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SPECTRUM ASTRO, INC.

HIGH ENERGY SOLAR SPECTROSCOPIC IMAGER (HESSI) PROGRAM

TELECOMMAND FORMAT SPECIFICATION

CONTRACT NO. PPB005884

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CONTRACT NO. PPB005884

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LIST OF ACRONYMS AND TERMS

ACS	ATTITUDE CONTROL SUBSYSTEM
CIB	COMMUNICATIONS INTERFACE BOARD
CPU	CENTRAL PROCESSING UNIT
FSW	FLIGHT SOFTWARE, WHICH IS DEFINED AS THE NON-ACS SOFTWARE
HESSI	HIGH ENERGY SOLAR SPECTROSCOPIC IMAGER
IDPU	INSTRUMENT DATA PROCESSING UNIT. THE MAIN DATA INTERFACE TO THE PAYLOAD INSTRUMENT.
PACI	PAYLOAD AND ATTITUDE CONTROL INTERFACE BOARD.
PCB	POWER CONTROL BOARD
TBD	TO BE DETERMINED
UML	UNIFIED MODELING LANGUAGE
SEQUENCE	A UNIQUELY IDENTIFIED SEQUENCE OF STORED TELECOMMANDS.

1. SCOPE.

1.1 Identification.

This document describes the High Energy Solar Spectroscopic Imager (HESSI) spacecraft flight software telecommand format. This document will eventually become part of the HESSI Spacecraft Handbook.

1.2 System Overview.

The HESSI spacecraft shall receive and execute telecommands that generally conform to the recommendations set out in the CCSDS documents listed below. For each of the pertinent telecommanding layers, the formats of the associated data structures and the values that these data shall take has been expressly stated. Any variance from the recommendations for any of the layers has also be included.

1.3 Applicable Documents.

The order of precedence for resolving conflicts between documents is in descending order.

1) Telemetry "Concept and Rationale", CCSDS 100.0-G-1, Issue 1, Green Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

2) "Packet Telemetry" Recommendation CCSDS 102.0-B-2, Issue 2, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

3) "Telemetry Channel Coding" Recommendation CCSDS 101.0-B-2 Issue 2, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

4) "Telecommand: Summary of Concept and Service," CCSDS 200.0-G-6, Issue 6, Green Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

5) "Time Code Formats", CCSDS 301.0-B-2, Issue 2, Blue Book, Consultative Committee for Space Data Systems, April 1990 or later issue.

6) "Telecommand, Part 3: Data Management Service, Architectural Definition", Recommendation CCSDS 203.0-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

7) "Telecommand, Part 2: Data Routing Service, Architectural Specification", Recommendation CCSDS 202.0-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later.

8) "Telecommand, Part 1: Channel Service, Architectural Specification", Recommendation CCSDS 201.0-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, January 1987 or later issue.

1.4 CCSDS Compliant Telecommand Format.

The HESSI implementation of telecommanding shall be in accordance with a subset of recommendations provided by the CCSDS standards (CCSDS 200.0-G-6 and 202.1-R-4). The size and scope of HESSI shall not warrant the use of all of the recommendations in the CCSDS standard.

2. PHYSICAL LAYER.

The Physical layer shall provide the radio frequency data path which connects the transmitting station to the HESSI spacecraft, and its associated Physical Layer Operational Procedures (PLOPs), in order to support the transmission of telecommand data.

2.1 Standard Data Structures.

The standard data structures within this layer are the Acquisition Sequence, CLTU, and the Idle Sequence.

2.1.1 Acquisition Sequence.

The length of the Acquisition Sequence shall be 144 bits. The pattern of the Acquisition Sequence shall be alternating “ones” and “zeros”, starting with either a “one” or a “zero”. (CCSDS 201.0-B2 (Blue Book), November 1995, section 4.2.1, page 4-1).

2.1.2 Command Link Transmission Unit (CLTU).

The Command Link Transmission Unit (CLTU) shall is furnished from the Coding Layer and is described in section 3.1.2.

2.1.3 Idle Sequence.

The Idle Sequence shall be a sequence of alternating "ones" and "zeros", beginning with a "zero". The length of the idle sequence shall be an unconstrained number of bits.

2.2 Standard Procedures.

2.2.1 Modulation.

All telecommands shall be NRZ-L, binary phase shift keyed (BPSK) at 2 Kbps onto a 16 Khz subcarrier, which shall be phase modulated onto the main RF carrier. Resolving the ambiguity of whether the data is inverted or true shall be required of the spacecraft data system.

2.2.2 Carrier Modulation Modes.

The Carrier Modulation Modes shall be as shown in Table 1. A Telecommand Session shall begin with initial application of RF carrier (CMM-1) and shall end with the removal of the carrier. The path shall be further controlled by the selection of appropriated Physical Layer Operations Procedures (PLOPs).

Mode	State
CMM-1	Unmodulated Carrier Only
CMM-2	Carrier modulated with Acquisition Sequence
CMM-3	Carrier modulated with CLTUs
CMM-4	Carrier modulated with Idle Sequence

Table 1. Carrier Modulation Modes.

2.2.3 Physical Link Operation Procedures (PLOPs).

A Physical Link Operation Procedure (PLOP) shall consist of the sequential application of various CMMs to activate and deactivate the physical telecommand channel (CCSDS 202.1-R-4, Issue 4). PLOP-2 shall be used by the HESSI spacecraft and ground system. The termination of an individual CLTU shall be provided only through the data path using the CLTU Tail Sequence, optionally using Idle Sequences but not the decoder itself.

3. CODING LAYER.

3.1 Standard Data Structures.

The two standard data structures used in the Coding Layer are the TC Codeblock and the CLTU.

3.1.1 TC Codeblock Format.

All telecommands shall conform to the fixed-length TC Codeblock format that is 64 bits in length: 56 data bits, 7 parity check bits and 1 fill bit. The fill bit shall always be set to 0B. The format shall comply with that described in CCSDS 201.0-B-2 (Blue Book), section 3.2.1 on page 3-1.

3.1.2 Command Link Transmission Unit (CLTU) Format.

The Command Link Transmission Unit shall comprise a 16-bit CTLU start sequence, an Encoded TC Data field and a 64 bit CTLU tail sequence. The CLTU length shall be constrained to be no greater than 306 bytes. See section 4.1.1.1.7. (CCSDS 201.0-B2 (Blue Book), section 3.3.3, on page 3-2).

3.1.2.1 CLTU Start Sequence.

The CLTU Start Sequence shall be set to the following pattern (CCSDS 201.0-B2 (Blue Book), section 3.2.2.1, page 3-3):

Bit #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit Value	1	1	1	0	1	0	1	1	1	0	0	1	0	0	0	0

3.1.2.2 Encoded TC Data Field.

The Encoded TC Data field shall consist of a set of TC Codeblocks which have been encoded in accordance with the TC Codeblock encoding procedure (CCSDS 201.0-B-2 (Blue Book), section 3.3.2, page 3-5).

These codeblocks shall contain the Input Data to this layer, plus any fill bits that were appended to meet codeblock length constraints.

3.1.2.3 Tail Sequence.

The Tail Sequence shall be 64 bits long and have a pattern of alternating "ones" and "zeros", beginning with "zero" and ending with a "one".

3.2 Standard Procedures.

3.2.1 TC Codeblock Encoding.

The TC codeblocks shall be block coded with a (63,56) modified Bose-Chaudhuri-Hocquenghem (BCH) code. The parity bits in the last octet of the codeblock shall be the complements of the BCH code parity bits. The generator polynomial to produce the seven parity bits shall be:

$$g(x) = x^7 + x^6 + x^2 + x^0.$$

TC Codeblock encoding shall be performed on all data excluding the CLTU start and tail sequences.

3.2.2 Fill Bits.

If the Input Data does not fit exactly within an integral number of TC Codeblocks, the last octet(s) of the information field of the last Codeblock within the CLTU shall contain Fill bits when the Input Data do not fit exactly within an integral number of TC Codeblocks. The Fill bits shall be introduced, if necessary, during the encoding procedure. The pattern of the Fill shall consist of a sequence of alternating “ones” and “zeros” starting with a “zero” (CCSDS 201.0-B2 (Blue Book), section 3.3.3 on page 3-6).

4. TRANSFER LAYER.

4.1 Standard Data Structures.

The two data structures used in the transfer layer are Transfer Frames and Command Link Control Words (CLCWs).

4.1.1 TC Transfer Frame Format.

The TC Frame shall consist of the following major fields, namely, the TC Transfer Frame Header field and the TC Transfer Frame Data field. HESSI shall not support Frame Error Control on Virtual Channel 0 (VC0) nor on Virtual Channel 1 (VC1)

4.1.1.1 TC Transfer Frame Header Field.

All telecommands shall conform to the TC Transfer Frame Header as described in CCSDS 202.0-B2 (Blue Book), section 4.2.1, on page 4-3. The frame header of the TC Transfer Frame shall consist of the following fields, grouped into octets as shown in Table 2.

Field	#Bits	#Octets
Version Number	2	2
Bypass Flag	1	
Control Command Flag	1	
Reserved Spares	2	
Spacecraft ID	10	
Virtual Channel ID	6	2
Frame Length	10	
Frame Sequence Number	8	1
TOTAL		5

Table 2. Telecommand Transfer Frame Header.

4.1.1.1.1 Version Number.

The Version Number field shall be set to 00B.

4.1.1.1.2 Bypass Flag.

The Bypass Flag field shall be set to 0B when a telecommand is required to be subjected to Frame Acceptance Tests and to 1B when a telecommand is not required to be subjected to Frame Acceptance Tests (i.e. bypassed). All Virtual Channel 0 (VC0) commands shall have the Bypass Flag set to 1B.

4.1.1.1.3 Control Command Flag.

The Control Command Flag shall be set to either 0B when the frame carries a transfer layer Data Unit or the Control Command Flag shall be set to 1B when the frame carries a transfer layer Control Command.

4.1.1.1.4 Reserved Spares.

The Reserved Spares field shall be set to 00B.

4.1.1.1.5 Spacecraft ID.

The Spacecraft ID field shall be set to XXXXXXXXXXB (YYYD) **[TBD].**

4.1.1.1.6 Virtual Channel ID.

The Virtual Channel ID shall be set to either 000000B for Virtual Channel 0 (VC0) or 000001B for Virtual Channel 1 (VC1). Only virtual channels VC0 and VC1 shall be allowed.

4.1.1.1.7 Frame Length.

The Frame Length field shall be set to one fewer than the total octets in the TC Transfer Frame. The count shall be measured from the first bit of the Frame Header to the last bit of the Frame Data Field if the error

control is omitted. The maximum length of the transfer frame shall be 256 bytes. The minimum length restriction shall be either 6 bytes or 9 bytes for control commands and 14 bytes for all other commands.

4.1.1.1.8 Frame Sequence Number.

The Frame Sequence Number field shall be an up-counting modulo-256 binary number and shall be assigned to each TC Frame by the TC Transfer layer. The Frame Sequence Number shall enable the FARM to determine whether the incoming Type-A TC Frames are being received in the correct sequence. The Transfer layer shall maintain a separate Frame Sequence Number for each of the Virtual Channels, namely, VC0 and VC1. The Frame Sequence Number field shall be set to 00000000B when operating with Type-B TC Frames.

4.1.2 TC Transfer Frame Data Field.

The TC Transfer Frame Data Field shall contain shall contain either an integral number of octets of telecommand data corresponding to one TC Frame Data Unit or an integral number of octets of Control Command information. The Frame Data Field shall be inserted directly after the Frame Header with no filler between. When the Control Command Flag in the Frame Header is set to 0B, the data field shall contain a TC Data Unit. When the Control Command Flag is set to 1B, the data field shall contain a TC Control Command. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.1.2, Page 4-7, November 1992].

4.1.2.1 TC Transfer Frame Data Unit.

Virtual Channel 0 (VC0) shall use neither the segmentation nor the packetization layers. The TC Frame Data Unit shall always be 2 bytes for VC0.

For Virtual Channel 1 (VC1), the TC Frame Data Unit shall be supplied by the Segmentation layer. See section 5.1.2. TC Frame Data Unit shall be a variable length field of up to a maximum 251 octets. A TC Data Unit shall contain a TC Segment that shall consist of a 1 octet header and up to a 250 octet segment data field. The segment data field shall contain the packetization. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.1.2.1, Page 4-7, November 1992].

4.2 Control Commands.

The two Control Commands, namely Unlock and Set V(R) shall be supported. TC Control Commands shall be used to specify to the spacecraft the governing Frame Acceptance Reporting Mechanism (FARM) parameters.

4.2.1 Control Command Type.

The Unlock control command shall consist of a single octet set to 00000000B. The Set V(R) control command shall consist of three octets with the following values:

10000010B, 00000000B, XXXXXXXXB where XXXXXXXXB is the value to which the FARM should set V(R), the Receiver_Frame_Sequence_Number. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.1.2.2, Page 4-7, November 1992].

4.3 Transfer Frame Error Control Field.

HESSI shall not support Frame Error Control for Virtual Channel 0 (VC0) nor for Virtual Channel 1 (VC1). The Transfer Frame Error Control Field shall not appear in the TC Transfer Frame Data Field for

Virtual Channel 0 (VC0) nor for Virtual Channel 1 (VC1). [CCSDS 202.0-B-2 (Blue Book), section, 4.2.1.3, Page 4-8, November 1992].

4.3.1 Command Link Control Word (CLCW) Format.

The Command Link Control Word (CLCW) shall not be available for Virtual Channel 0 (VC0). There shall be CLCW data for Virtual Channel 1 (VC1) only.

The Command Link Control Word (CLCW) format shall be as that shown in Table 3. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2, Page 4-9, November 1992].

4.3.1.1 Control Word Type Field.

The Control Word Type field shall be set to 0B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(1), Page 4-11, November 1992].

4.3.1.2 CLCW Version Number Field.

The CLCW Version Number field shall be set to 00B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(2), Page 4-11, November 1992].

4.3.1.3 Status Field.

The Status field shall be set to 000B. The Status field shall not be used by HESSI. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(3), Page 4-11, November 1992].

4.3.1.4 COP In Effect Field.

The COP In Effect field shall be set to 01B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(4), Page 4-11, November 1992].

4.3.1.5 Virtual Channel ID Field.

The Virtual Channel ID field shall be set to 000001B for Virtual Channel 1. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(5), Page 4-11, November 1992].

4.3.1.6 Reserved Spare Field.

The Reserved Spare field shall be set to 00B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(6), Page 4-11, November 1992].

4.3.1.6.1 Flags.

There are five flag bits in the CLCW, namely, No Rf Available, No Bit Lock, Lockout, Wait, and Retransmit.

4.3.1.6.1.1 No RF Available Flag.

The No RF Available flag shall not be used and shall always be set to 0B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(7a), Page 4-12, November 1992].

4.3.1.6.1.2 No Bit Lock Flag.

The No Bit Lock flag shall be set to 0B when there is sufficient signal energy to achieve bit synchronization with the received data stream and shall be set to 1B when there is insufficient signal energy to achieve bit

synchronization with the received data stream. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(7b), Page 4-12, November 1992].

For Virtual Channel 1 only, this bit field, as it appears in the CLCW, shall indicate the status of the Command Decoder Unit (CDU) of the Transponder. If the CDU is in bit lock then this flag shall be set to 0B. If the CDU is not in lock then it shall be set to 1B.

4.3.1.6.1.3 Lockout Flag.

The Lockout flag shall be set to 0B when a Type-A TC Frame received on Virtual Channel 1 does not violate the frame acceptance checks. The Lockout flag shall be set to 1B when a Type-A TC Frame received on Virtual Channel 1 violates the frame acceptance checks. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(7c), Page 4-12, November 1992].

4.3.1.6.1.4 Wait Flag.

The Wait flag shall not be used and shall always be set to 0B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(7d), Page 4-13, November 1992].

4.3.1.6.1.5 Re-transmit Flag.

The Re-transmit flag be shall set to 1B when one or more Type-A frames on Virtual Channel 1 have been rejected or found missing by the FARM. The Re-transmit flag be shall set to 0B when there have been no outstanding Type-A frame rejections in the sequence received. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(7e), Page 4-13, November 1992].

4.3.1.6.1.6 FARM B Counter Field.

The FARM B Counter field shall contain the two least significant bits of the FARM-B Counter. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(8), Page 4-13, November 1992].

4.3.1.6.1.7 Reserved Spare Field.

The Reserved Spare field shall be set to 0B. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(9), Page 4-14, November 1992].

4.3.1.6.1.8 Report Value Field.

The Report Value field shall contain the value of N(R), the current observed value of the Next Expected Frame Sequence Number, V(R) maintained by the FARM. [CCSDS 202.0-B-2 (Blue Book), section, 4.2.2(10), Page 4-14, November 1992].

Field		#Bits	#Octets
Control Word Type		1	
CLCW Version Number		2	
Status Field		3	
COP In Effect		2	1
Virtual Channel Id		6	
Reserved Spare		2	1
Flags	No RF Available	1	
	No Bit Lock	1	
	Lockout	1	
	Wait	1	
	Re-transmit	1	
FARM B Counter		2	
Reserved Spare		1	1
Report Value		8	1
TOTAL		32	4

Table 3. Command Link Control Word (CLCW) Format.

4.4 Standard Procedures.

4.4.1 Frame Validation Check Procedure.

All telecommands shall be validated using the frame validation check procedure specified in CCSDS 202.0-B2 (Blue Book), section 4.3.2, on page 4-15, November 1992. These tests shall consist of the following:

1) The TC Frame must have an expected Version Number.
2) The TC Frame must have the expected Spacecraft Id.
3) The TC Frame Header must not contain any values that are not consistent with the implemented features for that spacecraft.
4) The value of the Frame Length must be consistent with the number of octets that are present.
5) The Frame Error Control test is not supported by HESSI.
6) The Data Field of a TC Frame containing a Control Command must be consistent with the allowed Control Commands, namely, Unlock or Set Next Expected Frame Sequence Number.

4.4.2 Command Operation Procedure (COP).

HESSI shall support COP-1. (CCSDS 202.1-R-4.)

The Farm Sliding Window shall be a fixed size of 127. The Farm Negative Edge shall be set at 63 of the Farm Sliding Window. The use of Farm Fixed Window shall not be supported.

4.4.3 Virtual Channel Assignment.

The COP-1 and FARM shall only be supported for Virtual Channel 1, (VC1).

4.4.3.1 Virtual Channel 0.

There shall be no COP support for Virtual Channel 0 (VC0). For commands sent on Virtual Channel 0 the TC Transfer Frame Header shall be set such that the VC ID is set to 000000B, the Bypass Flag is set to 1B, and the Control Command Flag is set to 0B.

4.4.3.2 Virtual Channel 1.

The COP-1 and FARM shall only be supported for Virtual Channel 1, (VC1).

4.4.4 Frame Delimiting and Fill Removal Procedure.

The frame delimiting and fill removal procedures shall follow those specified in CCSDS 202.0-B2 (Blue Book), section 4.3.1, on page 4-14, November 1992.

5. SEGMENTATION LAYER.

Segmentation shall not be used on Virtual Channel 0 or on Virtual Channel 1. However, to maintain command commonality with past SMEX missions, the TC Segment Header shall be present on Virtual Channel 1 (VC1) only.

5.1 TC Segment Format.

The TC segment shall consist of a Segment Header and a Segment Data Field. See Table 4. [CCSDS 202.0-B-2 (Blue Book), section 3.2.2, Page 3-2]

5.1.1 Segment Header.

The Segment Header shall consist of a Sequence Flags field and a Multiplexer Access Point (MAP) ID field. See Table 4. [CCSDS 202.0-B-2 (Blue Book), section 3.2.2, on page 3-2].

Field Name	Sub-Field Name	#Bits	#Octets
Segment Header	Sequence Flags	2	
	Multiplexer Access Point (MAP) ID	6	1
TOTAL		8	1

Table 4. TC Segment Format

5.1.1.1 Sequence Flags Field.

The Sequence Flags field shall be set to 11B. [CCSDS 202.0-B-2 (Blue Book), section, 3.2.2.1(1), Page3-3].

5.1.1.2 Multiplexer Access Point (MAP) ID Field.

The Multiplexer Access Point (MAP) ID field shall be set to 000001B [CCSDS 202.0-B-2 (Blue Book), section, 3.2.2.1(2), Page3-3].

5.1.2 Segment Data Field.

The Segment Data Field shall only contain a single TC (Telecommand) Packet. [CCSDS 202.0-B-2 (Blue Book), section, 3.2.2.2, Page3-4].

6. PACKETIZATION LAYER.

6.1 Standard Data Structures.

The TC packet is the only data structure of the Packetization Layer. Only Virtual Channel 1 (VC1) shall use the Packetization Layer.

6.1.1 TC Packet Format.

The TC Packet shall consist of a Primary Header, Secondary Header and Application Data. The length of TC Packets shall not exceed 250 octets. [CCSDS 203.0-B-1 (Blue Book), section 5.2, page 5-1]

6.1.1.1 Primary Header Format.

The Primary Header shall consist of 6 octets subdivided into the following fields shown in Table 5. [CCSDS 203.0-B-1 (Blue Book), section 5.2.1, page 5-2].

6.1.1.1.1 Packet Identification Field.

The packet identification shall be two octets in length and shall consist of 4 fields.

6.1.1.1.2 Version Number Sub-field.

The Version Number sub-field shall be set to 000B.

6.1.1.1.3 Type Sub-field.

The Type field shall be set to 1B.

6.1.1.1.3.1 Secondary Header Flag Sub-field.

The Secondary Header Flag sub-field shall be set to 1B.

6.1.1.1.3.2 Application Processor Identifier Sub-field.

The Application Processor Identifier sub-field shall be used to address commands to different subsystems of the spacecraft. Assignments of commands to APIDs are documented in the TBD Spacecraft Handbook.

Field Name	Sub-Field Name	#Bits	#Octets
Packet Identification	Version Number	3	2
	Type	1	
	Secondary Header Flag	1	
	Application Process ID	11	
Packet Sequence Control	Sequence Flags	2	2
	Packet Name or Sequence Count	14	
Packet Length		16	2
TOTAL		48	6

Table 5. Primary Header Format.

6.1.1.1.4 Packet Sequence Control Field.

The Packet Sequence Control field shall be two octets in length and shall contain a Sequence Flag sub-field and a Sequence Count sub-field.

6.1.1.1.4.1 Sequence Flags Sub-field.

The Sequence Flags sub-field shall be set to 11B. Segmentation of TC packets shall not be support by HESSI.

6.1.1.1.4.2 Packet Name or Sequence Count Sub-field.

The Packet Name or Sequence Count sub-field shall not be used on HESSI. The Packet Name or Sequence Count sub-field shall be set to all zeros.

6.1.1.1.5 Packet Length Field.

The Packet Length field shall contain the length (in octets) of the remainder of the data structure that is enclosed between the first bit of the Secondary Header and the last bit of the Packet (i.e., the last bit of the Application Data field).

The field is expressed as follows:

Packet Length = {(Number of octets) – 1}.

6.1.1.2 Secondary Header Format.

The Secondary Header shall consist of 2 octets subdivided into the following fields as shown in Table 6.

Field Name	Sub-Field Name	#Bits	#Octets
Command Function	Secondary Header Flag	1	
	Reserved Spare	7	1
	Command Op-Code	8	1
TOTAL		16	2

Table 6. Secondary Header Format.

6.1.1.2.1 Command Function Field.

6.1.1.2.1.1 Secondary Header Flag Sub-field.

The Secondary Header Flag sub-field shall be set to 0B.

6.1.1.2.1.2 Reserved Spare Sub-field.

The Reserved Spare sub-field shall be set 0B.

6.1.1.2.1.3 Command Op-code Sub-field.

The Command Op-code field shall contain a code that provides a numerical identifier for an individual command. Assignment of Command Op-codes shall be provided in TBD Spacecraft Handbook.

6.1.1.3 Application Data Format.

The data format of the application data depends on the specific Command Op-code. Details of the data format for each Command Op-code shall be documented in the TBD Spacecraft Handbook.

6.1.1.3.1 Application Data Checksum.

The last 16 bits of the Application Data fields shall contain the checksum of the packet**.** The checksum shall be a modulo 65536 addition of each octet of the secondary header and application data fields, excluding the 2 octets of the checksum field.

6.2 Standard Procedures.

6.2.1 Command Identification.

A telecommand shall be uniquely identified by a combination of both the Application Process ID and Command Op-code.

6.2.2 Exclusive-OR Application (Application Data Field De-randomization).

Every telecommand packet shall have a pseudo-random operation applied to the Application Data Field, which includes the Secondary Header and the Application Data.

The command packet Application Data Field shall be de-randomized in accordance with the following algorithm: for each 16-bit word W(I) in the TC data field, W(I) := W(I) XOR A55AH.

7. SYSTEM MANAGEMENT/APPLICATION LAYER.

7.1 Standard Data Types.

All application data for commands shall be composed only of specific, pre-defined data types. These data types are specified in Table 7.

Table 7 maps the bytes from MSB to LSB order into their transmission order for each data type. The Octet Order column provides this mapping. The byte identifiers in this column (N | N+1, etc.) indicate the position of a byte in a given data type.

The standard definition of byte ordering within any data type is defined as (add the other swapped data types):

7.1.1 Integer Data.

Integer binary data shall be formatted as 8, 16, or 32 bit unsigned or signed (2's complement) fields.

7.1.1.1 Signed Integer.

When signed data values are defined by a non-octet-integral number of bits, the sign bit shall be extended up to the next largest 8, 16, or 32-bit length.

7.1.1.2 Unsigned Integer.

Unsigned binary integer fields shall be zero extended up to the next larger 8, 16, or 32 bit length.

7.1.2 Floating Point Data.

HESSI shall use the typical IEEE-754 standard for real numbers.

7.1.3 Time Code Data.

All time codes (TIME40, TIME20, RTIME40 and RTIME20) shall be formatted to correspond to a subset of the CCSDS Unsegmented Time Code (CUC) as defined in CCSDS 301.0-B-2, Issue 2. For HESSI, no more than a four-octet seconds field shall be used. TIME40 shall be used for Absolute Time and TIME20 shall be used for Relative Time.

7.2 Standard Procedures.

A telecommand shall be uniquely identified by a combination of both the Application Process ID and Command Op-code. A single telecommand shall execute only one event.

MSB
LSB

N	N + 1	N + 2	N + 3	N + 4	N + ...

Data Description	Type Name	Length	Octet Order
Unsigned Byte	UB	1	N
Signed Byte	SB	1	N
Unsigned Word	U2I	2	N+1 | N
Signed Word	I21	2	N+1 | N
Unsigned Longword	U4321	4	N+3 | N+2 | N+1 | N
Signed Longword	I4321	4	N+3 | N+2 | N+1 | N
Single Precision Real	SFP	4	N+3 | N+2 | N+1 | N
Double Precision Real	DFP	8	N+7 | N+6 | N+5 | N+4 | N+3 | N+2 | N + 1 | N
CUC(No Pre, Sec 4, Subsec 0)	TIME40	4	N | N+1 | N+2 | N+3
CUC(No Pre, Sec 2, Subsec 0)	TIME20	2	N | N+1
CUC(No Pre, Sec 4, Subsec 0)	RTIME40	4	N +3 | N+2 | N+1 | N
CUC(No Pre, Sec 2, Subsec 0)	RTIME20	2	N +1 | N

Table 7. Standard Command Data Types.

7.2.1 Spacecraft Commands.

Each Application Process ID and Command Op-code combination shall refer to a specific command packet of pre-defined fixed format, fixed length and shall be identified by a defined command mnemonic. The application data in any command packet shall consist of only those data types defined in Table 7.

Table and memory load command packets (which by definition are real time only) shall have from 0 to 200 bytes of application data. Sections 7.2.3 and 7.2.4 describe the memory and table load formats that are transmitted to the spacecraft.

7.2.2 Data Field Structuring.

Standard octet order, bit order, and data alignment procedures shall be used to facilitate the transfer of data between different computer architectures.

7.2.2.1 Octet Ordering.

When creating a command load, the ground system shall order the bytes for each data type as shown in Table 7.

7.2.2.2 Bit Ordering.

The CCSDS nomenclature for bit ordering shall be used. [CCSDS 202.0-B-2 (Blue Book), November 1992, Section 1-3, page 1-2]

7.2.2.3 Data Alignment.

The first octet of the packet shall be referred to as octet zero. All subsequent octets in the packet shall be referred to incrementally. Data types in the data field shall be placed contiguously. The leading bit of any defined data type field shall begin on an octet boundary. Bit sub-fields within a data type used for specific telemetry values may begin anywhere in an octet.

7.2.3 Memory Loads.

All memory load commands shall use the same format as shown in Table 8. The first entry in the table shall be placed at octet zero of the command packet application data and the remaining items follow sequentially. The octet array of data shall be uplinked in octet consecutive order and shall include any required octet or word swapping of the data types.

Data Item	Data Type	Description
Starting Address	U4321	Starting address for loading this packet
Memory Type	U21	EEPROM =1, RAM = 2
Packet Data Size	UB	Number of valid load bytes in this packet (must be <= 200)
Data	UB	Octet array of memory data (must be <= 200 bytes)

Table 8. Memory Load Format.

7.2.4 Table Loads.

All table load commands shall use the same format as shown in Table 9. The first entry in the data portion of every table shall be a four-byte load generation time and the remaining items follow sequentially starting at octet four. The load generation time-stamp is in the TIME40 format and is present only in the first packet of the load. The octet array of data shall be uplinked in octet consecutive order and shall include any required octet or word swapping of the data types.

Data Item	Data Type	Description
Starting Offset	U4321	Starting offset to load this packet.
Spare	UB	Spare to maintain the same structure as the memory load format.
Packet Data Size	UB	Number of valid load bytes in this packet (must be <= 200 bytes).
Data	UB	Octet array of table data (must be <= 200 bytes).

Table 9. Table Load Format.

7.2.5 Stored Command Processor (SCP) Table Formats.

The spacecraft shall use a Stored Command Processor (SCP) approach for executing commands at a time later than uplink. The SCP shall keep the stored commands in buffers. There shall be two types of stored commands: absolute time commands and relative time commands.

7.2.6 TC Application Data format for ATS Buffers.

The spacecraft shall provide an Absolute Time Sequence (ATS) command capability. Two ATS command buffers, buffer 'A' and buffer 'B', shall be provided Each ATS buffer shall have a command capacity not to exceed 35,004 bytes. (This includes the four-byte table time-stamp. The format of this time stamp shall be RTIME40.). The commands must be in time sequence order. The variable length structures shown are packed into the buffers so that the Command Number of one structure follows immediately after the checksum of the previous structure. The TC Application Data format for a stored telecommand to be loaded into an ATS Buffer is shown in Figure 1.

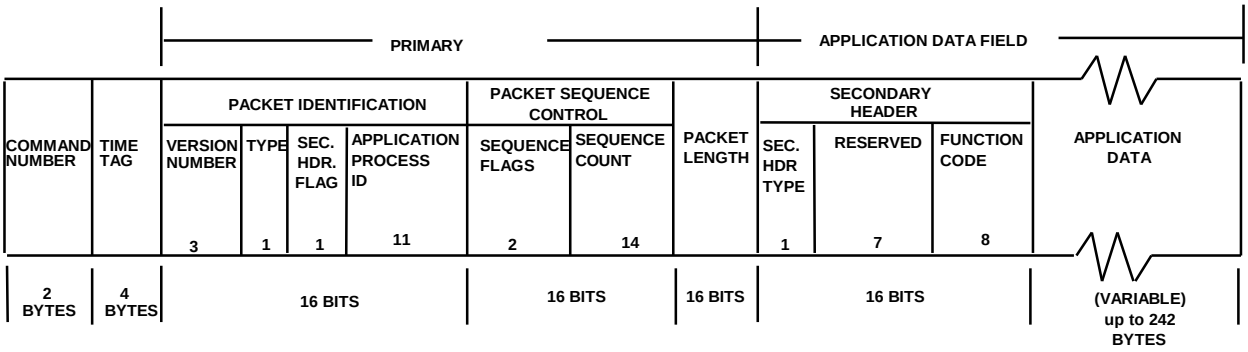

Figure 1. TC Application Data format for ATS Buffers.

7.2.6.1 Command Number

The command number shall be an unsigned integer.

7.2.6.2 Time Tag.

The Time Tag shall be in RTIME40 format.

7.2.6.3 Primary Header.

The packet primary header is defined in Section 6.1.1.1 of this document.

7.2.6.4 Secondary Header.

The secondary header is defined in Section 6.1.1.2 of this document.

7.2.6.5 Application Data.

The command application data typically includes data indicating a selected option (e.g., off, low, high), a set-to value, or other data necessary for command execution.

The last 16 bits of the Application Data shall contain the checksum of the packet and shall be an unsigned integer. The checksum shall be a modulo 65536 addition of each octet of the secondary header and application data fields, excluding the 2 octets of the checksum field.

7.2.7 TC Application Data format for RTS Buffers.

The spacecraft shall accommodate 64 Relative Time Sequences (RTSs), with each RTS not to exceed 300 bytes, plus the four-byte table time-stamp. The format of this time stamp shall be RTIME40.The RTS commands must be time ordered. The variable length structures shown are packed into the buffers so that Delay Time of one structure follows immediately after the checksum of the previous structure. The TC Application Data format for a stored telecommand to be loaded into an RTS Buffer is shown in Figure 2.

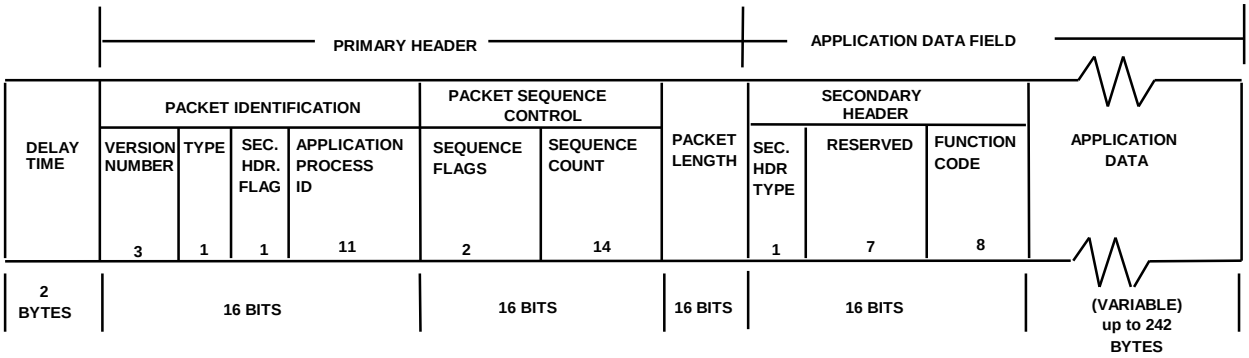

Figure 2. TC Application Data format for RTS Buffers.

7.2.7.1 Delay Time.

The Delay Time shall specify the number of seconds the processor will delay before processing the associated command relative to previous command. The Delay Time shall have an RTIME20 format.

7.2.7.2 Primary Header.

The packet primary header is defined in Section 6.1.1.1 of this document.

7.2.7.3 Secondary Header.

The secondary header is defined in Section 6.1.1.2 of this document.

7.2.7.4 Application Data.

The command application data typically includes data indicating a selected option (e.g., off, low, high), a set-to value, or other data necessary for command execution.

The last 16 bits of the Application Data shall contain the checksum of the packet and shall be an unsigned integer. The checksum shall be a modulo 65536 addition of each octet of the secondary header and application data fields, excluding the 2 octets of the checksum field.