TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

Section 3.0
Command and Data Handling Interface

TECHNICAL CONTENT APPROVAL (PAGE 1 OF 2)

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88898	A	7363-9050 11/11/97
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TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

Section 3.0
Command and Data Handling Interface

TECHNICAL CONTENT APPROVAL (PAGE 2 OF 2)

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		11/11/97
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TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

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Command and Data Handling Interface

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TIMED Spacecraft Approval Page

Rev #	Date	D. Kusnierkiewicz	K. Heffernan	J. Perschy	S. Williams
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					

Rev #	Date	A. El-Dinary			
A					
B					
C					
D					
E					
F					
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I					
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GUVI Instrument Approval Page

Rev #	Date	B. Ogorzalek	D. Mabry		
A					
B					
C					
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E					
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G					
H					
I					
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TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

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SABER Instrument Approval Page

Rev #	Date	M. Vanek	S. Brown	M. Jensen	
A					
B					
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TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

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SEE Instrument Approval Page

Rev #	Date	G. Ucker	M. Lankton		
A					
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TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

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TIDI Instrument Approval Page

Rev #	Date	C. Edmonson	S. Musko		
A					
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3. COMMAND AND DATA HANDLING INTERFACE REQUIREMENTS

3.1 REFERENCES

3.1.1 MIL-STD-1553 Bus

The instrument suppliers have agreed to use the MIL-STD-1553 bus standard for the control and data interface to the TIMED spacecraft command and data handling subsystem. This standard is described in the following references:

MIL-STD-1553B	Aircraft Internal Time Division Command/Response Multiplex Data Bus , with Notice II, 9/8/86
ILC Data Device Corp	MIL-STD-1553 Designers Guide, Third Edition, 1990
UTMC	MIL-STD-1553 Product Handbook, 1991
7363-9111	TIMED Command and Data Handling 1553 Bus Specification

3.1.2 CCSDS Commands

TIMED will make use of the Consultative Committee for Space Data Systems (CCSDS) standards for transmission of command data to the instruments. These standards are described in the following references:

CCSDS 201.0-B-1	Telecommand Part 1 Channel Service Architectural Specification, Blue Book, CCSDS, NASA Communications & Data Systems Division, January 1987.
CCSDS 102.0-B-2	Telecommand Part 2 Data Routing Service, Blue Book, CCSDS, NASA Communications & Data Systems Division, November, 1992.
CCSDS 201.1-B-1	Telecommand Part 2.1 Command Operation Procedures, Blue Book, CCSDS, NASA Communications & Data Systems Division, October, 1991.
CCSDS 200.0-G-6	Telecommand Summary of Concept and Service, Green Book, CCSDS, NASA Communications Data Systems Division, January, 1987.

3.1.3 CCSDS Telemetry

A variable length telemetry message is packaged into fixed length packets as defined in the reference document CCSDS 102.0-B-4. The packet data field shall be 256 octets giving a total size with header of 262 octets (131 words, 5 messages on the 1553 bus). The CCSDS telemetry standard is described in the following references:

CCSDS 102.0-B-4	Packet Telemetry, Blue Book, CCSDS, NASA Communications & Data Systems Division, November, 1995.
CCSDS 101.0-B-3	Telemetry Channel Coding, Blue Book, CCSDS, NASA Communications & Data Systems Division, May, 1992.

3.2 TIMED C&DH SUBSYSTEM SERVICES

The C&DH electronics provides:

- Uplink command processing
- Telemetry data collection and processing
- Mass storage of science and engineering data
- Autonomous fault protection using currents, temperatures and telltales
- Subsystem intercommunication
- Spacecraft timekeeping and synchronization

3.2.1 Command Types

The type of commands processed are:

- Relay
- Subsystem/Instrument data loads
- Execute 1553 bus mode codes

3.2.2 Power Switching Services

Power switching provides switched power, pulsed relay outputs for switching relays in other subsystems. Relay coils and drive circuits are redundant.

3.2.3 MIL-STD-1553 Bus Network Services To Instruments

The TIMED C&DH 1553 bus network provides the following services:

1. Distribution of CCSDS command packets
2. Collection of packetized data
3. Collection of real time telemetry (non-packetized)
4. Distribution of spacecraft time
5. Synchronization to better than 10-ms

6 Distribution of spacecraft status
7 Remote terminal to remote terminal transfers
8 Remote terminal data wrap-around test
9 Remote terminal diagnostic functions

The TIMED C&DH 1553 bus network runs at a minor frame rate of 8-Hz. The major frame rate is 1 Hz. Bus minor frames are numbered 0 to 7.

Figure 3.2.3-1 is a diagram giving the physical interface between an instrument and the MIL-STD-1553 bus. The bus is dual redundant and consists of side A and side B. Data is biphase modulated onto one side of the bus so that both clock and data can be retrieved. The instrument designers are required to use a SEAFAC tested interface circuit which previously has been certified to be in compliance with MIL-STD-1553. Recommended vendors are: ILC DDC, UTMC, and GEC Plessey. It is recommended that the isolation transformer be located as close to the instrument interface connector as practical. During each instrument's Critical Design Review, the detailed package design of the instrument will be reviewed for an acceptably low risk of a short to, or across, the 1553 bus.

Figure 3.2.3-1. MIL-STD-1553 interface.

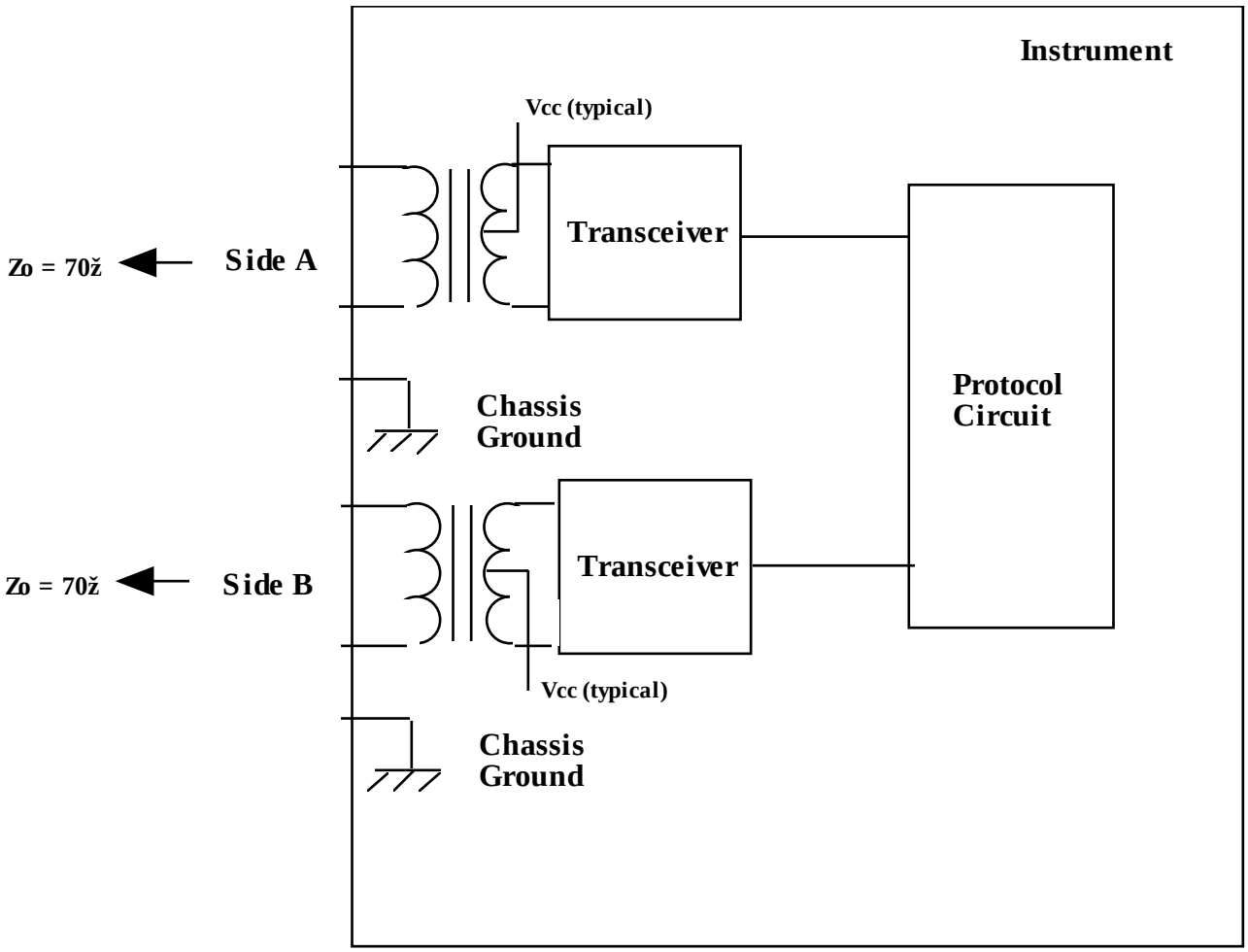

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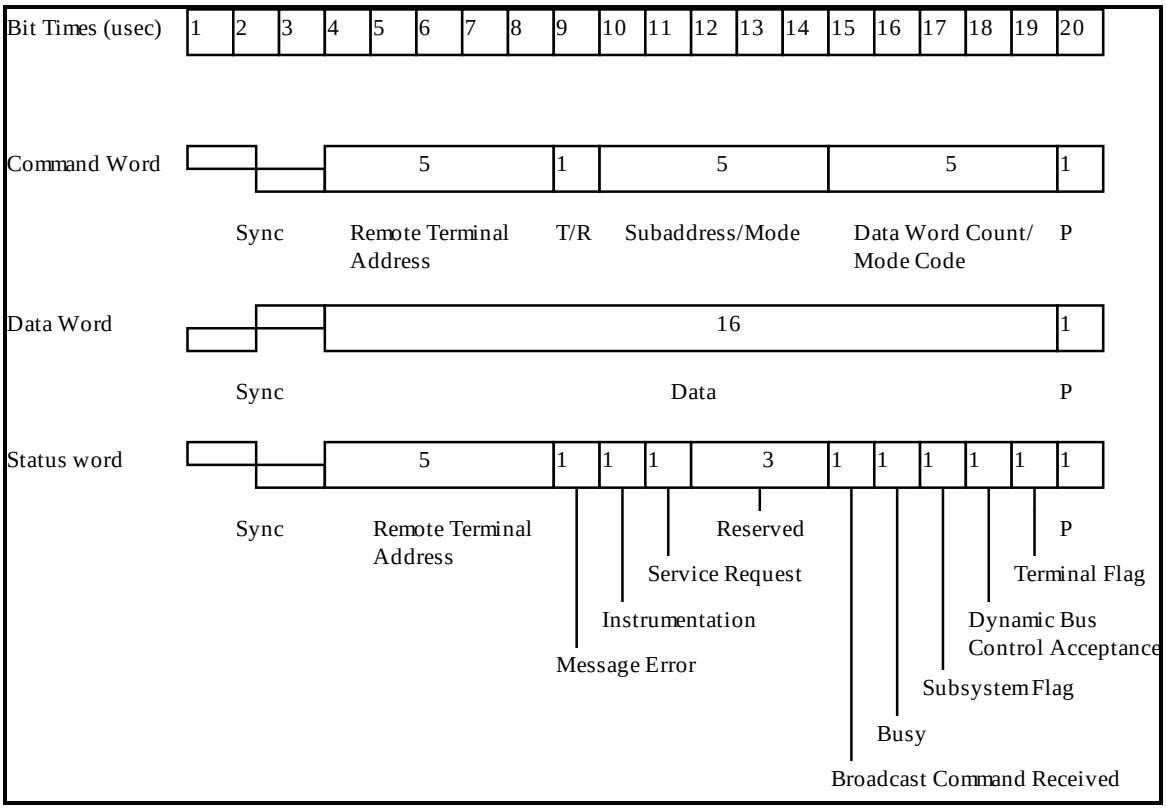
Figure 3.2.3-2 gives the word formats used for MIL-STD-1553. The instrument will be commanded to transmit or receive from 1 to 32, 16-bit words from/to a subaddress. The instrument will respond with a status word, either before transmitting data or after receiving data. Subaddresses 0 and 31 are not used for data transfer, but are reserved to signal predefined mode commands. The word count field is used to define the mode command sent.

Figure 3.2.3-2. MIL-STD-1553 word formats.



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3.2.3.1 MIL-STD-1553 Bus Remote Terminal Address Assignments

The TIMED remote terminal address assignments are:

Subsystem	Address
C&DH RT Mode	1
Attitude ~~A~~	~~2~~
~~Attitude B~~1	~~2~~
Attitude 2	3
Power ~~A~~1	4
SABER Cryogen Electronics	6
GUVI	9
TIDI	10
SABER	11
SEE	12
Power 2	20

3.2.3.2 MIL-STD-1553 Bus Mode Codes

For the TIMED mission the following 1553 bus mode codes will be supported:

Function	Mode Code	T/R	Data Word
Transmit status word	00010	T	No
Initiate self test	00011	T	No
Transmitter shutdown	00100	T	No
Override transmitter shutdown	00101	T	No
Inhibit terminal flag bit	00110	T	No
Override inhibit terminal flag bit	00111	T	No
Reset remote terminal	01000	T	No
Transmit vector word	10000	T	Yes
Synchronize with data word	10001	R	Yes
Transmit last command	10010	T	Yes
Transmit BIT word	10011	T	Yes

All instruments should support all of these mode codes except Transmit vector word and Synchronize with data word. These two mode codes are supported by certain spacecraft sub-systems, but need not be supported by the instruments.

3.2.3.3 Instrument MIL-STD-1553 bus subaddress assignments

The table below represents the general 1553-bus subaddress assignments for the instruments. Individual instruments may have slightly different assignments. These differences will be specified in the SIIS for each instrument.

Addr	Receive	Transmit
0	Reserved for Mode Codes	Reserved for Mode Codes
1	Command buffer 1	Science telemetry buffer 1
2	Command buffer 1	Science telemetry buffer 1
3	Command buffer 1	Science telemetry buffer 1
4	Command buffer 1	Science telemetry buffer 1
5	(assign as illegal)	Science telemetry buffer 1
6	Command buffer 2	Science telemetry buffer 2
7	Command buffer 2	Science telemetry buffer 2
8	Command buffer 2	Science telemetry buffer 2
9	Command buffer 2	Science telemetry buffer 2
10	(assign as illegal)	Science telemetry buffer 2
11	Command buffer status	Telemetry configuration
12	(assign as illegal)	Real time telemetry
13	(assign as illegal)	(assign as illegal)
14	(assign as illegal)	(assign as illegal)
15	(assign as illegal)	(assign as illegal)
16	(assign as illegal)	(assign as illegal)
17	(assign as illegal)	(assign as illegal)
18	(assign as illegal)	(assign as illegal)
19	Time code message	Time code received status
20	Spacecraft status	(assign as illegal)
21	(assign as illegal)	(assign as illegal)
22	(assign as illegal)	(assign as illegal)
23	(assign as illegal)	(assign as illegal)
24	(assign as illegal)	(assign as illegal)
25	(assign as illegal)	(assign as illegal)
26	(assign as illegal)	(assign as illegal)
27	(assign as illegal)	(assign as illegal)
28	(assign as illegal)	(assign as illegal)
29	(assign as illegal)	(assign as illegal)
30	Data wrap around test	Data wrap around test
31	Reserved for Mode Codes	Reserved for Mode Codes

3.2.3.4 Subaddress Assignment Definitions (R=Receive, T=Transmit)

3.2.3.4.1 Receive Subaddress Assignments R0 Through R31

The following represent general receive subaddress assignments. Individual instrument subaddress assignments may differ. This is documented in the instrument SIIS.

R0

Reserved for MIL-STD-1553 defined receive mode codes. However, the only receive mode code is Synchronize with data word, which is being used by several spacecraft sub-systems, but none of the instruments. Therefore, all instruments should illegalize subaddress R0.

R1-R4

This is buffer 1 of the command input double-buffer (see Figure 3.2.3.5-1). A CCSDS formatted command packet is loaded as 1553 messages starting at R1 and finishing at R4. Since a maximum of 32 16-bit words can be loaded to a 1553 subaddress, 128 words will be loaded to this buffer each time. If the last message associated with a given packet requires less than 128 words, zeros will be appended to give 128 words. Three flags at subaddress R11 contain information about the status of this buffer; please refer to the section on subaddress R11.

Command messages will be sent to the two command buffers at a combined maximum rate of 8 Hz, i.e., the sum of the number of messages loaded to the two command buffers in a one second interval will be less than or equal to eight. Messages within a command packet will be strictly alternated between the two command buffers, with the first message of the packet always being sent to buffer 1. The first message sent in any one second major frame will also be sent to buffer 1. Messages will be sent to command buffer 1 only in bus minor frames 0, 2, 4 and 6, while messages to command buffer 2 will be sent only in bus minor frames 1, 3, 5, and 7. These messages will be sent at the same time in each bus minor frame, meaning that successive messages will be spaced 125 msec. apart. An instrument must keep up with the loading of these two buffers.

It should be noted that since the first message of any packet will be sent to buffer 1, and buffer 1 is only loaded in bus minor frames 0, 2, 4 and 6, that no more than four packets per seconds can be delivered over the bus.

If an instrument chooses to use message indexing for command inputs, all messages to the command buffer 1 shall be loaded to R1. The message will still consist of 128 words.

The length and contents of the CCSDS command packets sent to an instrument must be defined by that instrument. The maximum length of the application data portion of a command packet is 4000 bytes.

R5 (the instrument should assign this subaddress as illegal)

R6-R9

This is buffer 2 of the command input double-buffer (see Figure 3.2.3.5-1). A CCSDS formatted command packet is loaded as 1553 messages starting at R6 and finishing at R9. Since a maximum of 32 16-bit words can be loaded to a 1553 subaddress, 128 words will be loaded to this buffer each time. If the last message associated with a given packet requires less

than 128 words, zeros will be appended to give 128 words. Three flags at subaddress R11 contain information about the status of this buffer; please refer to the section on subaddress R11.

Command messages will be sent to the two command buffers at a combined maximum rate of 8 Hz, i.e., the sum of the number of messages loaded to the two command buffers in a one second interval will be less than or equal to eight. Messages within a command packet will be strictly alternated between the two command buffers, with the first message of the packet always being sent to buffer 1. The first message sent in any one second major frame will also be sent to buffer 1. Messages will be sent to command buffer 1 only in bus minor frames 0, 2, 4 and 6, while messages to command buffer 2 will be sent only in bus minor frames 1, 3, 5, and 7. These messages will be sent at the same time in each bus minor frame, meaning that successive messages will be spaced 125 msec. apart. An instrument must keep up with the loading of these two buffers.

It should be noted that since the first message of any packet will be sent to buffer 1, and buffer 1 is only loaded in bus minor frames 0, 2, 4 and 6, that no more than four packets per seconds can be delivered over the bus.

If an instrument chooses to use message indexing for command inputs, all messages to the command buffer 2 shall be loaded to R6. The message will still consist of 128 words.

The length and contents of the CCSDS command packets sent to an instrument must be defined by that instrument. The maximum length of the application data portion of a command packet is 4000 bytes.

R10 (the instrument should assign this subaddress as illegal)

R11

The command bus status word provides three flags defining the condition of the command double buffer (see Figure 3.2.3.5-1). Bits 15 and 13 define the status of command buffer 1, while bit 14 defines the status of command buffer 2.

Bit 15 indicates when 1553 messages have been loaded to the subaddresses that constitute command buffer 1, and bit 13 indicates when that data is the start of a new CCSDS command packet. Bit 15 will be set by the C & DH software immediately after it loads command buffer 1. Bit 13 will be set at the same time if the data in command buffer 1 contains the start of a new CCSDS command packet. Since buffer 1 can only be loaded in minor frames 0, 2, 4 and 6, these bits can only be set in minor frames 0, 2, 4 and 6. After reading the contents of buffer 1, the remote terminal may clear bits 15 and 13 of R11. Regardless of what the instrument does, the C & DH will clear these bits 125 msec. after they are set, in minor frames 1, 3, 5 and 7. A remote terminal must thus detect that these bits are set within 125 msec., and must read the contents of buffer 1 within 250 msec.

Bit 14 indicates when 1553 messages have been loaded to the subaddresses that constitute command buffer 2. Bit 14 will be set by the C & DH software immediately after it loads command buffer 2. Since buffer 2 can only be loaded in minor frames 1, 3, 5 and 7, this bit can only be set in minor frames 1, 3, 5 and 7. After reading the contents of buffer 2, the instrument may clear bit 14 of R11. Regardless of what the instrument does, the C & DH will clear this bit 125 msec. after they are set, in minor frames 0, 2, 4 and 6. A remote terminal must thus detect that this bit is set within 125 msec., and must read the contents of buffer 2 within 250 msec.

R12 (the instrument should assign this subaddress as illegal)

R13 (the instrument should assign this subaddress as illegal)

R14 (the instrument should assign this subaddress as illegal)

R15 (the instrument should assign this subaddress as illegal)

R16 (the instrument should assign this subaddress as illegal)

R17 (the instrument should assign this subaddress as illegal)

R18 (the instrument should assign this subaddress as illegal)

R19

Subaddress R19 is allocated for time distribution. A 2-word (32 bits total) time code message, is transmitted to R19. The message defines the start time of the next 1-second interval. In the spacecraft operational mode, the message contains universal time derived from the on board GPS receiver. This time message is used by the instrument to derive its packetized telemetry secondary header. The message conforms to time code format CCSDS 301.0-B-1, blue book, section 2.2 “CCSDS unsegmented time code” (CUC). It is a binary weighted sequence transmitted msb (bit weight 136 years) first and lsb (bit weight one second) last. A separate time code transmission message is sent to each instrument and a valid message response word is expected from each instrument. Broadcast type messages, that do not require a response word, are not sent over the TIMED C&DH 1553 bus. The time code message is sent as the last message of a 1-second major frame interval before the guaranteed quiet time.

The start of the next 1-second interval is marked by the C&DH bus controller reading from T19. The C&DH 1553 bus controller completes reading T19 of all instruments within 2 milliseconds. The instrument recognizes reading from T19 as the set mark for the last transmitted time code. The instrument’s 1553 remote terminal protocol circuit is set to output an interrupt (or time mark pulse) upon receiving a T19 read request. On interrupt, the instrument processor clears its subsecond vernier clock counter and updates its one second resolution clock.

The spacecraft clock maintained by the instrument is read each packetization interval to time tag its data.

Message Field	1553 Sub-address	Word Numbers	Number of Words	Comments
Warnings	R20	0	1	One word that will contain information about terminator crossings, power down indicators, etc.
				Bit 15 - Warning Flag Validity Bit 1: 1 = flags in bits 14-12 are valid; 0 = flags in bits 14-12 are not valid
				Bit 14 - Day/Night indicator: 1 = day, 0 = night
				Bit 13 - South Atlantic Anomaly (SAA) indicator: 1 = In SAA, 0 = not in SAA
				Bit 12 - Polar Region indicator: 1 = in polar region, 0 = not in polar region
				Bit 11 - GUVI powerdown: bit is set 10 seconds before power is removed from the instrument, and cleared after power is removed.
				Bit 10 - SABER powerdown: bit is set 10 seconds before power is removed from the instrument, and cleared after power is removed.
				Bit 9 - TIDI powerdown: bit is set 10 seconds before power is removed from the instrument, and cleared after power is removed.
				Bit 8 - SEE powerdown: bit is set 10 seconds before power is removed from the instrument, and cleared after power is removed.
				Bit 7 - Warning Flag Validity Bit 2: 1 = flags in bits 6-4 are valid; 0 = flags in bits 6-4 are not valid
				Bit 6 - Yaw maneuver indicator: bit is set 60 seconds prior to the start of a maneuver, and cleared when operational pointing accuracy is achieved.
				Bit 5 - Solar Panel Rotation indicator: bit is set 15 seconds before the solar panel rotation starts, and cleared when the rotation has completed.
				Bit 4 - Spacecraft Attitude Sun Safe Indicator: 1 = spacecraft is in Sun Safe Mode, 0 = spacecraft is in Nadir Pointing or Operational Mode (See Spacecraft Attitude Nadir Pointing Indicator)
				Bit 3 - Software LVS indicator: 1 = the software has detected an LVS, and instruments will be turned off with 10 seconds notice; 0 = no LVS has occurred
				Bit 2 - Extended 1553 Dead Time Indicator: 1 = the 1553 bus dead time starting at the end of the current second will extend up to 1 second longer than normal; 0 = normal operation.
				Bit 1 - Spacecraft Attitude Nadir Pointing Indicator: 1 = spacecraft is in Nadir Pointing Mode; 0 = spacecraft is in Operational Mode
				Bit 0 : spare
Data Validity Word	R20	1	1	One word containing information about whether the fields of the status message contain valid data.
				Bit 15: 1 = time offset, position and velocity are valid, 0 = time offset, position and velocity are not valid
				Bit 14: 1 = G & C time and attitude are valid, 0 = G & C time and attitude are not valid
				Bit 13: 1 = G & C time and sun vector are valid, 0 = G & C time and sun vector are not valid
				Bits 12-0: spare
Position - Latitude	R20	2-3	2	Geodetic Latitude, value is 32 bit signed integer, LSB is 128/(2**31) degrees
Position - Longitude	R20	4-5	2	Geodetic Longitude, value is 32 bit unsigned integer, LSB is 512/(2**32) degrees
Position - Height	R20	6-7	2	Height, WGS-84 Reference Ellipsoid, 32 bit unsigned integer, LSB = (2**23)/(2**32) meters
Velocity - East	R20	8-9	2	Earth Centered Earth Fixed - CTS, Earth Relative, 32 bit signed integer, LSB = (2**13)/(2**31) meters/second
Velocity - North	R20	10-11	2	Earth Centered Earth Fixed - CTS, Earth Relative, 32 bit signed integer, LSB = (2**13)/(2**31) meters/second
Velocity - Up	R20	12-13	2	Earth Centered Earth Fixed - CTS, Earth Relative, 32 bit signed integer, LSB = (2**13)/(2**31) meters/second
G & C Time	R20	14-15	2	G&C Time UCU (Time when sun vector and attitude are valid)
G&C Time Vernier	R20	16	1	G&C Time Vernier (Time when sun vector and attitude are valid)
Sun Vector	R20	17-19	3	Sun unit vector supplied by G & C in body coordinates; 3 elements, ordered x, y,and z; 16 bit unsigned integer per element; LSB = 1/(2**16). A value of all zeros represents -1; 2^15 represents 0; all bits set represents +1.
Roll	R20	20-21	2	32 bit unsigned integer, LSB =360/(2**32) degrees. A value of 0 is an angle of -180 degrees, a value of 2^31 is zero degrees and all bits set is 180 degrees.
Pitch	R20	22-23	2	32 bit unsigned integer, LSB =360/(2**32) degrees. A value of 0 is an angle of -180 degrees, a value of 2^31 is zero degrees and all bits set is 180 degrees.
Yaw	R20	24-25	2	32 bit unsigned integer, LSB =360/(2**32) degrees. A value of 0 is an angle of -180 degrees, a value of 2^31 is zero degrees and all bits set is 180 degrees.

Table 3.2.3-1 Spacecraft Status Message

R20

The spacecraft status information shown in the following table is sent once per second to each instrument. The spacecraft status message is sent to all instruments in bus minor frame 5.

The spacecraft position and velocity are provided from the GPS Navigation System. These values are valid at the next one second interval (see R19). The time associated with the GPS estimates is given in the time message provided in R19.

The spacecraft sun vector and attitude data are provided from the Guidance and Control System. These data are valid at the time provided in the status message. The data will have a latency of 0.7 to 3.9 seconds.

R21 (the instrument should assign this subaddress as illegal)

R22 (the instrument should assign this subaddress as illegal)

R23 (the instrument should assign this subaddress as illegal)

R24 (the instrument should assign this subaddress as illegal)

R25 (the instrument should assign this subaddress as illegal)

R26 (the instrument should assign this subaddress as illegal)

R27 (the instrument should assign this subaddress as illegal)

R28 (the instrument should assign this subaddress as illegal)

R29 (the instrument should assign this subaddress as illegal)

R30

Data wrap around test. Subaddresses R30 and T30 must be assigned the same address space in the instrument 1553 file memory. The wrap around test consists of writing data into R30 and reading the same data back from T30. The size of the data wrap around is 32 words. The data wrap around test will be performed on a given instrument once every 16 seconds.

R31

Reserved for MIL-STD-1553 defined receive mode codes. However, the only receive mode code is Synchronize with data word, which is being used by several spacecraft sub-

systems, but none of the instruments. Therefore, all instruments should illegalize subaddress R31.

3.2.3.4.2 Transmit Subaddress Assignments T0 Through T31

The following represent general transmit subaddress assignments. Individual instrument subaddress assignments may differ. This is documented in the instrument SIIS.

T0

Reserved for MIL-STD-1553 defined mode codes. An instrument should support both T0 and T31 for transmit mode codes. Legal TIMED C&DH 1553 bus transmit mode codes are:

Function	Mode Code	Data Word
Transmit status word	00010	No
Initiate self test	00011	No
Transmitter shutdown	00100	No
Override transmitter shutdown	00101	No
Inhibit terminal flag bit	00110	No
Override inhibit terminal flag bit	00111	No
Reset remote terminal	01000	No
Transmit vector word	10000	Yes
Transmit last command	10010	Yes
Transmit BIT word	10011	Yes

An instrument must support all bus transmit mode codes except Transmit vector word. The instrument must assign transmit mode codes that are not supported as illegal.

T1-T5

This is buffer 1 of the telemetry double-buffer (see Figure 3.2.3.6-1). The instrument loads variable length telemetry messages as standard CCSDS size packets. Each packet is 2096 bits long and consists of a 48-bit primary header, a 48-bit secondary header and a 2000-bit data field. The packet is divided into 131, 16-bit words and packaged into five, MIL-STD-1553 messages. The first four MIL-STD-1553 messages are 32-words long (maximum length). The packet header is contained in the first portion of the first message. The fifth, and last MIL-STD-1553 message, the last part of the packet, is 3-words long. Packets are filled contiguously starting at T1. Bit 15 of subaddress T11 controls the reading of this buffer; please refer to the section on T11 for details. Instrument packets will be collected in bus minor frames 1, 3, 5 and 7.

An instrument must “ping-pong” between the two telemetry buffers, both within a bus major frame and across major frame boundaries. Successive packets can not be loaded to the same buffer.

If an instrument chooses to use message indexing for telemetry messages, all messages for telemetry buffer 1 shall be placed in T1. The message length will still be 131 words.

There will be a limit on the number of telemetry packets that the C & DH will collect from an instrument in each bus major frame. This limit will be independent of the daily limit of packets stored to the Solid State Recorder. The limit will be specified in the instrument SIIS.

T6-T10

This is buffer 2 of the telemetry double-buffer (see Figure 3.2.3.6-1). The instrument loads variable length telemetry messages as standard CCSDS size packets. Each packet is 2096 bits long and consists of a 48-bit primary header, a 48-bit secondary header and a 2000-bit data field. The packet is divided into 131, 16-bit words and packaged into five, MIL-STD-1553 messages. The first four MIL-STD-1553 messages are 32-words long (maximum length). The packet header is contained in the first portion of the first message. The fifth, and last MIL-STD-1553 message, the last part of the packet, is 3-words long. Packets are filled contiguously starting at T6. Bit 14 of subaddress T11 controls the reading of this buffer; please refer to the section on T11 for details. Instrument packets will be collected in bus minor frames 1, 3, 5 and 7.

An instrument must “ping-pong” between the two telemetry buffers. Successive packets can not be loaded to the same buffer.

If an instrument chooses to use message indexing for telemetry messages, all messages for telemetry buffer 2 shall be placed in T6. The message length will still be 131 words.

T11

The telemetry configuration word contains two bits that indicate when the two telemetry buffers are available to be read by the C & DH system. Bit 15 is the “ready to read” bit for buffer 1 and bit 14 is the “ready to read” bit for buffer 2. T11 is read (polled) by the C&DH processor 4 times per second in bus minor frames 0, 2, 4, and 6 for the GUVI, SABER, and TIDI instruments, and once per second in bus minor frame 0 for the SEE instrument. There are many instrument unique details concerning the polling of T11 and the collection of telemetry packets, and they are document in the various instrument SIISs.

T12

Subaddress T12 is used for the instrument status words. An instrument may have up to four status words. The instrument should include in these status words information about the operating mode of the instrument, indications of any problems within the instrument, and information about whether the last CCSDS command packet addressed to the instrument was

accepted or rejected. All instrument status will be collected once per major frame in bus minor frame 2. Instrument status words will be defined in the appropriate SIIS document.

The C&DH system provides an optional heartbeat monitor function and an optional instrument defined autonomy bit. Information regarding these optional services is given in the section on Autonomy Services 3.2.5. These bits are located in the instrument status word.

Due to limited instrument telemetry visibility, a set of three counters have been defined to aid in troubleshooting. These counters, a 3 bit command packet received counter, a 3 bit command reject counter, and a 4 bit error counter should also be located in the instrument status words. The command packet received counter shall be a sum of all command packets received by the instrument (modulo 8). The command reject counter be a sum of all command packets rejected by the instrument (modulo 8). The error counter shall be a sum of all flagged instrument errors (modulo 16). The first two of these counters are mandatory while the last (error counter) is optional.

In order to ease the ground system development effort, standard locations for each of these parameters within the instrument status words has been defined and is detailed in Table 3.2.3.4.1-1.

Word Number	Bit Number	Parameter
T12, Word 0	15	Heartbeat (optional)
	14	Autonomy (optional)
	13	Command Packet received counter bit 2 (MSB)
	12	Command packet received counter bit 1
	11	Command packet received counter bit 0 (LSB)
	10	Command reject counter bit 2 (MSB)
	9	Command reject counter bit 1
	8	Command reject counter bit 0 (LSB)
	7	Error counter bit 3 (MSB)
	6	Error counter bit 2
	5	Error counter bit 1
	4	Error counter bit 0 (LSB)

Table 3.2.3-2 Instrument Status Word Format

T13 (the instrument should assign this subaddress as illegal)

T14 (the instrument should assign this subaddress as illegal)

T15 (the instrument should assign this subaddress as illegal)

T16 (the instrument should assign this subaddress as illegal)

T17 (the instrument should assign this subaddress as illegal)

T18 (the instrument should assign this subaddress as illegal)

T19

Subaddress R19 is allocated for time distribution. A 2-word (32 bits total) time code message, is transmitted to R19. The message defines the start time of the next 1-second interval. In the spacecraft operational mode, the message contains universal time derived from the on board GPS receiver. This time message is used by the instrument to derive its packetized telemetry secondary header. The message conforms to time code format CCSDS 301.0-B-1, blue book, section 2.2 “CCSDS unsegmented time code” (CUC). It is a binary weighted sequence transmitted msb (bit weight 136 years) first and lsb (bit weight one second) last. A separate time code transmission message is sent to each instrument and a valid message response word is expected from each instrument. Broadcast type messages, that do not require a response word, are not sent over the TIMED C&DH 1553 bus. The time code message is sent as the last message of a 1-second major frame interval before the guaranteed quiet time.

The start of the next 1-second interval is marked by the C&DH bus controller reading from T19. The C&DH 1553 bus controller completes reading T19 of all instruments within 2 milliseconds. The instrument recognizes reading from T19 as the set mark for the last transmitted time code. The instrument's 1553 remote terminal protocol circuit is set to output an interrupt (or time mark pulse) upon receiving a T19 read request. On interrupt, the instrument processor clears its subsecond vernier clock counter and updates its one second resolution clock. The spacecraft clock maintained by the instrument is read each packetization interval to time tag its data.

T20 (the instrument should assign this subaddress as illegal)

T21 (the instrument should assign this subaddress as illegal)

T22 (the instrument should assign this subaddress as illegal)

T23 (the instrument should assign this subaddress as illegal)

T24 (the instrument should assign this subaddress as illegal)

T25 (the instrument should assign this subaddress as illegal)

T26 (the instrument should assign this subaddress as illegal)

T27 (the instrument should assign this subaddress as illegal)

T28 (the instrument should assign this subaddress as illegal)

T29 (the instrument should assign this subaddress as illegal)

T30

Data wrap around test. Subaddress R30 and T30 must be defined as the same address space in the instrument. The wrap around test consists of writing data into R30 and reading the same data back from T30. The data wrap around test will always occur in bus minor frame 4. The size of the data wrap around is 32 words. The data wrap around test will be performed on a given instrument once every 16 seconds.

T31

Reserved for MIL-STD-1553 defined mode codes. An instrument should support both T0 and T31 for transmit mode codes. Legal TIMED C&DH 1553 bus transmit mode codes are:

Function	Mode Code	Data Word

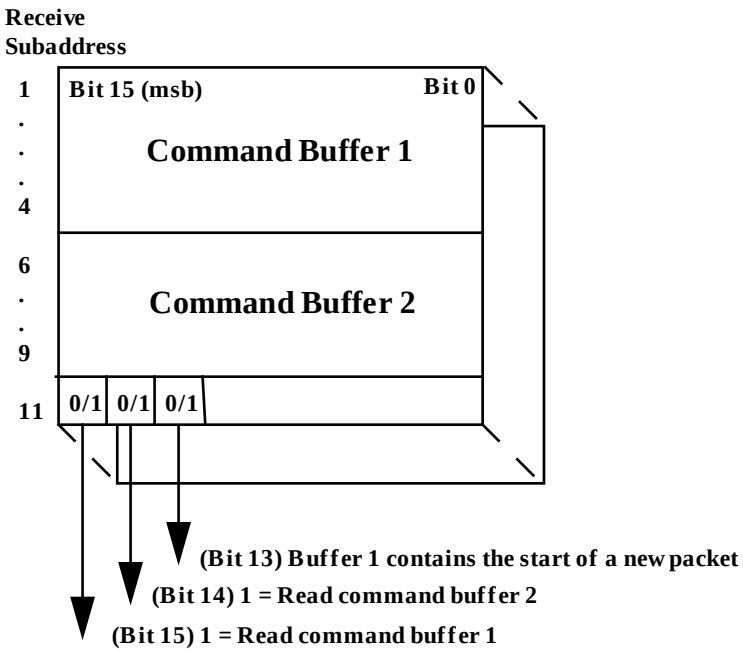
Transmit status word	00010	No
Initiate self test	00011	No
Transmitter shutdown	00100	No
Override transmitter shutdown	00101	No
Inhibit terminal flag bit	00110	No
Override inhibit terminal flag bit	00111	No
Reset remote terminal	01000	No
Transmit vector word	10000	Yes
Transmit last command	10010	Yes
Transmit BIT word	10011	Yes

An instrument must support all bus transmit mode codes except Transmit vector word. The instrument must assign transmit mode codes that are not supported as illegal.

3.2.3.5 Instrument MIL-STD-1553 Subaddress Assignments For Commands

Figure 3.2.3.5-1 gives an overview of the use of the MIL-STD-1553 bus for the transfer of an uplink command packet to an instrument.

Figure 3.2.3.5-1. 1553 bus uplink command packet subaddress assignments.

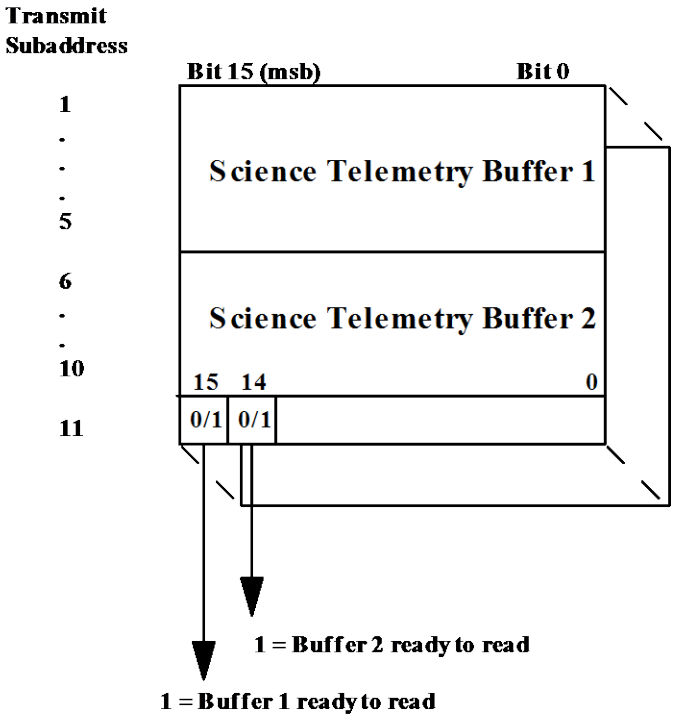


NOTES:
1. **1553 bus protocol allows 32-words (max) per message**
2. **A message is transmitted to one subaddress**
3. **Most 1553 protocol ICs allow multiple messages per subaddress (message indexing)**

3.2.3.6 Instrument Mil-Std-1553 Subaddress Assignments For Telemetry

Figure 3.2.3.6-1 gives an overview of the use of the MIL-STD-1553 bus for transfer of telemetry.

Figure 3.2.3.6-1. 1553 bus packet telemetry subaddress assignments.



NOTES:
1. 1553 bus protocol allows 32-words (max) per message
2. A message is read from one subaddress
3. A telemetry packet is 2092-bits, 131-words, 5-1553 messages
4. The buffer status bits in T11 are read (polled) 4-times per second.

3.2.4 Instrument Housekeeping

The C & DH system will collect, record and downlink several housekeeping parameters for each instrument. Main bus current, operational heater bus current, and survival heater bus current will be collected for each instrument. Data from survival temperature sensors in each instrument will be collected. TIDI has five such sensors, GUVI has two sensors, and SEE and SABER each have four sensors. Telltales from relays used to switch power to the instruments will also be collected.

3.2.5 Autonomy Services

The C & DH system has the ability to take autonomous action based on the value of housekeeping parameters that it has collected. These parameters are collected once per second by the C & DH system, and can be evaluated in autonomy rules once per second. Any instrument housekeeping parameters mentioned in section 3.2.4 can serve as the basis of autonomy rules. In addition, one bit from the instrument's status telemetry in T12 (separate from the instrument heartbeat described in the next paragraph) can serve as the basis for an autonomy rule to be kept in the C & DH system. The definition of the bit and the autonomy rule are up to the instrument.

The C & DH system will treat one bit of an instrument's real time telemetry as an instrument heartbeat, if requested by the instrument. The instrument should use bit 15 of the first word of its real time telemetry for this purpose. It should toggle this bit every two seconds. An autonomy rule can be loaded to the C & DH system that will allow it to monitor the instrument heartbeat bit and take pre-determined actions if this bit remains in the same state for a period of time specified in the rule. There is no requirement for an instrument to have a heartbeat in its real time telemetry.

3.2.6 1553 Bus Quiet Time

The time distribution message written to an instrument at subaddress R19 near the end of bus minor frame 7 will mark the start of a quiet time on the 1553 bus. During that time, there will be no messages addressed to that instrument on the 1553 bus. The quiet time will last for a minimum of 25 msec. The quiet time will terminate with the time synchronization message to that instrument at the start of the next bus major frame.

In normal operation, the spacecraft GPS Navigation System (GNS) provides a time synchronization signal to the C & DH system that is exactly one second later than the previous time synchronization signal. The C & DH in turn uses this signal to begin the start of the next 1553 bus major frame. When the GNS transitions from non-navigational mode to navigational mode, the time between two successive time synchronization signals will be greater than 1 second, and as long as two seconds. When this occurs, the C & DH will extend the dead time period, up to one second longer than the normal dead time. A bit in the spacecraft status

message will warn the instruments that this is about to occur. See the definition of this message (R20) for details.

3.2.7 1553 Bus Retries

1553 bus protocol chips have the ability to retry individual 1553 bus messages if they detect that an error has occurred in transmitting the message the first time. Up to three retries will take place on the individual messages that make up the time distribution, time synchronization, spacecraft status and command packet messages. Up to one retry will take place on the individual messages that make up the packetized telemetry, instrument status telemetry and diagnostic mode code messages. No retries will take place on the messages used in the data wrap around test.

3.2.8 Hardware Reset Function

An optional instrument reset capability exists for instruments. The function will be implemented via a separate discrete interface. The standard interface circuit for the function is shown below.

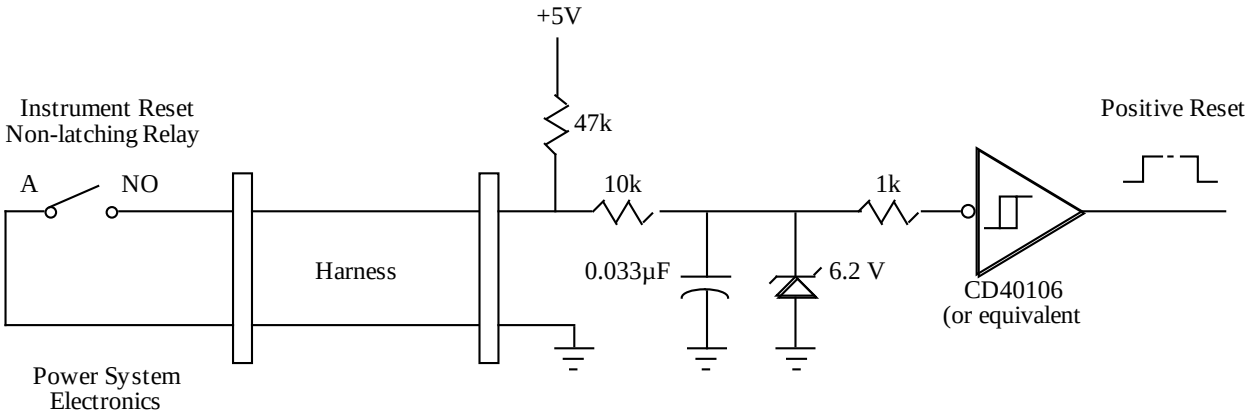


Figure 3.2.1-1 Hardware Reset Standard Interface Circuit

3.3 PACKETIZED TELEMETRY FORMAT

The bit field definitions for instrument packet headers are given in Table 3.3-1. All packets must have a primary header and a secondary header. The version number, type indicator and packet secondary header flag field are all fixed, as shown in Table 3.3-1. Each instrument has a range of 128 valid 11 bit application process identifiers (Ap IDs). Different instrument data field formats must be identified by different Ap IDs within that range.

An instrument message may consist of one or more packets. The grouping flags in the first packet of a multi packet group are set to “01”. Intermediate packets within the group have “00” grouping flags. The last packet within a group has “10” grouping flags. If a packet is not part of a group, these flags are set to “11”.

For all cases the 14-bit source sequence count will be stepped each time a new packet is generated. The packet length field is fixed, as shown in Table 3.3-1.

The first 32 bits of the packet secondary header must contain the time at which the data was collected, with the least significant bit of the time having a value of 1 second. The last 16 bits of the secondary header are defined by the instrument. These bits can be used for a vernier time to give more precise information about when the data was collected.

TABLE 3.3-1

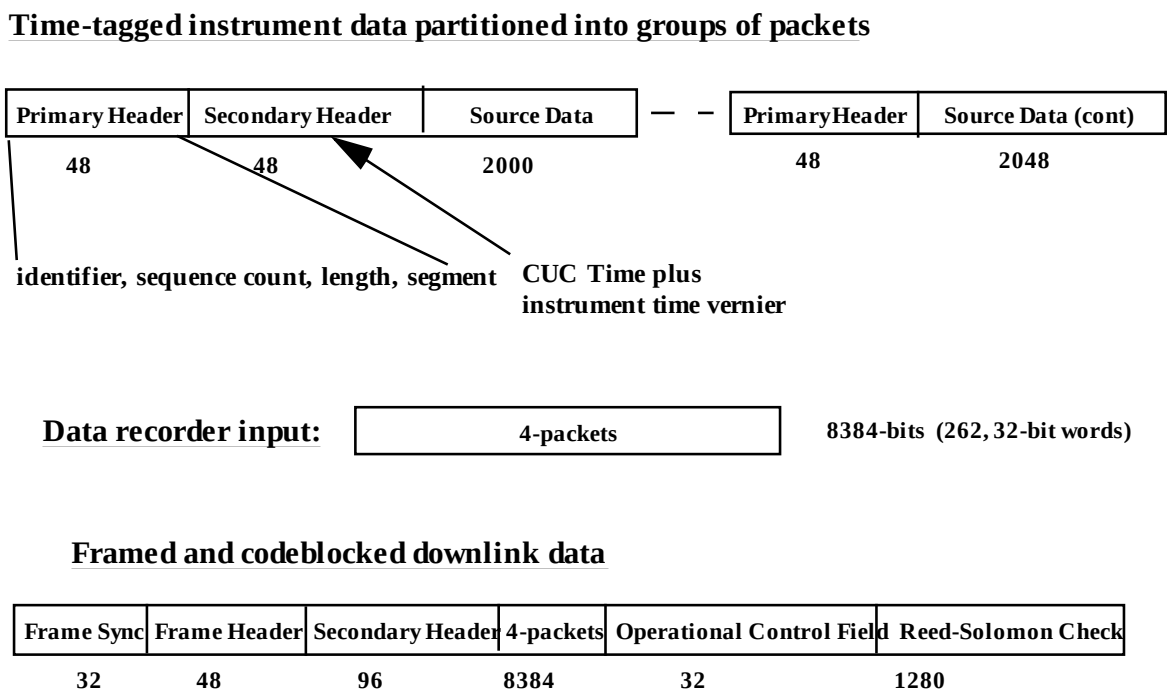
PACKETIZED TELEMETRY HEADER FORMAT.

ITEM	BIT FIELD	LENGTH (bits)	VALUE (binary)	DESCRIPTION
Primary Header	Version Number	3	000	Designates a source packet
	Type Indicator	1	0	Designates a telemetry packet
	Secondary header flag	1	1	Secondary header flag present
	Application process identifier (source ID)	11	000 0xxx xxxx	C&DH #1
			000 1xxx xxxx	C&DH #2
			001 0xxx xxxx	G&C #1
			001 1xxx xxxx	G&C #2
			010 0xxx xxxx	Active G&C
			010 1xxx xxxx	Inactive G&C
			011 0xxx xxxx	GPS Nav System #1
			011 1xxx xxxx	GPS Nav System #2
			100 0xxx xxxx	Ground System
			100 1xxx xxxx	GUVI
			101 0xxx xxxx	TIDI
			101 1xxx xxxx	SABER
			110 0xxx xxxx	SEE
			110 1xxx xxxx	Power System #1
			111 0xxx xxxx	Power System #2
			111 1111 1111	Idle Packets
	Grouping flags	2	01	First packet in group
			00	Intermediate packet
			10	Last packet in group
			11	Not part of group
	Source	14		Continuous sequence count (modulo 16384) of source for specific application ID
	Packet Length	16	0000 0000	Number of octets in [packet secondary header +
			1111 1111	packet data field] - 1
Secondary Header	Spacecraft Time	32		Packet source's value of mission at time of data

				sample
	Time Vernier (optional)	16		Time interpolation bits defined by instrument
Data		2000		With secondary header

Figure 3.3-1 gives an overview of a telemetry message divided into packets, stored in the data recorder, and placed into downlink frames.

Figure 3.3-1. Packetized and framed telemetry.

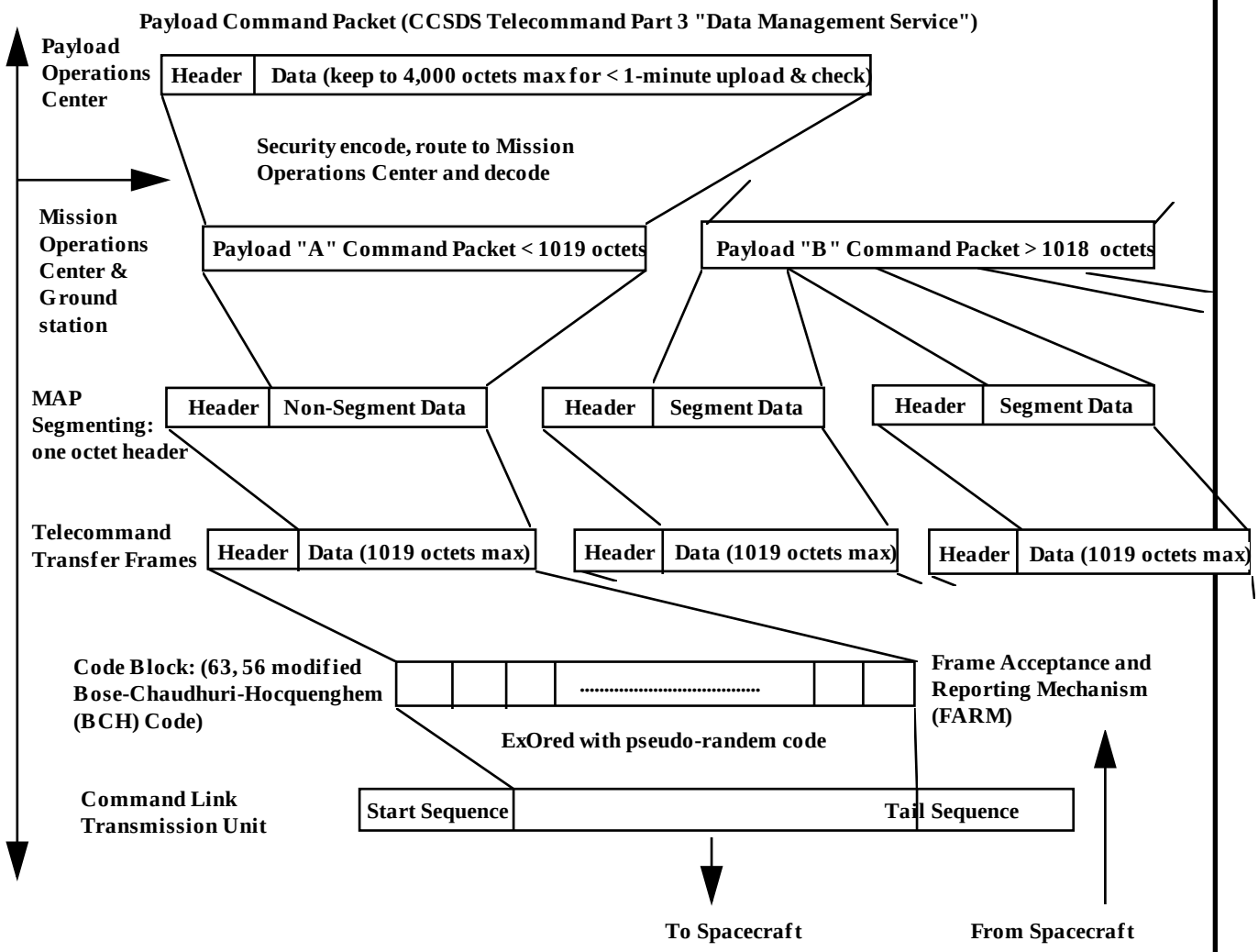


FSCM NO.	SIZE	DWG. NO.
88898	A	7363-9050 A
		4/3/98
SCALE	DO NOT SCALE PRINT	SHEET

3.4 TELECOMMAND FORMAT

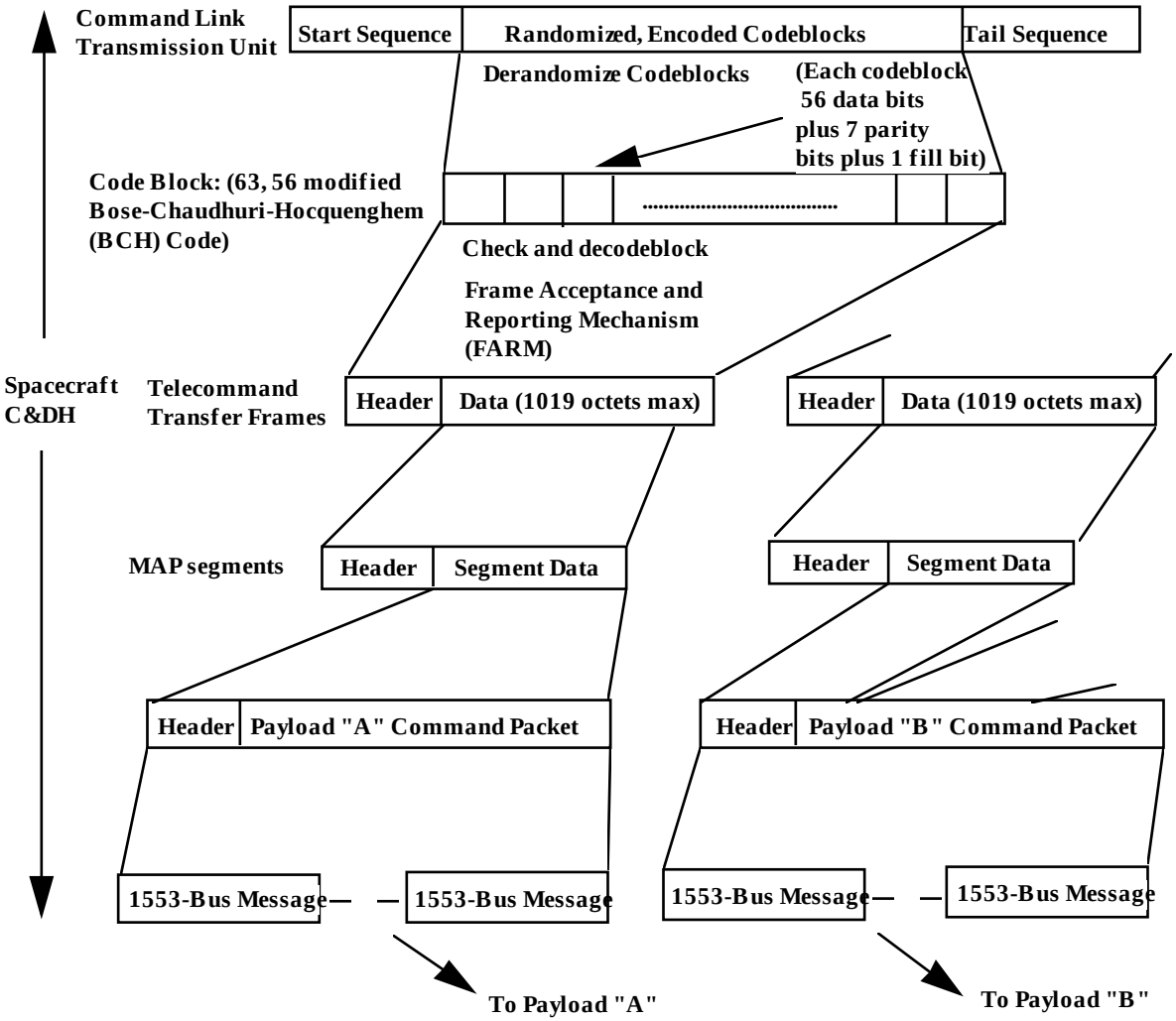
Figures 3.4-1 and 3.4-2 gives an overview of the telecommand coding/transport layers and the front end decoding within the spacecraft C&DH. The length of the application data field of a CCSDS telecommand packet must be no greater than 4000 bytes (octets).

Figure 3.4-1. Command packet generation and input to C&DH.



FSCM NO.	SIZE	DWG. NO.
88898	A	7363-9050 A
		4/3/98
SCALE	DO NOT SCALE PRINT	SHEET

Figure 3.4-2. Command link transmission unit to 1553 message.



FSCM NO.	SIZE	DWG. NO.
88898	A	7363-9050 A
		4/3/98
SCALE	DO NOT SCALE PRINT	SHEET

3.5 TELEMETRY PACKET LIMITS

There will be a limit on the number of telemetry packets that the C & DH will collect from an instrument in each bus major frame. This limit will be independent of the daily limit of packets stored to the Solid State Recorder. The limit will be specified in the instrument SIIS.

Once collected, the telemetry packets from each instrument will be stored on the TIMED spacecraft solid-state recorder (SSR). The SSR has a total data capacity of 2.5 gigabits (Gb). The C&DH software will manage two separate memory buffers on the SSR: one buffer for diagostic data from the spacecraft Guidance and Control system, the other buffer for data (housekeeping and telemetry) produced by the instruments and spacecraft subsystems. Instrument real time telemetry and housekeeping will be collected by the C&DH and stored on the SSR. In normal operation, the SSR contents will be dumped and telemetered to the ground station once per 24.25 hour period.

Each instrument will have a maximum number of data packets which can be stored on the SSR in a 24.25 hour period. The maximum number of packets allowed for each instrument will be a function of the instrument's average daily data rate. The Instrument SIIS will contain data on the maximum number of allowed packets. This limit may be changed in software via a command from the ground. Once an instrument exceeds its maximum allowed data volume, no more data from that instrument will be stored on the SSR until a ground command tells the C & DH to start a new collection period. The daily data volume counter for each instrument will be reset at 0:00 UTC. The number of packets stored to the SSR for each instrument in the current period will be in spacecraft telemetry. Collection of telemetry packets from an instrument will continue even when no more instrument packets are stored to the SSR. If a downlink channel is available, excess telemetry packets will be transmitted via the downlink. Otherwise, excess telemetry packets will be lost.

The spacecraft has both a wideband and a narrow band downlink. When the wideband downlink is established and real time downlinking is enabled, all telemetry packets collected from instruments will be placed in the real time downlink.