JPL D-71987
Discovery Program

GRAIL

Telemetry Dictionary (TD)

Gravity Recovery Processor Assembly (GPA) Flight Software

Rev. E (Telemetry dictionary documentation extracted from JPL D-49059)

Prepared by:

GRAIL GPA Software Lead: Tim Rogstad	**date**

Approval:

Flight System Engineer: Kevin Barltrop	**date**
Payload Manager: Bill Klipstein	**date**

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Jet Propulsion Laboratory
California Institute of Technology

GRAIL
Telemetry Dictionary
Document Change Log

Date	Release	Change Description	Author
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24 Oct 2008	0.2	Rogstad/Stecheson Corrections	T. Rogstad
5 Nov 2008	0.3	Added the antenna pattern telemetry packet	M. Girard
6 Jan 2009	0.4	Barltrop Corrections	M. Girard
27 Jan 2009	1.0	Replaced Antenna State with Time Transfer Packet	M. Girard
2 Feb 2009	1.1	Changed clock, delay fields to double from float in time trasfer packet	M. Girard
25 Feb 2009	1.2 Initial Release	Added description of the BlackJack Protocol	M. Girard
17 Oct 2009	Rev. A	Added final Stecheson recommendations, and final formatting touches	T. Rogstad
26 Feb 2010	Rev. B	Added the DoScrubFPGA command (Table 3, and Section 6.7.2), and took out the FlashBankStatusLog Telemetry packet (obselete packet)	T. Rogstad
31 May 2010	Rev. C	Added the information for the new "GrailHealthStatus" telemetry packet (Table 35, in Section 9, and Table 44 , in Section 11.4.6). Also added description of the detrending of phase observable data (Section 10).	T. Rogstad
28 June 2011	Rev. D	- Updated QuadraticFitObservables Pkt to reflect that CA range is in microseconds, not CA-chips (Section 11.1) - added KaTimeoutEnable Get and Set commands (Section 4; Section 6.2.5; Section 6.2.6) - corrected TimeTransfer Packet fields (Section 11.6.1) - stripped out most of the "Table" titles (unsustainable) - corrected wrong descriptor field for GRAILHealth packet	T. Rogstad
6 October 2011	Rev. E	Added the STimeoutEnable Get and Set commands (Section 4; Section 6.2.7, Section 6.2.8)	T. Rogstad
27 August 2012	Rev. E	Removed command dictionary documentation from document	G. Kruizinga

Table of Contents

1. INTRODUCTION

1.1 IDENTIFICATION

This document is the Telemetry Dictionary for the Gravity Recovery Processor Assembly (GPA) Instrument of the GRAIL Project. It applies to all telemetry sent between the Project spacecraft and the Instrument. This document contains the telemetry dictionary contents of the project document Command and Telemetry Dictionary (JPL D-49059)

1.2 OVERVIEW

By mapping the lunar gravitational field globally to unprecedented accuracy and resolution, GRAIL will peer deep inside the Moon to reveal its internal structure and thermal history.

Knowledge acquired about the Moon from GRAIL will be extended to understand the broader evolutionary histories of the other rocky planets in the inner solar system: Earth, Venus, Mars, and Mercury. Indeed, the Moon is a linchpin for understanding how the terrestrial planets evolved.

GRAIL is the lunar analog of the successful GRACE (2002) twin-spacecraft terrestrial gravity recovery mission that continues to operate. GRAIL will be implemented with a science payload derived from GRACE and a spacecraft derived from the (2005 launch) LM Experimental Small Satellite-11 (XSS-11). GRAIL will place twin spacecraft (represented as GRAIL-A and GRAIL-B in Figure D.1-2) in a low-altitude (50 km), near circular, polar lunar orbit to perform high-precision range-rate measurements between them using a Ka-band payload.

Subsequent analysis of the spacecraft-to-spacecraft range-rate data provides a direct measure of the lunar gravity.

Each of the two GRAIL satellites carries an LGRS system that is a single frequency Kaband-only version of the dual frequency GRACE KBRS. The LGRS contains an instrument called the Gravity Recovery Processor Assembly (GPA) that process the Ka-band ranging data, and the S-Band time-transfer system data.

The GPA will be built at JPL from the primary flight proven components of the GRACE processor. Sufficient quantities of these are in stock at JPL and available for use in the GPA including the TurboRogue ASIC, 603e PowerPC CPU, and AMD Flash Memory. The required FPGAs are available from Xilinx. With these components available, design and flight software modifications over the GRACE design will be minimal.

1.3 DOCUMENT SCOPE

In order for the Flight Software for the GPA Instrument to meet its requirements, scientific and engineering information must be sent to the Ground in the form of telemetry packets. This document describes to the bit-level the contents and definitions of telemetry packets.

1.4 METHOD

The telemetry formats of the GRAIL Instrument are direct adaptations of those of the predecessor mission, GRACE.

1.5 NOTATION

When this document refers to the Instrument, it is referring to the GRAIL/GPA Instrument.

When this document refers to the Flight Computer, it is referring to the Flight Computer specified by the Project. Alternately, the terms Flight Processor and Gravity Recovery Processor Assembly may be used. Abbreviations for these terms are FC, FP, and GPA, respectively.

The term, TBD, refers to items that are “to be determined”.

By FSW, it is meant the GPA flight software that executes in the Flight Computer specified by the Project.

The GRAIL/GPA FSW is an adaptation of the FSW from a predecessor mission called GRACE. In this document reference to the Predecessor Project or the Inherited Project will mean the GRACE Project.

The term, Ground, is meant to include all software, hardware, and operational activities supporting the sending of commands and the reception of telemetry to and from the Spacecraft and Instrument. The GRAIL Spacecraft minimally interacts with the command and telemetry of the Instrument other than to store the same for opportune moments to conduct appropriate uploads and downloads.

1.6 CONTROLLING DOCUMENTS

Title/Revision	Location	Doc-ID
Software Development Requirements, rev. 6	JPL Rules!	Rules-57653 D-23713
Project Reviews, rev. D, August 4, 2003	JPL Rules!	Rules-35163 D-10401
Design, Verification/Validation and Operations Principles for Flight Systems, rev. 3, December 11, 2006	JPL Rules!	Rules-43913 D-17868

Title/Revision	Location	Doc-ID
Flight Project Practices, rev. 6, March 6, 2006	JPL Rules!	Rules-58032

1.7 APPLICABLE DOCUMENTS

1. Gravity Recovery and Interior Laboratory (GRAIL) Project Software Management Plan (PSMP) D-38908
2. Gravity Recovery and Interior Laboratory (GRAIL) Instrument Software Management Plan, Rev B (SMP) D-44366, April 13, 2010
3. BlackJack Data Link Protocol, Interface and Implementation Description (JPL D-20675)
4. GRAIL Command and Telemetry Dictionary, Rev E (CTD), October 6, 2011 (JPL D-49059)

2. SPACECRAFT TELEMETRY COMMUNICATION

2.1 SPACECRAFT BUS ARCHITECTURE

Telemetry is returned to the Spacecraft over a dedicated RS-422 link operating at 19.2 kiloBaud.

This data port carries science data to be archived and forwarded to the ground.

A second port (operating at 57.6 kiloBaud) is used for receiving telemetry during pre-flight operations.

2.2 TELEMETRY SYSTEM BUS TRANSACTION PROTOCOLS

The telemetry system bus is a standard RS-422 serial communication line. The data rate is 19.2 kiloBaud.

The order in which bits within bytes are transmitted is per the definition of the physical link layer.

In multi-byte numeric quantities, the most significant byte and bit shall be transmitted first. Floating point numbers are represented using the ANSI/IEEE Standard 754-1985 for Binary Floating-Point Arithmetic.

For ASCII strings, the first byte transferred is the leading byte of the string with subsequent characters following sequentially.

2.3 TELEMETRY PHILOSOPHY

Telemetry bears all the information produced by the Instrument. The FSW has a certain flexibility in that not all telemetry packets need be sent at any time. Certain telemetry packets are always sent. Others may be requested. Return rates of telemetry packets may vary.

Telemetry packets are of six distinct types:

1. Observables
2. ToneStatus
3. TrackDescriptor
4. Receiver Management
5. Configuration
6. Time

These correspond to functional libraries or modules within the FSW.

The formats of these packets are based on a common standard which is described below.

2.4 TELEMETRY MESSAGE FORMATS

All packets emitted by the spacecraft have a common header type. A sequence of arguments o varying types may follow the header. A single packet type may have various lengths usually due to single variable string argument at the end of the command.

The Observables packet has a variable format, where the definition of the packet varies according t the states of certain parameters or conditions. The length of the packet, as coded in the header, allow for correct parsing as the varying states have unique lengths.

The standard telemtry packet format is as follows:

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	example "OBSD"; see table 32 in section 9	8	char[4]

64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	example "qfit"; see table 32 in section 9	12	unsigned int
96	Arguments...	A sequence of arguments possibly varying in length and format	variable	variable	variable	variable	variable

Table 4. Telemetry Format Template

3. TELEMETRY PROCESSING

3.1 TELEMETRY TIMESTAMPS

Only certain packets contain a timestamp. Precise timestamps are returned when Science values are returned in the packet and the time of science or engineering acquisition is important for ground processing of the packet contents. For other, non-timestamped packets, the time of acquisition by the spacecraft is adequate to interpret the packet contents.

3.2 TELEMETRY CHECKSUMS

Checksums are not used for any GRAIL telemetry packets.

3.3 TELEMETRY RATES

For those packets emitted regularly, typical rates are given in the following table:

Packet	Rate: seconds between packets
Observables	10
Antenna State	10
ADC	120
ADC Fixed Point	60

3.4 TELEMETRY COUNTERS

Packet counters are not employed for any GRAIL telemetry packet.

4. TELEMETRY CAPABILITIES

tlm Packet	tlm type or library	description	Packet id
QuadraticFit Observables	"OBSD"	Contains observable data by PRN. This format is flexible so that different observable situations can be reported in this data packet.	"qfit"
ToneStatus	"TONE"	Contains status information for the Kband tracking loops	"tsta"
TrackDescriptor	"GPST"	Contains status information about a requested track. Also carries control information for tracks	"trkd"
ADC	"RCVM"	Contains the onboard sensor values, which may be temperatures, voltages or calculated currents	"adcp"
ADCFixedPoint	"RCVM"	Contains a fixed-point version of a subset of onboard sensor values, which may be temperatures, voltages, or calculated currents	"adcf"
DirTable	"RCVM"	Contains directory information for the FLASH memory.	"fdir"
CommandAck	"RCVM"	Acknowledges commands as taken or ignored.	"cmdr"
LogMessage	"RCVM"	Contains null-terminated ascii text.	“logm”
GrailHealthStatus	“RCVM”	Packet steered to the engineering port summarizing more detailed data being sent to the science port.	“meok”
PortSetting	"CONF"	Carries the output port steering settings for a given packet type. .	
Antenna Configuration	"CONF"	Contains an Antenna configuration record. This record describes the configured antenna in terms of its boresight and name	"pset"

tlm Packet	tlm type or library	description	Packet id
PPSTime	"TIME"	**Contains the receiver time of the previous PPS pulse. This packet is guaranteed to be transmitted before the next PPS.**	"ppst"
ExternalEventTime	"TIME"	**Contains the receiver time of the external stimulus, rising edge. This packet requires custom hardware.**	"extt"
TimeTransfer	"NAVG"	**Contains range information**	“time”

Table 5. Telemetrys Packets

5. TELEMETRY CONSTRAINTS

The GPA will not send data that is known to be bad or unusable. No data is sent if the necessary RF signal is not “locked,” or if the SNR is too low to produce reliable data.

In the event of a sensor-specific outage, data from the functioning sensors will continue to be processed. Housekeeping data is always sent.

For S-Band phase and pseudorange tracking, and for Ka-Band tone tracking, the local oscillator frequency is not detrended from phase measurements. When the phase count exceeds 1e10 cycles (positive or negative), a constant 1e10 cycles is removed from the count in order to maintain precision.

6. TELEMETRY DETAILED DESCRIPTION

6.1 OBSERVABLES

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	QuadraticFit Observables	Contains observable data by PRN. This format is flexible so that different observable					

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
		situations can be reported in this data packet.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"OBSD"	8	char[4]
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"qfit"	12	unsigned int
96	ObsTime	Identification key for this tone	32	128	variable	16	unsigned long
128	PRN	Local Oscillator band	8	136	variable	17	unsigned char
136	AntennaInput	Start time of this set of predicts, in seconds.	8	144	variable	18	char
144	ObsType	Valid duration of this set of predicts, in seconds.	8	152	variable	19	unsigned char
152	SampleInterval	Frequency, in Hz; where to start this tracker.	8	160	variable	20	char
160	CAChannel	Receiver channel, modulo 128, for the CA Data.	8	168	variable	21	unsigned char
168	CASNR	SNR in volts per volt for CA channel.	16	184	variable	23	short
184	CAPhase	Carrier phase meas. for CA channel in L1 cycles.	64	248	variable	31	double
248	CARange	Tau meas. for CA channel’s data in microseconds.	64	312	variable	39	double
If any residual output is enabled, these values are output							
376	ResidualType	Data type byte for the following three fields.	8	384	variable	48	char
384	ScaleFactor	Residual scale factor (dimensionless).	16	400	variable	50	char
400	ResidualRate	Rate for Residual data, in Hz.	32	432	variable	54	char

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
432	PhaseRes	An array of elements, with ResidualRate entries (i.e. a ResidualRate of 50Hz means 50 elements in the array for each second of the SampleInterval). Each element contains the difference between the particular type's actual value and the quadratic fit for the data.	variable	variable	variable	variable	short[]
If any residual output is enabled, these values are output							
variable	ResidualType	Data type byte for the following three fields.	8	variable	variable	variable	char
variable	ScaleFactor	Amplitude scale factor (dimensionless).	16	variable	variable	variable	char
variable	AmplitudeRate	Rate for Amplitude data, in Hz.	32	variable	variable	variable	char
variable	Amplitudes	Signal amplitudes array, similar to PhaseRes above.	variable	variable	variable	variable	short[]

6.2 TONE STATUS

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	ToneStatus	Contains status information for the Kband tracking loops					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	41	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"TONE"	8	char[4]
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"tsta"	12	unsigned int
96	SatelliteID	PRN number of the Satellite	8	104	variable	13	char
104	SNREst	Estimate of the SNR. (Pc/No)	32	136	variable	17	float

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
136	SNR	The actual SNR	32	168	variable	21	float
168	LockQuality	Lock Quality Factor, 0 to 1, 0 is bad, 1 is good.	32	200	0 or 1	25	float
200	LoopSNREst	Estimate of the loop SNR.	32	232	variable	29	float
232	ElaspedTime	Elasped time of track, in seconds.	32	264	variable	33	long
264	PhaseResidual	Residual of the tracking phase, in cycles.	32	296	variable	37	float
296	DiagnosticFlags	Loop flags.	32	328	variable	41	long
328	Time	Time that this status was generated	32	360	variable	45	long

6.3 TRACK DESCRIPTOR

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	TrackDescriptor	Contains status information about a requested track. Also carries control information for tracks					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"GPST"	8	char[4]
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"trkd"	12	unsigned int
96	PRN	PRN of this track.	8	104	variable	13	char
104	Antenna	NULL-terminated name of the Antenna of this track.	variable	variable	variable	variable	unsigned int
variable	Channel	The ASIC hardware channel for this track.	8	variable	0- false 1: true	variable	char
variable	ElapsedTime	Elapsed time of this track, in seconds	32	variable	0- false 1: true	variable	unsigned int
variable	Status	Status Code of this track	32	variable	0- false 1: true	variable	unsigned int

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
variable	ActiveTrack	If true, this track is active; if false, this descriptor is the default settings for these tracks	8	variable	0- false 1: true	variable	char[ ]
variable	CAFit	If true, produced Quadratic Fit Data for the CA channel	8	variable	0- false 1: true	variable	char
variable	P1Fit	If true, produced Quadratic Fit Data for the P1 channel	8	variable	0- false 1: true	variable	char
variable	P2Fit	If true, produced Quadratic Fit Data for the P2 channel	8	variable	0- false 1: true	variable	char
variable	CAResAmp	If true, produce Amplitude Residual Data for the CA channel.	8	variable	0- false 1: true	variable	char
variable	P1ResAmp	If true, produce Amplitude Residual Data for the P1 channel.	8	variable	0- false 1: true	variable	char
variable	P2ResAmp	If true, produce Amplitude Residual Data for the P2 channel.	8	variable	0- false 1: true	variable	char
variable	CAResPhase	If true, produce Phase Residual Data for the CA channel	8	variable	0- false 1: true	variable	char
variable	P1ResPhase	If true, produce Phase Residual Data for the P1 channel	8	variable	0- false 1: true	variable	char
variable	P2ResPhase	If true, produce Phase Residual Data for the P2 channel	8	variable	0- false 1: true	variable	char
variable	CAResidualRate	Number of samples for residual data for the CA channel	8	variable	0- false 1: true	variable	char
variable	P1ResidualRate	Number of samples for residual data for the P1 channel	8	variable	variable	variable	char
variable	P2ResidualRate	Number of samples for residual data for the P2 channel	8	variable	variable	variable	char
variable	FitInterval	Number of seconds for the span of the Quadratic Fit	8	variable	variable	variable	char
variable	FitCenter	Number of seconds from the beginning of the fit to center of the Fit.	8	variable	variable	variable	char

6.4 RECEIVER MANAGEMENT

6.4.1 ADC

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	ADC	Contains the onboard sensor values, which may be temperatures, voltages or calculated currents					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"RCVM"	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"adcp"	12	unsigned int
96	ADCTime	Time, in receiver seconds, of this solution	32	128	variable	16	unsigned int
128	SensorValue	Value associated with the named sensor (unit specified below).	64	192	variable	24	double
192	SensorType	The type of value.	8	200	'T' (0x54): temp C 'V' (0x56): voltage V 'A' (0x41): current A	25	char
200	SensorName	Null-terminated value name	variable	variable	variable	variable	char[ ]

6.4.2 ADCFixedPoint

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	ADCFixedPoint	Contains a fixed-point version of a subset of onboard sensor values, which may be temperatures, voltages, or calculated currents					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"RCVM"	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"adcf"	12	unsigned int
96	ADCTime	Time, in receiver seconds, of this solution	32	128	variable	16	unsigned int
128	SensorValue	Value associated with the named sensor (unit specified below).	32	160	variable	20	long int
160	SensorType	The type of value.	8	168	'T' (0x54): temp C 'V' (0x56): voltage V 'A' (0x41): current A	21	char
168	SensorName	Null-terminated value name	variable	variable	variable	variable	char[ ]

6.4.3 DirTable

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	DirTable	Contains directory information for the FLASH memory.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"RCVM"	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"fdir"	12	unsigned int
96	Name	NULL-terminated name of the file.	variable	variable	variable	variable	char[ ]
variable	Sector	Sector of this flash file.	8	variable	variable	variable	char
variable	Size	Size of the file in bytes	32	variable	variable	variable	unsigned long
variable	Type	4-byte character string denoting file type	32	variable	**’Joy!’**, PEF type **’BJdf’**, BlackJack data **’BJbt’**, BlackJack bootcode. **’FPGA’**, FPGA configuration files	variable	unsigned long
variable	PEFCV	If Type==’Joy!’, then this field contains PEF current version	32	variable	variable	variable	unsigned long
variable	PEFOD	If Type==’Joy!’, then this field contains PEF old def version	32	variable	variable	variable	unsigned long
variable	PEFOI	If Type==’Joy!’, then this field contains PEF old impl version	32	variable	variable	variable	unsigned long

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
variable	LoadType	OS LoadType	8	variable	LoadType == 0, **Application.** LoadType == 1, **Thread.** LoadType == 2, **Boot.** LoadType == 3, **System.** LoadType == 4, **Library.**	variable	Char
variable	PEFTime	Compile Date of the PEF File, in Mac time	32	variable	variable	variable	unsigned long
variable	BootCodeVersion	Null-terminated value name	variable	variable	variable	variable	char[ ]

6.4.4 Command Ack

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	CommandAck	Acknowledges commands as taken or ignored.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"RCVM"	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"cmdr"	12	unsigned int

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
96	Status	If true, the command was accepted	8	104	0: false 1: true	13	char
104	LibraryID	LibraryID of the command	32	136	variable	17	unsigned int
136	CommandCode	CommandCode of the command	32	168	variable	21	unsigned int
168	StatusCode	Command-specific status code.	32	200	variable	25	unsigned int
200	Message	NULL-terminated ASCII text message, command-specific	variable	variable	variable	variable	char[ ]

6.4.5 LogMessage

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	LogMessage	Contains null-terminated ascii text.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	“RCVM”	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	“logm”	12	unsigned int
96	Message	NULL-terminated ASCII text.	8	104	variable	13	char[ ]

6.4.6 GrailHealthStatus

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	GrailHealthStatus	Contains the time transfer information					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"RCVM"	8	char[4]
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"meok"	12	unsigned int
96	ClockOffset	Clock offset reported in latest Time Transfer Packet	64	160	variable	20	double
160	TimeSinceReboot	Seconds expired since last reboot	32	192	variable	24	long int
192	LastPPSTime	Time reported in latest PPSTime packet	32	224	variable	28	long int
224	IntegrityResetCount	Count of times since reboot that Integrity Monitor has restarted trackers	32	256	variable	32	int
256	KaBandSNR	SNR reported in latest Ka band quad fit packet	16	272	variable	34	short int
272	SBandSNR	SNR reported in latest S-band quad fit packet	16	288	variable	36	short int

6.4.7 Configuration

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	PortSetting	Carries the output port steering settings for a given packet type. The RT1553 interface is available only for Jason and the associated parameter is ignored for other missions. The mapping of UART# to JNN connector is mission-specific.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	20	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"CONF"	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"pset"	12	unsigned int
96	LibraryID	Library ID of the packet that will be steered using these settings.	32	128	variable	16	unsigned int
128	PacketID	Packet ID of the packet that will be steered using these settings.	32	160	variable	20	unsigned int
160	RS422Port0	If true, output this packet on UART #0.	8	168	0- false 1: true	21	char
168	RS422Port1	If true, output this packet on UART #1.	8	176	0- false 1: true	22	char
176	RS422Port2	If true, output this packet on UART #2.	8	184	0- false 1: true	23	char
184	RT1553	If true, output this packet on RT1553 interface	8	192	0- false 1: true	24	char

6.5 TIME

6.5.1 PPSTime

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	PPSTime	Contains the receiver time of the previous PPS pulse. This packet is guaranteed to be transmitted before the next PPS.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	12	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"TIME"	8	unsigned int
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"ppst"	12	unsigned int
96	PPSTime	Time, in receiver seconds, of the previous pulse	32	128	variable	16	unsigned int

6.5.2 External Event Time

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	ExternalEventTime	Contains the receiver time of the external stimulus, rising edge. This packet requires custom hardware.					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	16	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"TIME"	8	unsigned int

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"extt"	12	unsigned int
96	ExternalTimeInt	Integer time, in receiver seconds, of the external event	32	128	variable	16	unsigned int
128	ExternalTimeFrac	Fractional portion of external event time in seconds (50nS resolution).	32	160	variable	20	float

6.6 NAVIGATION

6.6.1 TimeTransfer

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
	TimeTransfer	Contains the time transfer information					
0	Header ID	Standard ID	8	8	0xBB	1	char
8	ID Subtype	Indicates whether the BlackJack packet is a command or a data packet.	8	16	0xBD	2	char
16	Length	Number of bytes in the packet starting after this field and continuing to the end	16	32	variable	4	short int
32	Library ID	A 4-byte ASCII string denoting the command library.	32	64	"NAVG"	8	char[4]
64	Packet ID	A 4-byte ASCII string denoting the command code.	32	96	"time"	12	unsigned int
96	ExternalTimeInt	Integer Time tag from Tracking code: seconds	32	128	variable	16	unsigned long int
128	ExternalTimeFrac	Fractional Time tag from Tracking code: seconds (50nSec resolution)	64	192	variable	24	double
192	Delay	“true” range delay = (localDelay+remoteDelay)/2	64	256	variable	32	double
256	Clock	“true” clock offset = (localDelay-remoteDelay)/2	64	320	var	40	double
320	SNR1	Local SBand SNR	16	336	var	42	unsigned short int
336	SNR2	Remote SNR from SBand data	16	352	var	44	unsigned short int
352	KaSNR1	Local KaBand SNR	16	368	var	46	unsigned short int

bit offset	field name	description	field length (bits)	running length (bits)	value	byte count	format
368	KaSNR2	Remote KaBand SNR from SBand data	16	384	var	48	unsigned short int

7. APPENDICES

7.1 BLACKJACK PROTOCOL CRC LOOKUP TABLE

Example: If the lookup key, ((CRC >> 8) XOR NewByte), is 0x68, the lookup value is 0xEDAE.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0X	0000	1021	2042	3063	4084	50A5	60C6	70E7	8108	9129	A14A	B16B	C18C	D1AD	E1CE	F1EF
1X	1231	0210	3273	2252	52B5	4294	72F7	62D6	9339	8318	B37B	A35A	D3BD	C39C	F3FF	E3DE
2X	2462	3443	0420	1401	64E6	74C7	44A4	5485	A56A	B54B	8528	9509	E5EE	F5CF	C5AC	D58D
3X	3653	2672	1611	0630	76D7	66F6	5695	46B4	B75B	A77A	9719	8738	F7DF	E7FE	D79D	C7BC
4X	48C4	58E5	6886	78A7	0840	1861	2802	3823	C9CC	D9ED	E98E	F9AF	8948	9969	A90A	B92B
5X	5AF5	4AD4	7AB7	6A96	1A71	0A50	3A33	2A12	DBFD	CBDC	FBBF	EB9E	9B79	8B58	BB3B	AB1A
6X	6CA6	7C87	4CE4	5CC5	2C22	3C03	0C60	1C41	EDAE	FD8F	CDEC	DDCD	AD2A	BD0B	8D68	9D49
7X	7E97	6EB6	5ED5	4EF4	3E13	2E32	1E51	0E70	FF9F	EFBE	DFDD	CFFC	BF1B	AF3A	9F59	8F78
8X	9188	81A9	B1CA	A1EB	D10C	C12D	F14E	E16F	1080	00A1	30C2	20E3	5004	4025	7046	6067
9X	83B9	9398	A3FB	B3DA	C33D	D31C	E37F	F35E	02B1	1290	22F3	32D2	4235	5214	6277	7256
AX	B5EA	A5CB	95A8	8589	F56E	E54F	D52C	C50D	34E2	24C3	14A0	0481	7466	6447	5424	4405
BX	A7DB	B7FA	8799	97B8	E75F	F77E	C71D	D73C	26D3	36F2	0691	16B0	6657	7676	4615	5634
CX	D94C	C96D	F90E	E92F	99C8	89E9	B98A	A9AB	5844	4865	7806	6827	18C0	08E1	3882	28A3
DX	CB7D	DB5C	EB3F	FB1E	8BF9	9BD8	ABBB	BB9A	4A75	5A54	6A37	7A16	0AF1	1AD0	2AB3	3A92
EX	FD2E	ED0F	DD6C	CD4D	BDAA	AD8B	9DE8	8DC9	7C26	6C07	5C64	4C45	3CA2	2C83	1CE0	0CC1
FX	EF1F	FF3E	CF5D	DF7C	AF9B	BFBA	8FD9	9FF8	6E17	7E36	4E55	5E74	2E93	3EB2	0ED1	1EF0

7.2 ACRONYMS

ACC	Accelerometer
AOCS	Attitude and Orbit Control System
ASIC	Application-Specific Integrated Circuit
CHU	Camera Head Unit
CG	Center of Gravity
CR	Condition Register
CRC	Cyclic Redundancy Check
CTD	Command and Telemetry Dictionary
ECI	Earth-Centered Inertial
EMC/EMI	Electromagnetic Compatibility/Interference
FC	Flight Computer
FP	Flight Processor
FPGA	Field Programmable Gate Array
FSW	Flight Software
GPA	Gravity Recovery Processor Assembly
GRACE	Gravity Recovery And Climate Experiment
GRAIL	Gravity Recovery and Interior Laboratory
IS	Instrument System
KBRS	K-Band Ranging System
LGRS	Lunar Gravity Ranging System
LO	Local Oscillator
MWA	Microwave Assembly
OBDH	On-Board Data Handling System
OCC	Occultation (antenna)
PCDU	Power Conditioning and Distribution Unit
POD	Precision Orbit Determination (antenna)
PPS	Pulse Per Second
PSMP	Project Software Management Plan
RF	Radio Frequency
SMP	Software Management Plan
SNR	Signal to Noise Ratio
SPU	Signal Processing Unit
TBD	To Be Determined
TML	Total Mass Loss
TR	TurboRogue
USO	Ultra Stable Oscillator
VCML	Volatile Condensable Material Loss