifying and self-delimiting. The value field contains user-defined data in any format. The LVOs themselves are made up of a sequence of octets. In this module, LVO is used in a generic sense to refer to any data structure with these attributes.

b) An LVO may be a *simple LVO* or a *compound LVO*. If the value field of the LVO contains purely user data, it is a simple LVO. If the value field of the LVO contains purely LVOs, it is a compound LVO. The value field of a compound LVO consists of a sequence of one or more LVOs, each of which can be a simple or compound LVO itself.

c) A *standard formatted data unit* (SFDU) is an LVO that conforms to a defined set of structure and construction rules, namely the specification in reference [3] or the specification in reference [7]. Unfortunately, the two specifications are slightly different, leading to two different definitions of what an SFDU is. The term *DSN telemetry SFDU* (or, more simply, *telemetry SFDU*) refers to the SFDU defined and controlled by this module. The DSN telemetry SFDU conforms to the structure and construction rules specified in reference [3]. It does not strictly conform to the internationally recognized SFDU structure and construction rules recommended by CCSDS in reference [7].

d) A *compressed header data object* (CHDO), as defined in reference [3], is an LVO. Its design is modeled on the SFDU concept, but a CHDO is not an SFDU. The CHDO derives its name from that fact that the label field of a CHDO is considerably shorter that the label field of an SFDU (four octets instead of twenty). The CHDO provides a means of structuring user data with less overhead than would be obtained if an SFDU were used. However, with respect to SFDU structure and construction rules, a CHDO (or a sequence of CHDOs) is merely user data contained in the value field of an SFDU.

e) The term *type attribute* is used to refer to the subfield(s) of an LVO label field that effect the self-identifying property of the LVO. Within the applicable domain, the type attribute is a unique reference to a description of the format and meaning of the data contained in the value field of the LVO.

f) All of the LVOs described in this module contain a *length attribute* in their label field. The length attribute is a subfield of the LVO label field; it contains the length, in octets, of the value field of the LVO. When interpreted in the context of the structure and construction rules specified in reference [3], the length attribute effects the self-delimiting property of the LVO. The use of a length attribute is not the only means by which an LVO can be self-delimiting; reference [7], for example, provides several mechanisms that do not rely on an explicit length.

g) The terms *byte* and *octet* are used interchangeably in this module to refer to an eight-bit quantity. The term *word* is used to refer to a sixteen-bit quantity.

h) The term *ASCII* refers to the American Standard Code for Information Interchange, a seven-bit code for representing letters, digits, and symbols which has been standardized by the American National Standards Institute (ANSI X3.4-1977). This code has been incorporated into the ISO code of the same nature (ISO 646-1983) which includes other symbols and alphabets. Since the ISO code is an eight-bit code, the ASCII code is embedded in an eight-bit field in which the most significant bit is set to zero. In this module, ASCII always refers to the seven-bit ASCII code embedded, as described, in an eight-bit field. When applied to a multi-octet field, it implies that each octet in the field contains an ASCII code.

i) The term *restricted ASCII (RA)* refers to the subset of ASCII consisting of the codes for the twenty-six upper-case letters ('A'–'Z') and the ten decimal digits ('0'–'9'). When applied to a multi-octet field, it implies that each octet in the field contains an RA code.

1.4.2 Conventions

The following conventions are used in this module.

a) All numbers are expressed in decimal unless explicitly indicated otherwise by means of a subscript designating another base (e.g., $4F_{16}$ for hexadecimal).

b) Although LVOs are defined as being made up of a sequence of octets, data structures in this module are illustrated as a sequence of sixteen-bit words. This convention is used for consistency with other modules in this document. Since all data structures defined in this module are an even number of octets in length, no conflict arises. Given a data structure that is N words in length, the first word in the structure is drawn in the most top justified position and is identified as "word 1." The following word is identified as "word 2" and so on, to "word N" which is drawn in the most bottom justified position. Within each word, the most significant bit is drawn in the most left justified position and is identified as "bit 1." The next most significant bit is identified as "bit 2" and so on, to "bit 16" which is drawn in the most right justified position. Any bit in a data structure is uniquely identified by specifying the word within which it occurs and its position within that word (e.g., "word 5, bit 16").

c) Data structures are divided into fields, where a field is a sequence of bits. Fields are identified by specifying the starting and ending bits of the field (e.g., "word 2, bit 9, through word 2, bit 16," identifies the right octet in word 2). For fields that cross word boundaries, bit 16 of word M is more significant than, and is immediately followed by, bit 1 of word M+1. A field may be divided into subfields in a similar manner.

d) Several conventions for expressing the length of a data structure, or a part of a data structure, are used in this module. The length attribute of an LVO is always given in octets and always refers to the length of the value field of the LVO (i.e., excluding the label field). In other contexts, a length may be given in bits, octets, or words; and the length may refer to the entire data structure or only a part of it. In all such cases, the units and meaning are explicitly stated.

e) In the data structure descriptions in this module, many fields are defined to contain a numerical value. Several different formats for expressing numbers are used, as follows:

   1) *Binary unsigned integer.* An integer number is expressed in binary, using all bits of the field as necessary. Negative quantities cannot be expressed. For an n-bit field, the range of values that can be represented is from 0 to $2^n - 1$.

   2) *Binary integer.* An integer number is expressed in binary, using two's complement notation. For an n-bit field, the range of values that can be represented is from -2^{n-1} to $2^{n-1} - 1$.

   3) *Restricted ASCII.* Each decimal digit of an integer number is expressed by its corresponding RA code. The field must be an integral number of octets in length. For multi-digit fields, the first octet of the field contains the most significant digit, the second octet contains the next most significant digit, and so on. If the number of digits is less than the number of octets in the field, leading zeroes are used to fill the field. Negative quantities cannot be expressed. In an n-octet field, the range of values that can be represented is from 0 to $10^n - 1$.

   4) *Binary-coded decimal (BCD).* Each decimal digit of an integer number is expressed in binary in a four-bit subfield. The length of the entire field, in bits, must be an integral multiple of four. For multi-digit fields, the first four-bit subfield contains the most significant digit, the second four-bit subfield contains the next most significant digit, and so on. If the number of digits is less than the number of four-bit subfields, leading zeroes are used to fill the field. Negative quantities cannot be expressed. In an n-bit field, the range of values that can be represented is from 0 to $10^{n/4} - 1$. In certain rare cases, where it is known that a digit cannot be greater than three (e.g., the hundreds digit of the day-of-year), a BCD digit is allowed to occupy a two-bit subfield, and the length of the field and the range of values are adjusted accordingly.

5) *Floating point.* A 32-bit, single precision, floating point format is used to express real numbers. Refer to section 6.3.3.2 for details.

6) *Time.* The format of the Earth Received Time (ERT) field (in the secondary header CHDO of the telemetry SFDU) is described in section 6.3.3.1. The format of other fields related to time use the basic numeric formats already described.

7) *Facility/subfacility code.* Facility/subfacility codes are written using a dotted notation (e.g., 10.14). In this usage, the dot is not a decimal point; rather, it is a separator that delimits the facility code (10 in the example) from the subfacility code (14 in the example). In a data structure, the facility and subfacility codes are contained in separate subfields (a seven-bit subfield and a four-bit subfield, respectively) and each is expressed as a binary unsigned integer.

f) For fields defined to contain a constant value, the constant value will be enclosed in single quotes (e.g., '2') if the information is expressed in ASCII or RA and not so enclosed (e.g., 2) if the information is expressed in binary.

g) Unless explicitly stated otherwise, fields defined as "reserved" are to be set to binary zero by the originator and are to be ignored by the recipient.

1.5 Abbreviations and Acronyms

Acronyms are written out in full when they first occur in the text. A complete list of acronyms is provided here for reference.

ACE	Advanced Composition Explorer
ADID	Authority and Description Identifier
ANSI	American National Standards Institute
APC	Automatic Polarity Correction
ASCII	American Standard Code for Information Interchange
ASM	Attached Sync Marker
BCD	Binary-Coded Decimal
BET	Bit Error Tolerance
BSN	Block Serial Number
BWG	Beam Waveguide
CCSDS	Consultative Committee on Space Data Systems
CDE	Cognizant Develoopment Engineer
CDR	Central Data Recorder
CHDO	Compressed Header Data Object
DDD	DSN Data Delivery

DSCC	Deep Space Communications Complex
DSN	Deep Space Network
DSS	Deep Space Station
DTF	Development and Test Facility
DTM	DSCC Telemetry Subsystem
ERT	Earth Received Time
GCS	Ground Communications System
GOS	Grade of Service
GSFC	Goddard Space Flight Center
HEF	High Efficiency
HSB	High Speed Beam Waveguide
ID	Identifier
IDR	Intermediate Data Record
IP	Internet Protocol
ISO	International Standards Organization
JPL	Jet Propulsion Laboratory
LVO	Label-Value-Object
MIL	Merritt Island
MOC	Mission Operations Center
NaN	Not a Number
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications
RA	Restricted ASCII
RCP	Receiver Channel Processor
RS	Reed Solomon
RSN	Record Sequence Number
SDB	Standard DSN Block
SFDU	Standard Formatted Data Unit
SNR	Signal-to-Noise Ratio
STD	Standard
TBD	To Be Determined
TLM	Telemetry
TMOD	Telecommunications and Mission Operations Directorate
TMS	Telecommunications and Mission Services

UTC	Universal Time Coordinated
VC	Virtual Channel
VCID	Virtual Channel Identifier
VC1	Virtual Channel One
VC2	Virtual Channel Two
VS	Virtual Stream
VSID	Virtual Stream Identifier
VS1	Virtual Stream One
VS2	Virtual Streasm Two
VS3	Virtual Stream Three

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Section 2
Functional Overview

2.1 *General Information*

Telemetry data from the ACE spacecraft are acquired by ground equipment at each Deep Space Communications Complex (DSCC) of the DSN. The RF downlink from the spacecraft is down-converted, amplified, and demodulated to produce a stream of digital symbols. The digital symbols are bit synchronized, convolutionally decoded, frame synchronized, and Reed-Solomon decoded. The resultant telemetry data stream is annotated with status and configuration information and formatted into telemetry data blocks. The telemetry data blocks are transported in real time or near real time by the DSN Ground Communication System (GCS) from the DSCC to the ACE MOC where the data are further processed and made available to ACE mission controllers, engineers, and scientists. As well as being transmitted in real time, all telemetry data blocks are also recorded by the GCS and are recoverable for 30 days from the time they were acquired.

This module defines and controls the format and content of the telemetry data blocks that are produced by the DSCC and sent to the ACE MOC in support of the ACE mission. Other documents define the space link between the spacecraft and the DSCC (reference [4]) and the communications interface between the GCS and the MOC (references [1b] and [1c]).

2.2 *Standard Formatted Data Units*

The telemetry data blocks described in this module are Standard DSN Blocks (SDB) as defined in reference [2a]. An SDB consists of a fixed-length header, a user data field, and a fixed-length trailer. For ACE, the user data field of the SDB is a fixed-length field. It is formatted in accordance with the construction rules for a Standard Formatted Data Unit (SFDU) and is referred to as a DSN telemetry SFDU. Section 1.4.1 above briefly describes the SFDU concept.

Each telemetry SFDU normally contains one frame of telemetry data and associated status and configuration information. Alternatively, the SFDU may contain a length of telemetry data bits that are not frame synchronized. A detailed description of the format and content of the telemetry SFDU is presented in section 6 of this module.

The telemetry SFDU defined in this module is based on a multimission design that has been tailored to meet the requirements of the ACE mission. Some reserved or apparently redundant fields have been retained to maintain consistency between the format described here and the formats used with other missions supported by the DSN.

Some information in the DDD header is duplicated, or essentially duplicated, in the telemetry SFDU. The intent is that all information required to interpret and process the telemetry data delivered through this interface is contained within the telemetry SFDU itself and should not require access to the DDD header. The DDD header is an internal DSN requirement on all DSN systems to ensure accountable transport between DSN facilities and correct routing to destinations outside the DSN.

2.3 *Virtual Channels and Virtual Streams*

2.3.1 Virtual Channels

Telemetry data from the ACE spacecraft are formatted into fixed-length *transfer frames* in accordance with the CCSDS recommendation on packet telemetry (reference [6]). Each transfer frame has a *transfer frame primary header* of a standard format. Among other things, the primary header contains a *virtual channel identifier*. Transfer frames with different virtual channel identifiers are interleaved onto one physical channel transmitted by the spacecraft. The time-ordered sequence of transfer frames with the same virtual channel identifier constitutes a *virtual channel*. The use of virtual channels allows logically distinct data streams to share one physical channel.

The ACE spacecraft uses two virtual channels for telemetry. Virtual channel one may contain spacecraft housekeeping, attitude, memory dump, bin dump, or science data. Virtual channel two contains playback data from the onboard recorders.

2.3.2 Virtual Streams

A *virtual stream* is a time-ordered sequence of telemetry data blocks generated by a DSN telemetry processor. All blocks in a particular virtual stream share certain characteristics, namely, the identity of the telemetry processor that generated the data block, the identity of the spacecraft from which the data contained within the block were acquired, and a *virtual stream identifier* used to distinguish logically distinct data streams generated by a single DTM telemetry processor. All parameters required to distinguish different virtual streams are contained in data fields within each telemetry data block.

A DSN telemetry processor supporting the ACE mission may generate up to three virtual streams. Virtual stream one consists exclusively of telemetry data blocks containing ACE transfer frames from virtual channel one that have been acquired by the DSN (i.e., the data were successfully frame synchronized and Reed-Solomon decoded). Virtual stream two consists exclusively of telemetry data blocks containing ACE transfer frames from virtual channel two that have been acquired by the DSN. Virtual stream three consists of the complete, raw telemetry bit stream (at the output of the DSN convolutional decoder), arbitrarily blocked into telemetry data blocks.

Virtual stream one is normally transmitted to the MOC in real time (i.e., with a transmission latency of less than ten seconds). Virtual stream two is nornally transmitted to the MOC in near real time (i.e., with a transmission latency of less than ten minutes). Virtual stream three is not normally transmitted to the MOC; however, it is recorded to allow for analysis and possible data recovery in the event of anomalous behavior.

Section 3
Environment

3.1 Hardware Characteristics and Limitations

Telemetry data blocks originate at the DSCC Telemetry Subsystem (DTM), are transported by the GCS, and are delivered to the ACE MOC. The hardware interface between the GCS and the MOC is defined and controlled by reference [1c]. The telemetry data blocks themselves are specified in a manner independent of any particular hardware implementation.

3.2 Interface Medium and Characteristics

Telemetry data blocks are transmitted from the DSCCs to the MOC via the GCS utilizing multiple communications devices and transmission media in the path. The design of the telemetry data blocks is predicated on certain assumed characteristics of the transmission path:

a) The transit delay may vary from a few seconds (real time delivery) to a few minutes (near real time delivery) to several days (playback or electronic file transfer).

b) Telemetry data block boundaries are preserved by the communications process.

c) The sequential ordering of telemetry data blocks is preserved by the communications process.

d) The GCS employs an error detecting code sufficiently sensitive that the probability of an undetected error is small enough to be ignored.

3.3 Communication Protocol

Telemetry data blocks are delivered to the ACE MOC utilizing the communications protocols defined in references [1b] and [1c].

3.4 Failure Protection, Detection, and Recovery

Reliable communications protocols will be used for all ACE telemetry data between the DSCC and the MOC, so there should be few, if any, data gaps or errors.

Telemetry data blocks are sequentially numbered to enable the detection of missing data blocks. If missing data blocks are detected (indicated by a break in the numbering sequence), the missing data may be recoverable from the GCS recording of the data, as described in section 6.5.

The detection and handling of ground data transmission errors are defined and controlled by reference [1c].

3.5 *End-of-File (or Medium) Conventions*

A sequence of telemetry data blocks will generally begin and end with a *pass* of the spacecraft, corresponding more or less to rise and set times as viewed from the DSCC. Based on mission coverage requirements and DSN scheduling constraints, the spacecraft may be tracked, and telemetry data acquired, for only a portion of the pass. This interface does not provide for indicators to mark the beginning or ending of the sequence of telemetry data blocks that corresponds to a pass. At the beginning of a tracking activity, the DSCC will be configured to acquire the spacecraft signal and begin transmission of telemetry data; at the end of the tracking activity, the DSCC will terminate telemetry data processing. Beginning and ending telemetry data blocks are not marked in any special way; the stream of telemetry data blocks simply begins and later ceases.

Section 4
Data Flow Characteristics

4.1 Operational Characteristics

At the beginning of a tracking activity, a DSCC antenna is pointed at the spacecraft and the telemetry acquisition process is started. Because the symbol synchronizer clock is always active and the convolutional decoder always generates an output, virtual stream three begins to flow as soon as the convolutional decoder is started, possibly even before carrier lock is achieved. Virtual streams one and two will not begin to flow until the frame synchronizer is in lock, Reed-Solomon decoding is successful, and a transfer frame with the corresponding virtual channel identifier is detected at the output of the Reed-Solomon decoder.

Virtual stream three flows continuously until the end of the tracking activity at a rate determined by the downlink bit rate and the output blocking factor. Virtual streams one and two continue to flow as long as telemetry lock is maintained and the corresponding virtual channels are present on the downlink. Their rate is determined by the downlink bit rate, the transfer frame length, and the interleaving of virtual channels on the downlink (which, for ACE, is a function of bit rate). The flow of data may be interrupted on occasion due to equipment failure or communications circuit outage.

It is possible in atypical circumstances for more than three virtual streams to flow simultaneously. This may happen, for example, if the ACE downlink is tracked simultaneously from two different antennas or if two telemetry processors are operated in parallel on the signal from a single antenna. In any such instance, the virtual stream identifier is always either one, two, or three; however, the different virtual streams are distinguished by the telemetry processor identifier.

The above description of telemetry data flow is from the point of view of the DSCC telemetry processor. The appearance of these flows at the MOC is further influenced by characteristics of the ground communications channel and the communications protocols employed. For example, the flow of virtual stream one may be affected by retransmissions undertaken by a reliable communications protocol. Virtual stream two may be affected by routing policy in the presence of higher priority data flows on a shared bandwidth channel. Virtual stream three will normally not be delivered to the MOC at all. Refer to reference [1c] for ground communications characteristics.

4.2 Time Span of Product

All telemetry data blocks generated by the DSCC are recorded by the GCS. The recorded data blocks are kept for 30 days to allow for data recovery if required for any reason. Data recovery methods are described in section 6.5.

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Section 5
Telemetry Characteristics

5.1 Spacecraft Telemetry Format

The format, coding, modulation and other characteristics of the telemetry data transmitted by the ACE spacecraft are specified in reference [4]. This module includes information extracted from that document.

5.2 Modulation, Bit Rates, and Modes

All telemetry data is biphase-L modulated direct on the carrier. The spacecraft may transmit at three different bit rates. The three bit rates, after Reed-Solomon encoding, are 498, 7,968, and 87,648 bits/second. Each bit rate is associated with a characteristic mode. At the two lower bit rates, only virtual channel one appears on the downlink. At the highest bit rate, virtual channels one and two are interleaved at a fixed ratio of ten VC2 frames for every one VC1 frame.

5.3 Attached Sync Marker

The telemetry data transmitted by the ACE spacecraft consists of a stream of fixed-length *transmitted codeblocks* with an *attached sync marker* (ASM) between them. A transmitted codeblock consists of a *telemetry transfer frame* and *Reed-Solomon check symbols*. The sync marker is described as attached in that it is not part of the data space protected by the Reed-Solomon code. ACE uses the CCSDS recommended sync marker which is 32 bits long and has the value $1ACFFC1D_{16}$ (refer to reference [5]).

5.4 Telemetry Coding

The ACE spacecraft encodes telemetry data using a concatenated coding scheme consisting of an inner, convolutional code and an outer, Reed-Solomon code.

ACE telemetry data are convolutionally encoded using the CCSDS recommended (K=7, R=1/2) code and the CCSDS recommended connection vector (refer to reference [5]).

ACE telemetry data are Reed-Solomon encoded in accordance with the CCSDS recommendation (reference [5]). The ACE Reed-Solomon code is characterized by the following parameters: J = 8 bits per Reed-Solomon symbol; E = 16 Reed-Solomon symbol error correction capability within a Reed-Solomon codeword; I = interleave depth of 4; Q = virtual fill of 28 Reed-Solomon symbols per codeblock; dual basis symbol representation.

5.5 Frame Length

The generic term *frame* (without a qualifier) is used in this module to refer to a contiguous length of telemetry bits consisting of an attached sync marker and a transmitted codeblock. All ACE frames are the same length. The distance from the first bit of one attached sync marker to the first bit of the next attached sync marker is 7,968 bits. The 7,968 bits are composed of a 32-bit attached sync marker, a 6,912-bit telemetry transfer frame, and 1,024 bits of Reed-Solomon check symbols. The 6,912-bit transfer frame is a 7,136-bit frame shortened by 224 bits of virtual fill.

5.6 Spacecraft ID

Associated with the ACE spacecraft are two distinct numbers, both called Aspacecraft ID.@ One of those numbers is assigned by the CCSDS and is used, for example, in the header of each transfer frame transmitted by the spacecraft. The other number is assigned by the DSN and is used, for example, in SDB and SFDU headers. The CCSDS has assigned the spacecraft ID 92 ($5C_{16}$) to ACE. The DSN has also assigned the spacecraft ID 92 ($5C_{16}$) to ACE.

Section 6
Telemetry Data Block Detailed Definition

6.1 Telemetry Data Block Structure

All ACE telemetry data are delivered by the DSN to the MOC in the form of virtual streams. Each virtual stream consists of a sequence of telemetry data blocks. Telemetry data blocks are standard DSN blocks (SDBs) as defined by reference [2a]. Each telemetry data block is divided into three sections: a DSN Data Delivery (DDD) header, a telemetry SFDU, and a DDD trailer. The physical layout of the telemetry data block is shown in Figure 6-1. The following paragraphs describe in detail the three sections of the telemetry data block.

```
          BIT
          +-----------------------------------------------+
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------|
   WORD  1|                                               |
          +-                                             -|
          ...               DDD Header                  ...
          ...               (10 words)                  ...
          +-                                             -|
        10|                                               |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        11|                                               |
          +-                                             -|
          ...             Telemetry SFDU                 ...
          ...              (548 Words)                   ...
          +-                                             -|
       558|                                               |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
       559|            DDD Trailer (1 word)               |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------+
```

Figure 6-1. Telemetry Data Block Physical Layout

6.2 DDD Header Section

Words 1 through 10 of the telemetry data block contain the DDD header; its format is illustrated in Figure 6-2. The format, general content, and use of the DDD header are defined and controlled by reference [2a]. The specific values of the fields within the DDD header and their interpretation are defined and controlled by reference [1a]. The subset of allowable values applicable to ACE telemetry data blocks is listed in Table 6-1 of this module. All fields in the DDD header are formatted as binary unsigned integers unless specifically described otherwise in Table 6-1.

```
          BIT
          +-----------------------------------------------+
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------|
   WORD 1|            Destination Assembly                |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        2|              Source Assembly                   |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        3|             Stream Description                 |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        4|                Total Length                    |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        5|             Block Serial Number                |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        6|    Protocol        |       Day-of-Year         |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        7|                    Time                        |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        8|     Time (cont'd)     |   Virtual Stream ID    |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        9|                    Year                        |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
       10|          GOS          |       Reserved         |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------+
```

Figure 6-2. DDD Header

Table 6-1. DDD Header Field Definitions

16-bit Word /Bit(s)	Name	Permitted Value(s)	Interpretation
1	<u>Destination</u>		
1/1	Reserved	0	Reserved
1 / 2 to 8 and 1 / 9 to 12	Facility/Subfacility	 12.00 12.08	Formatted as described in Section 1.4.2 Used for VS1 or VS2 to GSFC Used for VS3 to GSFC
1 / 13 to 15	Assembly	1 2 0	Used for VS1 to GSFC Used for VS2 to GSFC Used for VS3 to GSFC
1 / 16	Reserved	0	Reserved
2	<u>Source</u>		
2 / 1	Reserved	0	Reserved
2 / 2 to 8 and 2 / 9 to 12	Facility/subfacility		Identifies the master (or only) antenna used to acquire the telemetry data contained in this block; formatted as described in section 1.4.2. The contents of this list are controlled by reference [1a] and are subject to change as new antennas are added to the

16-bit Word /Bit(s)	Name	Permitted Value(s)	Interpretation
			network.
		10.02	DSS 12
		10.04	DSS 14
		10.05	DSS 15
		10.06	DSS 16
		10.08	DSS 27
		10.09	DSS 28
		10.10	DSS 25
		10.11	DSS 26
		10.14	DSS 24
		21.05	Simulated 34m STD at DTF-21
		21.06	Simulated 70m at DTF-21
		21.07	Simulated 34m HEF at DTF-21
		21.08	Simulated 26m at DTF-21
		21.14	Simulated 34m BWG at DTF-21
		40.02	DSS 42
		40.03	DSS 43
		40.05	DSS 45
		40.06	DSS 46
		40.09	64m antenna at Parkes, Australia
		40.14	DSS 34
		60.01	DSS 61
		60.03	DSS 63
		60.05	DSS 65
		60.06	DSS 66
		60.14	DSS 54
		71.02	DSS 72 at MIL-71
2 / 13 to 15	Assembly		Identifies the DTM group (within the specified facility) that created this data block.
		1	DTM Group 1
		2	DTM Group 2
		3	DTM Group 3
		4	DTM Group 4
		5	DTM Group 5
		6	DTM Group 6
		7	DTM Group 7
		0	DTM Group 8
2 / 16	Reserved	0	Reserved
3	<u>Stream Description</u>		
3 / 1 to 8	Spacecraft ID	92	ACE spacecraft telemetry, in accordance with 820-013, OPS-6-21A, Table 3-4
3 / 9 to 15	Data Type	1 2	Identifies the telemetry channel (within the specified DTM group) that created this data block. Telemetry channel 1

16-bit Word /Bit(s)	Name	Permitted Value(s)	Interpretation
			Telemetry channel 2
3 / 16	Data Nature	0 1	Real-time data Playback data (i.e., from the GCS recording)
4 / 1 to 16	Total Block Length	1118	The total length, in octets, of the telemetry data block including the DDD header, the telemetry SFDU, and the DDD trailer.
5 / 1 to 16	Block Serial Number	0 to 65535	Begins with zero; increments by one for each successive telemetry data block; wraps around from 65535 to 0. Separate sequences are maintained for each virtual stream (where a virtual stream is defined as the time-ordered sequence of all telemetry data blocks containing the same virtual stream ID, and the virtual stream ID is defined as the value of the 56-bit field formed by the concatenation of words 1, 2, 3, and bits 9-16 of word 8). Resets to zero at the beginning of each pass and whenever the DSCC operator restarts the DTM (presumably due to equipment failure or major configuration change). The BSN is provided by the originator of the telemetry data block and is not changed subsequently; e.g., a block replayed from the GCF recording retains the BSN that was assigned when the block was created.
6 / 1 to 6	Protocol	1	DDD protocol (pure SDB, not Nascom).
6 / 7 to 16	Day-of-Year	1 to 366	6 / 7 to 8 Hundreds digit 6 / 9 to 12 Tens digit 6 / 13 to 16 Units digit
7 / 1 to 16 8 / 1 to 8	Time-of-Day	0 to 8640000	UTC time-of-day of the ERT for the telemetry data contained in this block, in centiseconds past midnight. The ERT is referenced to the trailing edge of the last bit of telemetry data in the block. The ERT is also given, to a greater accuracy, in the telemetry SFDU secondary header.
8 / 9 to 16	Virtual Stream ID	1 2 64	Virtual stream one Virtual stream two Virtual stream three
9 / 1 to 16	Year	1995 to 9999	UTC year of the ERT for the telemetry data contained in this block; formatted as binary-coded decimal. 9 / 1 to 4 Thousands digit 9 / 5 to 8 Hundreds digit 9 / 9 to 12 Tens digit

16-bit Word /Bit(s)	Name	Permitted Value(s)	Interpretation
			9 / 13 to 16 Units digit
10 / 1 to 8	Grade of Service	0	Not Implemented
10 / 9 to 16	Reserved	0	Reserved

6.3 Telemetry SFDU Section

Words 11 through 558 of the telemetry data block contain a telemetry SFDU. The format and content of the telemetry SFDU are defined in the following paragraphs.

6.3.1 Telemetry SFDU Structure

As described in section 1.4.1, a DSN telemetry SFDU is an LVO that adheres to the SFDU structure and construction rules specified in reference [3]. It is comprised of an SFDU label field and a value field. Viewed in a strict sense, the telemetry SFDU is a simple SFDU in that its value field contains purely user data; i.e., the value field of the telemetry SFDU is not itself an SFDU or a sequence of SFDUs. However, the value field of the SFDU does have structure in that it contains a sequence of CHDOs, which are a form of LVO (albeit a non-standard, locally defined form). In that sense, the telemetry SFDU is a compound LVO (i.e., its value field contains purely LVOs), and its LVO structure is depicted in Figure 6.3.

```
  +----------------------------------------------------+
 L|  Telemetry SFDU                                    |
  +-+  +----------------------------------------------+|
    | L|  Header Aggregation CHDO                     ||
    |  +-+  +---------------------------------------+||
    |    | L| Primary Header CHDO                   |||
    |    |  +-+                                     |||
    |    |    V|                                    |||
    |   V|  +--------------------------------------|||
    |    | L| Secondary Header CHDO                 |||
    |    |  +-+                                     |||
   V|    |    V|                                    |||
    |  +------------------------------------------- ||
    | L|  Telemetry Data CHDO                        ||
    |  +-+                                           ||
    |    |                                           ||
    |    |                                           ||
    |   V|                                           ||
    |    |                                           ||
    |    |                                           ||
    +-----------------------------------------------+
      L = label field          V = value field
```

Figure 6-3. LVO Structure of the Telemetry SFDU

Viewed as a compound LVO, the value field of the telemetry SFDU contains two LVOs, a *header aggregation CHDO* and a *telemetry data CHDO*. The header aggregation CHDO is a compound LVO; its value field contains two simple LVOs, a *primary header CHDO* and a *secondary header*

CHDO. The header aggregation CHDO exists solely for the purpose of allowing the primary and secondary header CHDOs to be grouped together and treated as a single LVO. The value fields of the primary and secondary header CHDOs contain annotation data (identification, configuration, status, and performance parameters) that pertain to the telemetry data in the telemetry SFDU. The telemetry data CHDO is a simple LVO; its value field contains the actual received telemetry data from the spacecraft.

Figure 6-4 shows the physical layout of the telemetry SFDU. It is divided into five sections: the telemetry SFDU label, the header aggregation CHDO label, the primary header CHDO, the secondary header CHDO, and the telemetry data CHDO. Figures 6-5 through 6-9, later in this section, present the detailed format of each of these structures.

```
         BIT
         +-----------------------------------------------+
         |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
         +-----------------------------------------------|
WORD  1|                                                 |
         +-                                             -|
         ...              SFDU LABEL                    ...
         ...           (SEE FIGURE 6-5)                 ...
         +-                                             -|
     10|                                                 |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
     11|                                                 |
         +-       HEADER AGGREGATION CHDO LABEL         -|
     12|               (SEE FIGURE 6-6)                  |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
     13|                                                 |
         +-                                             -|
         ...           PRIMARY HEADER CHDO              ...
         ...           (SEE FIGURE 6-7)                 ...
         +-                                             -|
     16|                                                 |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
     17|                                                 |
         +-                                             -|
         ...         SECONDARY HEADER CHDO              ...
         ...           (SEE FIGURE 6-8)                 ...
         +-                                             -|
     48|                                                 |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
     49|                                                 |
         +-                                             -|
         ...          TELEMETRY DATA CHDO               ...
         ...           (SEE FIGURE 6-9)                 ...
         +-                                             -|
    548|                                                 |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
         +-----------------------------------------------+
```

Figure 6-4. Telemetry SFDU Physical Layout

The value field of the telemetry data CHDO contains the spacecraft telemetry data that are acquired by the DSN. The length of the value field, in octets, is given by the length attribute in the label of the telemetry data CHDO; for ACE, the length attribute is always 996. The number of actual received telemetry bits contained in that field is given by word 14 of the secondary header CHDO. If the length of the received telemetry bits is less than the length of the field, unused bits appear at the end of the field and should be ignored. In other words, the content of the value field of the telemetry data CHDO is a variable-length bit string whose length is given by word 14 in the secondary header CHDO. For ACE, the value contained in word 14 (the number of valid telemetry bits in the field) for virtual streams one and two is guaranteed always to be 7,968 (the entire field). For virtual stream three, that number typically is 7,968 (the blocking factor for a raw bit stream) but may occasionally be less (e.g., for the last telemetry SFDU generated when telemetry processing is terminated).

Depending on the virtual stream, the value field of the telemetry data CHDO may contain a length of telemetry bits which has not been frame aligned or Reed-Solomon decoded, or it may contain a VC1 or VC2 frame which has been successfully frame synchronized and Reed-Solomon decoded. Virtual stream one contains every VC1 frame successfully acquired, frame synchronized, and Reed-Solomon decoded by the DSN, once and only once and in the order received; data which cannot be frame synchronized or is not successfully Reed-Solomon decoded is not delivered in virtual stream one. Similarly for virtual stream two and VC2 frames. Virtual stream three contains every telemetry bit acquired by the DSN, once and only once and in the order received regardless of whether it can be frame synchronized or Reed-Solomon decoded and regardless of whether that same bit is also delivered as part of a frame in virtual stream one or two.

6.3.2 Telemetry SFDU Detailed Definition

The following paragraphs present the detailed definition of the DSN telemetry SFDU.

6.3.2.1 Telemetry SFDU Label

Words 1 through 10 of the telemetry SFDU contain the SFDU label field. The format and content of the SFDU label are illustrated in Figure 6-5 and defined in the following paragraphs. The concatenation of words 1, 2, 5, and 6 constitutes the type attribute of the SFDU; in CCSDS parlance, this concatenated field is known as the Authority and Description Identifier (ADID). Words 7 through 10 constitute the length attribute.

WORDS 1 AND 2

BITS

1 thru 16 — Control authority identifier; value = 'NJPL' (indicates that the data description information for this SFDU is maintained and disseminated by NASA/JPL); restricted ASCII.

```
          BIT
         +-----------------------------------------------+
         |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
         +-----------------------------------------------|
  WORD 1| CONTROL AUTHORITY IDENTIFIER = 'NJPL'          |
         +-                                             -|
        2|                                               |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        3| VERSION ID = '2'       | CLASS ID = 'Z'       |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        4| SPARE = '00'                                  |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        5| DATA DESCRIPTION IDENTIFIER = '0067'          |
         +-                                             -|
        6|                                               |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
        7| LENGTH ATTRIBUTE                              |
         +-                                             -|
        8|                                               |
         +-                                             -|
        9|                                               |
         +-                                             -|
       10|                                               |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
         +-----------------------------------------------+
```

Figure 6-5. Telemetry SFDU Label

WORD 3
BITS

1 thru 8 — SFDU label version ID; value = '2' (indicates that the length attribute field in words 7-10 is formatted as a binary unsigned integer); restricted ASCII.

9 thru 16 — SFDU class ID; value = 'Z' (indicates that this SFDU is an unclassified aggregation); restricted ASCII.

WORD 4
BITS

1 thru 16 — Reserved; value = '00'; restricted ASCII.

WORDS 5 AND 6
BITS

1 thru 16 — Data description identifier; value = '0067' (uniquely identifies the data description information held by the control authority identified in words 1 and 2 for this type of SFDU); restricted ASCII.

WORDS 7 THRU 10
BITS

1 thru 16 — Length attribute of the telemetry SFDU; value = 1076 (indicates the length, in octets, of the value field of the telemetry SFDU, words 11 through 548 in Figure 6-4); binary unsigned integer. The length of the value field of the telemetry SFDU is the sum of the total lengths of the header aggregation CHDO and the telemetry data CHDO.

6.3.2.2 Header Aggregation CHDO Label

Words 11 and 12 of the telemetry SFDU contain the header aggregation CHDO label field which is illustrated in Figure 6-6 and defined in the following paragraphs. The value field of the header aggregation CHDO is composed of the primary header CHDO and the secondary header CHDO; they are described in sections 6.3.2.3 and 6.3.2.4, respectively.

```
         BIT
         +-----------------------------------------------+
         |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
         +-----------------------------------------------|
  WORD 1| TYPE ATTRIBUTE = 1                             |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
       2| LENGTH ATTRIBUTE = 72                          |
         +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
         +-----------------------------------------------+
```

Figure 6-6. Header Aggregation CHDO Label

WORD 1
BITS

1 thru 16 — Type attribute of the header aggregation CHDO; value = 1 (indicates that this CHDO is an aggregation of header CHDOs); binary unsigned integer.

WORD 2

BITS

1 thru 16 — Length attribute of the header aggregation CHDO; value = 72 (indicates the length, in octets, of the value field of the header aggregation CHDO, words 13 through 48 in Figure 6-4); binary unsigned integer.

6.3.2.3 Primary Header CHDO

Words 13 through 16 of the telemetry SFDU contain the primary header CHDO which is illustrated in Ffigure 6-7 and defined in the following paragraphs. Words 1 and 2 of the primary header CHDO are the label field; words 3 and 4 are the value field.

```
           BIT
           +-----------------------------------------------+
           |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
           +-----------------------------------------------|
   WORD 1| TYPE ATTRIBUTE = 2                              |
           +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         2| LENGTH ATTRIBUTE = 4                           |
           +-----------------------------------------------|
         3| MAJOR DATA CLASS = 1   | MINOR DATA CLASS      |
           +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         4| RESERVED                                       |
           +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
           |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
           +-----------------------------------------------+
```

Figure 6-7. Primary Header CHDO

WORD 1

BITS

1 thru 16 — Type attribute of the primary header CHDO; value = 2 (indicates that this CHDO is a primary header CHDO); binary unsigned integer.

WORD 2

BITS

1 thru 16 — Length attribute of the primary header CHDO; value = 4 (indicates the length, in octets, of the value field of the primary header CHDO); binary unsigned integer.

WORD 3

BITS

1 thru 8 — Major data class; value = 1 (indicates that the data in this SFDU is spacecraft telemetry data); binary unsigned integer.

9 thru 16 — Minor data class; value = 0, 1, or 2; binary unsigned integer. This field indicates the configuration (enabled/disabled) of the DSCC frame synchronization and Reed-Solomon decoding processes when the data in this SFDU were acquired, as per Table 6-2. If a process is disabled, the flow of telemetry data is configured to bypass the process entirely. If a process is enabled, the flow of telemetry data passes through the process, and the actual effect of the process on the data must be obtained from parameters in the secondary header CHDO. For ACE virtual streams one and two, the minor data class will always be 2. For ACE vitual stream three, the minor data class will always be 0.

Table 6-2. Minor Data Classes

Class	Frame Synchronizer Configuration	Reed-Solomon Decoder Configuration
0	Disabled	Disabled
1	Enabled	Disabled
2	Enabled	Enabled

WORD 4

BITS

1 thru 16 Reserved

6.3.2.4 Secondary Header CHDO

Words 17 through 48 of the telemetry SFDU contain the secondary header CHDO which is illustrated in Figure 6-8 and defined in the following paragraphs. Words 1 and 2 of the secondary header CHDO are the label field; words 3 through 32 are the value field.

WORD 1

BITS

1 thru 16 Type attribute of the secondary header CHDO; value = 70 (indicates that this CHDO is a telemetry secondary header CHDO); binary unsigned integer.

WORD 2

BITS

1 thru 16 Length attribute of the secondary header CHDO; value = 60 (indicates the length, in octets, of the value field of the secondary header CHDO); binary unsigned integer.

WORD 3

BITS

1 thru 8 Originator ID; value = 48 (indicates that this SFDU originated in the DSN); binary unsigned integer.

9 thru 16 Last modifier ID; value = 48 (indicates that the contents of this SFDU were last modified by the DSN); binary unsigned integer.

WORD 4

BITS

1 thru 8 DSN-assigned spacecraft ID as per reference [1a]; value = 92 (ACE spacecraft).

9 thru 16 Virtual stream identifier; value is 1, 2, or 64 (indicates virtual stream one, two, or three, respectively); binary unsigned integer.

WORD 5

BITS

1 thru 7 — Reserved.

8 — Earth received time status; value = 0 (if ERT is valid) or 1 (if ERT is known to be invalid); binary unsigned integer.

9 thru 16 — Reserved.

<u>WORDS 6 THRU 8</u>

BITS

1 thru 16 — Earth received time (ERT); format defined in section 6.3.3.1. Earth received time identifies the UTC time that the data were received at the input to the DSCC low noise amplifier, to an accuracy of one millisecond; it is referenced to the telemetry signal event corresponding to the trailing edge of the last bit of telemetry data contained in this SFDU.

<u>WORD 9</u>

BITS

1 thru 16 — Reserved.

<u>WORDS 10 AND 11</u>

BITS

1 thru 16 — Record sequence number (RSN); binary unsigned integer. Begins with one; increments by one for each successive telemetry SFDU; wraps around from $2^{32} - 1$ to zero. Separate sequences are maintained for each virtual stream (where a virtual stream is defined as the time-ordered sequence of all telemetry SFDUs containing the same virtual stream ID, and the virtual stream ID is defined as the concatenation of the following fields in the secondary header CHDO: master antenna number [word 28, bits 1-8], DTM group number [word 29, bits 1-8], DTM channel number [word 29, bits 9-16], spacecraft ID [word 4, bits 1-8], and virtual stream identifier [word 4, bits 9-16]). Resets to one at the beginning of each pass and whenever the DSCC operator restarts the DTM (presumably due to equipment failure or major configuration change). The RSN is provided by the originator of the telemetry SFDU and is not changed subsequently; e.g., a telemetry SFDU replayed from the GCS recording retains the RSN that was assigned when the SFDU was created.

<u>WORD 12</u>

BITS

1 thru 8 — Acquisition bit error tolerance (BET); number of allowed bit errors in the embedded sync marker during search and verify modes; value range 0-15; binary unsigned integer.

9 thru 16 — Maintenance BET; number of allowed bit errors in the embedded sync marker during lock and flywheel modes; value range 0-15; binary unsigned integer.

BIT 1–16

WORD	Field
1	TYPE ATTRIBUTE = 70
2	LENGTH ATTRIBUTE = 60
3	ORIGINATOR ID = 48 (bits 1–8) / LAST MODIFIER ID = 48 (bits 9–16)
4	SPACECRAFT ID (bits 1–8) / VIRTUAL STREAM ID (bits 9–16)
5	ERROR FLAGS
6–8	EARTH RECEIVED TIME
9	RESERVED
10–11	RECORD SEQUENCE NUMBER
12	ACQUISITION BET (bits 1–8) / MAINTENANCE BET (bits 9–16)
13	VERIFY COUNT (bits 1–8) / FLYWHEEL COUNT (bits 9–16)
14	NUMBER OF RECEIVED TELEMETRY BITS
15	FRAME SYNC MODE (bits 1–8) / FRAME SYNC STATUS (bits 9–16)
16	RS SYMBOL ERROR COUNT (1 OF 2)
17	SYNC BIT ERRORS (bits 1–8) / FREQUENCY BAND (bits 9–16)
18–19	MEASURED BIT RATE
20	RS SYMBOL ERROR COUNT (2 OF 2)
21–22	SYSTEM NOISE TEMPERATURE
23–24	SYMBOL SNR
25–26	RECEIVER SIGNAL LEVEL
27	RESERVED
28	MASTER ANTENNA NUMBER (bits 1–8) / MASTER RECEIVER NUMBER (bits 9–16)
29	DTM GROUP NUMBER (bits 1–8) / DTM CHANNEL NUMBER (bits 9–16)
30	TELEMETRY LOCK STATUS
31	DTM SOFTWARE IDENTIFIER
32	RESERVED

Figure 6-8. Secondary Header CHDO

WORD 13

BITS

1 thru 8 — Verify count; number of within-tolerance frames required, during verify mode, to transition to lock mode; value range 0-15; binary unsigned integer.

9 thru 16 — Flywheel count; number of out-of-tolerance frames required, during flywheel mode, to transition to search mode; value range 0-15; binary unsigned integer.

WORD 14

BITS

1 thru 16 — Number of received telemetry bits; indicates the number of actual received telemetry bits that are contained in the value field of the telemetry data CHDO in this SFDU; value is always 7,968 for VS1 and VS2; it is typically 7,968 for VS3 but, for VS3 only, it may range from 1 to 7,968; binary unsigned integer.

WORD 15

BITS

1 thru 8 — Frame sync mode flags; the specified condition is true if the corresponding bit is set equal to one.

Bit 1	Operator forced resynchronization
Bit 2	Reserved
Bit 3	Automatic polarity correction (APC) is enabled
Bit 4	Frame synchronizer is in flywheel mode
Bit 5	Frame synchronizer is in lock mode
Bit 6	Frame synchronizer is in verify mode
Bit 7	Frame synchronizer is in search mode
Bit 8	Frame synchronizer is in bypass mode

The following qualifications apply to the frame sync mode flags:

a) The bypass mode flag (bit 8) will be set to one if and only if the DSCC frame synchronizer is configured to bypass mode (i.e., frame synchronization is disabled). For ACE, this bit will always be zero for VS1 and VS2; it will always be one for VS3.

b) When the bypass mode flag (bit 8) is set to one, bits 4-7 of this word are meaningless and should be ignored.

c) When the bypass mode flag (bit 8) is set to zero, one and only one of bits 4-7 will be set to one (i.e., frame synchronization is enabled, and the frame synchronizer is in the specified mode).

d) When the frame synchronizer is in bypass mode or search mode, bits 9-16 of this word, bits 1-8 of word 17, and all of words 16 and 20, are meaningless and should be ignored.

e) When the frame synchronizer is in bypass mode or search mode, the value field of the telemetry data CHDO contains a length of telemetry bits that is not frame aligned. When the frame synchronizer is in verify mode or flywheel mode, the value field of the telemetry data CHDO contains a length of telemetry bits that has been tentatively identified as being frame aligned. When the frame synchronizer is in lock mode, the value field of the telemetry data CHDO contains a length of telemetry bits that has been positively identified as being frame aligned.

f) When APC is enabled (bit 3 = 1) and the frame synchronizer is in verify, lock, or flywheel mode, an attempt is made to resolve the ambiguity between true and complemented data. If APC is enabled and word 15, bit 9, is set to one, it indicates that the frame synchronizer inverted all bits in the frame to achieve true data polarity. For ACE, APC will always be enabled.

WORD 15

BITS

9 Data polarity flag; indicates the data polarity of the attached sync marker detected by the frame synchronizer. The flag is set to zero if the true sync marker is detected; it is set to one if the complemented sync marker is detected. If the complemented sync marker is detected and APC is enabled, the frame synchronizer inverts all bits in the frame. This field is meaningless and should be ignored if the frame synchronizer is in bypass or search mode. The ambiguity between true and complemented data should always be resolved, by APC or other means, before the data is presented to the Reed-Solomon decoder.

10 thru 16 Reserved.

WORD 16

BITS

1 thru 8 Number of corrected Reed-Solomon symbol errors in the codword that includes the first byte of the transfer frame; value range is 0-16; binary unsigned integer.

9 thru 16 Number of corrected Reed-Solomon symbol errors in the codword that includes the second byte of the transfer frame; value range is 0-16; binary unsigned integer.

WORD 17

BITS

1 thru 8 Attached sync marker bit error count; indicates the number of bit errors in the attached sync marker detected by the frame synchronizer; binary unsigned integer. This field is meaningless and should be ignored if the frame synchronizer is in bypass mode or search mode.

9 thru 16 Frequency band of the master receiver; value = 'S,' 'X,' or 'K' (indicates S-band, X-band, or Ka-band, respectively); restricted ASCII. For ACE, value is always 'S.'

WORDS 18 AND 19

BITS

1 thru 16 — Measured bit rate of the received telemetry data, in bits/second (with an accuracy of 0.1 bits/second); 32-bit floating point format (refer to section 6.3.3.2 for format details).

WORD 20

1 thru 8 — Number of corrected Reed-Solomon symbol errors in the codword that includes the third byte of the transfer frame; value range is 0-16; binary unsigned integer.

9 thru 16 — Number of corrected Reed-Solomon symbol errors in the codword that includes the fourth byte of the transfer frame; value range is 0-16; binary unsigned integer.

WORDS 21 AND 22

BITS

1 thru 16 — System noise temperature (in Kelvins with an accuracy of 0.1 Kelvin); 32-bit floating point format (refer to section 6.3.3.2 for format details).

WORDS 23 AND 24

BITS

1 thru 16 — Estimated signal-to-noise ratio (in dB) in the symbol domain (i.e., prior to convolutional decoding); 32-bit floating point format (refer to section 6.3.3.2 for format details).

WORDS 25 AND 26

BITS

1 thru 16 — Receiver signal level (in dBm); value is for master receiver in array mode; 32-bit floating point format (refer to section 6.3.3.2 for format details).

WORD 27

BITS

1 thru 16 — Reserved.

WORD 28

BITS

1 thru 8 — Master antenna number; value is chosen from the following list: 12, 14, 15, 16, 21, 24, 25, 26, 27, 28, 34, 42, 43, 45, 46, 49, 54, 61, 63, 65, 66 and 72 (e.g., 12 indicates DSS-12 was the antenna used to acquire the data in this SFDU; for antenna arrays, the master antenna is used); binary unsigned integer.

9 thru 16 — Master receiver number; value range 0-99; binary unsigned integer.

WORD 29

BITS

1 thru 8 — DTM group number (within the facility implied by the master antenna number); value range 1-8; binary unsigned integer.

9 thru 16 — DTM channel number (within the specified DTM group); value range 1-2; binary unsigned integer.

WORD 30

BITS

1 thru 16 — Telemetry lock status code; comprised of eight two-bit subfields. Each subfield indicates the lock status of selected equipment (if applicable to the configuration in use). Refer to Table 6-3 for values of each subfield. Subfields refer to the following equipment:

Bits 1-2 Receiver; in array mode, master receiver
Bits 3-4 Real-time combiner; used only in array mode
Bits 5-6 Subcarrier demodulator
Bits 7-8 Symbol synchronizer
Bits 9-10 Convolutional decoder
Bits 11-12 Frame synchronizer
Bits 13-14 Reed-Solomon decoder
Bits 15-16 Reserved

The following qualifications apply to the telemetry lock status codes:

a) The frame synchronizer is "in lock" during lock and flywheel modes, "out of lock" during search and verify modes, and "not in use" during bypass mode.

b) The Reed-Solomon decoder is "not in use" if the frame synchronizer mode is bypass or search or if the Reed-Solomon decoder status is 0, "in lock" if the Reed-Solomon decoder status is 1 or 2, and "out of lock" if the Reed-Solomon decoder status is 3.

Table 6-3. Telemetry Lock Status Codes

Code	Interpretation
00_2	Not in use or unknown
01_2	(Invalid code)
10_2	In lock
11_2	Out of lock

<u>WORD 31</u>

BITS

1 thru 8 — DTM software version operational level; assigned by DSN Operations; restricted ASCII.

9 thru 16 — DTM software version identifier; assigned by the DTM CDE; restricted ASCII.

<u>WORD 32</u>

BITS

1 thru 16 — Reserved.

6.3.2.5 Telemetry Data CHDO

Words 49 through 548 of the telemetry SFDU (Figure 6-4) contain the telemetry data CHDO which is illustrated in Figure 6-9 and defined in the following paragraphs. Words 1 and 2 of the telemetry data CHDO are the label field. Words 3 through 500 are the value field.

```
              BIT
             +-----------------------------------------------+
             |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
             +-----------------------------------------------|
      WORD 1| TYPE ATTRIBUTE = 10                            |
             +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
            2| LENGTH ATTRIBUTE = 996                        |
             +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
            3| RECEIVED TELEMETRY BITS                       |
             +-                                             -|
            ...                                              ...
            ...                                              ...
             +-                                             -|
          500|                                               |
             +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
             |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
             +-----------------------------------------------+
```

Figure 6-9. Telemetry Data CHDO

<u>WORD 1</u>
BITS
1 thru 16 — Type attribute of the telemetry data CHDO; value = 10 (indicates that this CHDO contains binary data); binary unsigned integer.

<u>WORD 2</u>
BITS
1 thru 16 — Length attribute of the telemetry data CHDO; value = 996 (indicates the length, in octets, of the value field of the telemetry data CHDO); binary unsigned integer.

<u>WORDS 3 THRU K</u>
BITS
1 thru 16 — Received telemetry bits; contains spacecraft telemetry data acquired by the DSCC; variable-length bit string. The number of actual received telemetry bits contained in this field (the length of the variable-length bit string) is specified in word 14 of the secondary header CHDO. For ACE VS1 or VS2, this field always contains a frame of telemetry data which has been successfully frame synchronized and Reed-Solomon decoded; the number of valid bits is always 7,968. For ACE VS3, this field always contains a length of telemetry bits which is neither frame synchronized nor Reed-Solomon decoded; the number of valid bits is normally 7,968 but under some circumstances may range from 1 to 7,968.

6.3.3 Data Representation Conventions

General data representation conventions are describe in section 1.4.2 above. This section defines the formats used for Earth received time and floating point numbers in the secondary header CHDO.

6.3.3.1 Earth Received Time Format

The format and interpretation of the Earth received time field in the secondary header CHDO is illustrated in Figure 6-10 and described in the following paragraphs.

```
          BIT
          +-----------------------------------------------+
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------|
   WORD 1| DAYS SINCE JANUARY 1, 1958                      |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         2| MILLISECONDS-OF-DAY                            |
          +-                                             -|
         3|                                               |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------+
```

Figure 6-10. Earth Received Time Format

<u>WORD 1</u>

BITS

1 thru 16 — Days since January 1, 1958 (e.g., January 2, 1958, is 1); value range 0-65535; binary unsigned integer.

<u>WORDS 2 AND 3</u>

BITS

1 thru 16 — Milliseconds-of-day (i.e., milliseconds since midnight UTC); value range 0-86,400,000 (allows for one leap second); binary unsigned integer.

6.3.3.2 32-bit Floating Point Format Description

Floating point numbers are expressed in the ANSI/IEEE standard single precision format (reference [8]) with a sign, 8-bit exponent, and 23-bit significant in the following pattern:

```
          BIT
          +-----------------------------------------------+
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------|
   WORD 1|S | EXPONENT                 | SIGNIFICANT      |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
         2| SIGNIFICANT (continued)                        |
          +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
          |1 |2 |3 |4 |5 |6 |7 |8 |9 |10|11|12|13|14|15|16|
          +-----------------------------------------------+
```

Figure 6-11. Floating Point Format

The value *v* of the number expressed in this format is determined as follows:

Let:

s be the value (0 or 1) of the S (sign) field;
e be the value in the EXPONENT field (interpreted as an unsigned integer); and
f be the value in the SIGNIFICANT field (interpreted as an unsigned integer).

Then:

if $e = 255$ and $f \neq 0$, then v is not a number (NaN) regardless of s;
if $e = 255$ and $f = 0$, then $v = (-1)^S$, (i.e., 1 or -1);
if $0 < e < 255$, then $v = (-1)^S(2^{e-127})(1+f/(2^{23}))$;
if $e = 0$ and $f = 0$, then $v = (-1)^S 0$, (i.e., +0 or -0).

Bit strings of the form e = 0 and f ≠ 0 (denormalized numbers) are not permitted in this interface.

6.4 DDD Trailer Section

The contents of this field are reserved. See references [1c] and [2a] for more information.

6.5 Intermediate Data Record

All ACE telemetry data blocks are recorded by the GCS and are retained for 30 days. The GCS recording of the data is referred to as an intermediate data record (IDR). Historically, the term IDR meant a recording on nine-track magnetic tape, but, as used here, it refers to the GCS 30-day recording regardless of the media on which it is stored or the means by which data recovery is accomplished.

Data contained in the IDR may be recovered and selectively replayed on a virtual stream basis to the ACE MOC on request. During replay, a sequence of telemetry data blocks is retransmitted to the MOC. At the interface to the MOC, replay data appears identical to real time data except that word 3, bit 16, of the DDD header is set to indicate replay and the data rate of the replay is independent of the original downlink bit rate.

Other methods for recovering data from the IDR (e.g., electronic file transfer) are outside the scope of this module. Such methods are documented in reference [1b].