Rev.	ECO	Description	Checked	Approval	Date
01	32-002	Initial Release for comment		RFGoeke	1/7/05

Spacecraft to CRaTER
Data
Interface Control Document

Dwg. No. 32-02001

Revision 01
January 7, 2005

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Preface

Revision 01 of this document is being circulated for comment. It contains a general proposal for the implementation of the experiment command and data interface. (It is derived from the SPIDR ICD.)

1. Introduction

The flight hardware for the Cosmic Ray Telescope for Effects of Radiation (CRaTER) instrument on the Lunar Reconnaissance Orbiter (LRO) is composed of a single assembly incorporating both radiation detector and all associated power, command, data processing, and telemetry electronics. Other ICDs control electrical (32-02002), mechanical (32-02003), and thermal (32-02004) interfaces.

1.1 Scope

This document describes the data interface between the CRaTER science instrument and the space craft bus. The meanings of individual bits and data words are defined, their composition into data and telemetry packets, and the timing relationships among those packets. All information necessary to define both command and telemetry dictionaries are contained herein.

1.2 Bit Numbering Convention

The following convention is used to identify each bit in an N-bit field. The first bit in the field to be transmitted (*i.e.* the most left justified when drawing a figure) is defined to be "Bit 0"; the following bit is defined to be "Bit 1" and so on up to "Bit N-1". When the field is used to express a numeric value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field. Unless otherwise noted, such values will be expressed in decimal notation within this document.

2 Commands

2.1 Packet Description

The following describes command packets which conform to the Consultative Committee for Space Data Systems (CCSDS) Recommendations for Packet Telecommands (CCSDS 201.0-B-3 and CCSDS 202.0-B-2) except as noted below. These telecommand (referred to hereafter simply as "command") packets are generated by ground software and uplinked to the spacecraft for delivery. The spacecraft C&DH maps the Application Process ID to a particular MIL-STD-1553 Remote Terminal (RT) address and sub-address and forwards only the data content of the packet to the individual instrument.

2.1.1 Primary Header Format

The format of the primary CCSDS header is as follows:

Bit Position(s)	Description	Usage Notes
0-2	Version Number	Static value of 0
3	Type	Value of 1 for Telecommand Packets
4	Secondary Header Flag	Value of 1 when a secondary header is present, as it is for telemetry packets; value of 0 for these command packets.
5-15	Application Process ID	Determines command routing; see the separate table below
16-17	Segmentation Flags	Static value of 3; no segmentation will be used
18-31	Sources Sequence Count	This counter is meant to be incremented separately for each Application ID.
32-47	Packet Length	The number of data bytes following the primary header

2.1.2 Application ID Assignments

The Application Process ID is used by the C&DH to route the packet data to the appropriate 1553 Remote Terminal and RT Sub-Address. Note that the primary header is not forwarded to the instrument, only the 16 or 32 bit application data. The table below shows the bit assignments:

Bit Positions	Description	RT Address	Usage Notes
5	Science ID		Static value of 1 for science instruments; a value of 0 is used for spacecraft functions
6-8	Instrument ID	16 17-21	CRaTER address Reserved for other science instruments
9-10	Reserved		Fixed value = 0
11-15	Command ID		Individual command decoding shown in Section 2.4

2.1.3 Secondary Header Format

There is no secondary header used in the command packets.

2.2 1 Hz Reference

A time synchronization pulse will be delivered to the instruments once each second. The leading edge will be synchronized to spacecraft time to within 1.0 millisecond. These pulses delimit one second data intervals in which telemetry data is accumulated.

2.3 Command Timing

Instrument commands (with the exception of Time of Next Sync Pulse, see section 2.5.1) shall occur no more often than once per (1 second) data interval. There is no minimum time requirement between commands (including the Time of Next Sync Pulse).

The time of command execution is not currently defined. Commands may take effect either on receipt or at the next 1 Hz Reference Pulse (the later is preferred).

2.4 Command Application Data Format

There are three types of commands sent to the instrument -- spacecraft time updates, magnitude commands, and discrete bit commands -- distinguished by the least significant 5 bits of the Application ID. The RT Sub-Addresses are identical to the specified bits of the Application ID.

App ID/ Sub-Add	No. of Data Bits	Description	Default	Reference
1	32	Time of next sync pulse	(none)	2.5.1
2-7	16	Command Echo	(none)	2.5.2
8	16	Discrete Commands Bit 0 = Detector Bias Off Bit 1 = Detector Bias On Bit 2 = Electrical Cal Off Bit 3 = Electrical Cal On Bit 11 = Data Test Mode Bit 14 = Clear all Commands Bit 15 = System Reset	 Off Off No action (none)	2.5.3
9-15	16	Reserved		
16	32	Discriminator Accept mask	0xFFFFFFFF	2.5.4
17	16	Event Amplitude Discriminator, Detector 1	255,0	2.5.5
18	16	Event Amplitude Discriminator, Detectors 2-5	255,0	2.5.5
18	16	Maximum number of data packets/second	32	2.5.6
18-30	16	Reserved		

2.5 Command Description

Note that the event processing commands (*e.g.:* Amplitude Discriminators, X Reject, Y Reject) are applied simultaneously to each event to determine its validity and subsequent disposition in the data stream.

2.5.1 Time of Next Sync Pulse

This is the value of a counter maintained by the C&DH which represents, nominally, the number of seconds which have elapsed since the Epoch of 1 January 1970. The value is valid on the next received 1 Hz Reference Pulse (Section 2.2). This command shall be sent during each (1 second) data interval, at least 100 milliseconds before the Reference Pulse to which its value applies, and at least 100 milliseconds following the previous Reference Pulse.

2.5.2 Command Echo

These commands have no effect within the instrument. The echo may be used for command/telemetry integrity tests on the ground and to tag science observations while on orbit (since the command is echoed into the data stream).

2.5.3 Discrete Commands

The discrete commands are used to control specific state changes within the instrument.

- Detector Bias on/off controls the application of (fixed) bias voltage to the silicon detectors
- Electrical Cal on/off controls a 10Hz calibration signal injected into the event chains
- The test mode is intended to verify internal data logic during instrument verification and is not intended for use at the obiter level.
- Clearing all commands will result in all values or functions reverting to their default (also initial power up) state.
- A System Reset command will have exactly the same effect as a power-up reset.

2.5.4 Discriminator Accept Mask

The five silicon detectors are numbered {1 .. 5} starting with the detector closest to the nadir window. Treating the output of the low level threshold detectors as a 5 bit number, there are 31 possible states by which a single event may be categorized. We set the corresponding bit to a one for each threshold state we wish to accept. (Example: mask := 0x0000404C selects events which trigger one and only one detector threshold.) Setting the mask to 0xFFFFFFFF accepts all events; setting the mask to 0x00000000 rejects all events.

2.5.5 Event Amplitude Discriminators

Amplitude discrimination is applied to the energy content of the events detected by an individual detector. The Most Significant 8 bits of the command are a High Level Discriminator, defining a limit beyond which events are considered invalid. The Least Significant 8 bits of the command are a Low Level Discriminator, defining a limit below which events are considered invalid. The settings are separately to Detector 1 and Detectors 2 – 5..

2.5.6 Maximum Number of Data Packets

The 8 Least Significant Bits set the maximum number of primary science data packets that will be queued for transmission per second; the 8 Most Significant Bits are ignored.

3 Telemetry

The following describes telemetry packets which conform to the Consultative Committee for Space Data Systems (CCSDS) Recommendations for Packet Telemetry (CCSDS 102.0-B-4) except as noted below.

3.1 MIL-STD-1553 Packet Description

The MIL-STD-1553 telemetry packets are of three separate types: a primary science packet, a secondary science packet, and a general housekeeping packet.

3.1.1 Primary Header Format

The Primary Header format for telemetry packets is identical to that described for use in telecommands (see section 2.1.1).

3.1.2 Application ID Assignments

The Application ID assignments for telemetry are similar to those used for commands (see section 2.1.2.).

Bit Positions	Description	RT Address	Usage Notes
5	Science ID		Static value of 1 for science instruments; a value of 0 is used for spacecraft functions
6-8	Instrument ID	16 17-21	CRaTER address Reserved for other science instruments
9-13	Reserved		Value = 0
14-15	Data ID		Value = 1 for primary science Value = 2 for secondary science Value = 3 for housekeeping

3.1.3 Secondary Header Format

The secondary header contains the spacecraft time valid for the data interval during which the telemetry request was made (note that bit 48 must be 0 to be CCSDS compliant):

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Bit Position	Data Description
48-51	Reserved; value = 0
52-55	Instrument Serial Number
56-63	Reserved; value = 0
64-95	Spacecraft time in seconds

3.1.4 Telemetry Flow Control

Primary science telemetry packets are filled without loss in an 8 byte repeating format as events arrive until 60 events have been collected. The resulting 492 byte packet (12 bytes of header and 480 bytes of data) is then queued for collection by the spacecraft C&DH system and the next event will start filling the subsequent packet. If the preceding packet has not been retrieved by the time this packet is filled, data collection will stall. (Statistics continue to be collected and reported in the secondary science packet.)

When the 1 second sync pulse arrives, the current packet fill will be terminated, the packet placed in the output queue, and a new packet started.

3.1.5 Telemetry Timing

Primary science telemetry packets queries would optimally occur every 40 ms, but there are no hardware restrictions on when or how often such queries occur.

Secondary science and housekeeping telemetry packets must be retrieved from the 1553 Remote Terminal in the interval between 100 and 900 milliseconds following a 1 Hz Reference Pulse.

Secondary science packets shall be read during every 1 second data interval during which primary science data is being collected.

Housekeeping packets shall be read every 16 seconds while 28VDC power is supplied to the instrument.

3.1.6 Telemetry Application Data Format

3.1.6.1 Primary Science

The event data for a single event in the primary science packet consists of an 8 byte block:

Relative Bit Position	Data Description
0-11	Event Amplitude, Detector 1
12-23	Event Amplitude, Detector 2
24-35	Event Amplitude, Detector 3
36-47	Event Amplitude, Detector 4
48-59	Event Amplitude, Detector 5
60-63	Reserved

3.1.6.2 Secondary Science

The application data contents of the secondary science packet are as follows:

Relative Bit Position	Data Description	Reference
0	Electrical Cal On = 1	3.2.4
1	Detector Bias Voltage On = 1	
2-6	Fixed value = 0	
7-10	Instrument Serial Number	
11-15	RT SubAddr of Last Command	
16-31	Contents of Last Command	
32-47	Telemetry Stall Counter	3.2.2
48-63	Event Reject Counter	3.2.3

This data in this packet was latched by the immediately preceding 1 Hz Reference Pulse. In this context "Last Command" means the command received during that preceding data interval; if no command was received during that interval, these bits have a value of zero.

3.1.6.3 Housekeeping

The application data contents of the housekeeping packet are as follows:

Relative Word Position	Data Description	Reference
0	Event Amplitude Discriminator Setting, D1	3.2.5
1	Event Amplitude Discriminator Setting, D2-5	
2-3	Discriminator Accept Mask	
4	28VDC Monitor	3.2.6
5	+5VDC Monitor	3.2.7
6	+15VDC Monitor	3.2.8
7	-15VDC Monitor	3.2.9
8	Detector Bias Current Monitor	3.2.10
9	Detector Bias Voltage Monitor	3.2.11
10	TBD Voltage	
11	Forward Bulkhead Temperature	3.2.12
12	Aft Bulkhead Temperature	
13	Analog Electronics Temperature	
14	Power Supply Temperature	
15	TBD Temperature	
16	Detector Assembly Temperature	

3.2 Telemetry Description

3.2.1 Event Records

Each detected photon event is recorded once and only once in the data stream. Events which are considered valid – those satisfying both amplitude and discriminator mask criteria – are either packed into a primary science packet or counted by the stall counter and reported in the secondary science packet. All other events – by definition invalid – increment the Event Reject counter.

3.2.2 Telemetry Stall Counter

While processing science telemetry packets the instrument must occasionally go “off line” to provide inter-packet timing gaps, generate headers, and wait for the Orbiter C&DH to retrieve a packet from the queue. In these cases, otherwise valid events are lost. The Stall Counter records a count of all events lost under these conditions. Upon receipt of the 1 Hz Reference Pulse the counter is read out into Secondary Science and reset to zero.

3.2.3 Event Reject Counter

This counter keeps track of every incident event ***not*** put into the data stream as a valid event because it has failed either amplitude or discriminator mask criteria. Note that these events, because they are never queued for telemetry, are never counted by the Stall counter. Upon receipt of the 1 Hz Reference Pulse the counter is read out into Secondary Science and reset to zero.

Both Stall and Event Reject counters are implemented as 16 bit counters. The analog circuitry is only capable of processing 2^{15} events per second, however, so the counters should never roll over.
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Because all event processing – whether valid, invalid, or lost – takes the same length of time (30 µs TBR), the sum of these two counters provides an accurate dead-time correction for each 1 second data interval.

3.2.4 Discrete State Indicators

There are three one bit state indicators:

- Electrical Calibration On/Off – indicates whether the 10Hz event injection circuitry is currently enabled.
- Detector Bias On/Off Command – indicates the state of the last detector bias command.

3.2.5 Command Settings

The telemetry words for

- Event Amplitude Discriminator Levels, Detector 1
- Event Amplitude Discriminator Levels, Detector 2-5
- Discriminator Mask

are readouts of the respective registers. The values should be identical to the last command which set these registers.

3.2.6 28VDC Monitor

A value indicating the voltage of the spacecraft 28VDC bus as seen by the instrument. The nominal engineering value in volts is

V = K * count, where K is TBR

The value of 1 LSB is TBR.

3.2.7 +5VDC Monitor

A value indicating the voltage of the instrument regulated +5VDC. The nominal engineering value in volts is

V = K * count, where K is TBR

The value of 1 LSB is TBR.

3.2.8 +15VDC Monitor

A value indicating the voltage of the instrument regulated +15VDC. The nominal engineering value in volts is

V = K * count, where K is TBR

The value of 1 LSB is TBR.

3.2.9 -15VDC Monitor

A value indicating the voltage of the instrument regulated -15VDC. The nominal engineering value in volts is

V = K * count, where K is TBR

The value of 1 LSB is TBR.

3.2.10 Detector Bias Current Monitor

A value indicating the current being drawn by the high voltage power supply. The nominal engineering value in amperes is

I = K * count, where K is TBR

The value of 1 LSB is TBR.

3.2.11 Detector Bias Voltage Monitor

A value indicating the voltage of the instrument high voltage. The nominal engineering value in volts is

V = K * count, where K is TBR

The value of 1 LSB is TBR.

3.2.12 Temperatures

Instrument temperature is measure by applying a 1.0 ma current to a parallel combination of a 2.25K@25C thermistor and a 5.23K resistor and reading the resulting voltage. The transfer function is as follows; it has an accuracy of approximately 0.3C over a range of –40 to +40C (TBR).

aa = (count * 20 * 5.23e3) / (5.23e3 – 20 * count)

qq = log(aa)

T = 1 / (1.074e-7 * qq * qq * qq + 2.372e-4 * qq + 1.4733e-3) - 273.16