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B	32-246	Minor tweaks to limits	RFGoeke		9/21/07
C	32-249	More minor tweaks as we use it more	RFGoeke		10/3/07
D	32-257	Change 28VDC measurements to GSE supply	RFGoeke		11/14/07

**CRaTER**  
**Short Form Functional**  
**Test Procedure**

Dwg. No. 32-06003.02

Revision D  
 November 8, 2007

Serial No \_\_\_\_\_

Date: \_\_\_\_\_

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## Preface

No special knowledge is required to run this Short Form Functional Procedure. It is intended to be run on many occasions by a variety of people.

Revision 01 of this document is being circulated for comment.

Revision 02 was a consistency revision to work with the Long Form Functional.

Revision 03 incorporated the experience of a first real test with S/N 10.

Revision A changed the names of the supporting test scripts, and made some minor procedural adjustments.

Revision B tweaked the test limits to be consistent with the flight units; purge flow monitor deleted (as it was deleted from the hardware).

Revision C changed some names in the tables to be consistent with the EGSE displays. We also added a change to revert to an 8Hz e-cal mode at the end if the instrument is to be left running.

Revision D accommodates the removal of the internal 28VDC sense lines; voltage and current is now measured at the bench power supply.

# 1 Introduction

The flight hardware for the Cosmic Ray Telescope for the 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. Its external (functional) properties are controlled by the data (32-02001) and electrical (32-02002) ICDs.

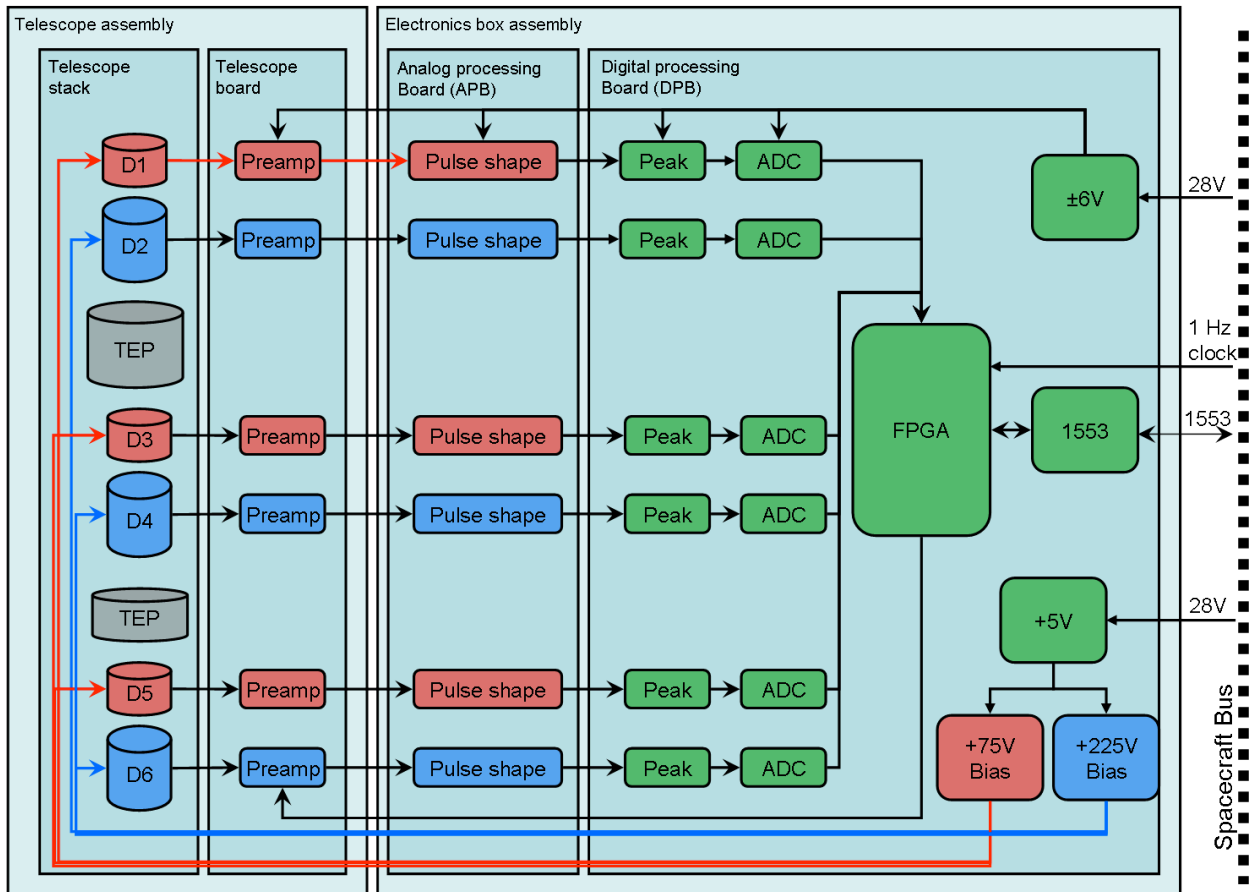
## 1.1 Activity Description

This procedure will provide a demonstration that the hardware meets its basic performance requirements within allowable tolerance.

All primary external interfaces are shown to meet the functional interface requirements. All primary functionality is also demonstrated. Verification of redundant interfaces and, to the extent possible, full hardware functionality is accomplished by the CRaTER Long Form Functional Test (32-06003.01).

## 1.2 Test Item Description

The following functional block diagram illustrates the data flow through the instrument.



Six silicon particle detectors (labeled D1, D3, D5 for the “thin” 140um units; D2, D4, D6 for the “thick” 1000um units) are arranged in a stack with intermediate cylinders of Tissue Equivalent Plastic (TEP). When used in coincidence, these detectors form a crude telescope with a 35 degree field-of-view. Charge collected by each detector is separately amplified, filtered, and converted by an A/D converter. The six values of deposited charge for a sextuple of 12-bit values which comprise the primary science data for a single event. The FPGA packs a series of these sextuples into a CCSDS primary science telemetry packet for transmission to the spacecraft data system. Similarly, secondary science information (*e.g.*: rejected event rates) and analog housekeeping values are packed by the FPGA into their own CCSDS telemetry packets. All telemetry is transmitted on a MIL-STD-1553 data bus.

Similarly, all instrument commands are received from the spacecraft *via* the 1553 bus.

More instrument design details may be had by reading the Instrument Functional Description and Performance Verification document (32-05002).

### **1.3 Support Item Description**

#### **1.3.1 Spacecraft Simulator**

The spacecraft simulator is composed of a single-board-computer (SBC) married to a MIL-STD-1553 bus controller. The SBC is programmed to interrogate the instrument on a fixed cadence, retrieving up to 25 primary science packets per second, 1 secondary science packet per second, and 1 housekeeping packet per second. (Once integrated with the LRO spacecraft, the housekeeping packets are only retrieved once every 16 seconds, but the packets are available from the instrument at the higher rate, since the instrument runs at a one second cadence.)

The SBC receives CCSDS telecommand packets as UDP packets addressed to port 11403, parses the contents per the Data ICD and delivers the commands to the instrument *via* the MIL-STD-1553 data bus.

The SBC also generates a 1 Hz tick to which the instrument synchronizes its activities. The SBC sends the instrument a time code at the same once-per-second rate which is used to time stamp the CCSDS telemetry packets.

The SBC retrieves telemetry from the instrument and constructs fully formed CCSDS packets, delivering each packet in a UDP stream aimed at localhost:11402 . A separate program – `pdist` – runs in the SBC that distributes the telemetry data as application ID filtered UDP streams.

#### **1.3.2 28VDC Power Supply**

A standard laboratory DC power supply, adjustable over the range of 27 to 35 VDC, 0.5 amperes maximum, is required to power the instrument.

## **2 Requirements**

### **2.1 Verification Plan**

This Procedure supports the activities contained in the CRaTER EMI/EMC Test Procedure (MIT Dwg. 32-06006.01), CRaTER Vibration Test Procedure (MIT Dwg. 32-06004.03), and the CRaTER Thermal-Vacuum Test Procedure (MIT Dwg. 32-06005.01).

### **2.2 List of Required Items**

- Spacecraft Simulator
- 28VDC Adjustable Power Supply
- Mate/Demate Log
- Flight CRaTER Instrument

## **3 Configuration**

### **3.1 General Constraints**

Electrostatic Discharge (ESD) protection procedures per MIT 99-01003 shall be observed.

Connector mating/demating procedures per MIT 99-03002 shall be observed. Any connections made directly to the unit under test shall be noted in the mate/demate log. *Although connector savers will normally be in use, there are times – such as during vibration testing – where these will have to be removed and later replaced.*

The flight instrument shall be maintained in a clean environment per MIT 32-01203.

The laboratory power supply shall only be operated within the range of 16 to 40 VDC.

A three-digit, calibrated digital volt meter shall be used for the initial setup of the input power. No other calibrated equipment is required.

### **3.2 Nomenclature**

The Electrical Ground Support Equipment (EGSE) consists of a 28 VDC power supply, a Ballard Technologies single board computer with 1553 interface (the spacecraft simulator), a computer workstation, and associated cabling.

### **3.3 Test Configurations**

The flight instrument is configured for test in an appropriate controlled area.

A three-wire cable connects the laboratory power supply to the instrument connector J2. (+28 VDC nominal, +28 Return, Chassis/Earth ground)

A two-wire cable connects the spacecraft simulator to the instrument signal connector J1.

A single MIL-STD-1553 dual-coax cable connects the spacecraft simulator to the instrument 1553 connector. Either J3 or J4 may be used; it is desirable, in fact, to vary which connector is used from day to day. On the spacecraft simulator side A is recommended, as the internal software defaults to this setting.

### **3.4 Hazardous Commands**

It is not permissible to turn on the detector bias supply in partial vacuum environments where the pressure is between 525 torr (10K feet altitude nominal) and  $10^{-3}$  torr.

### **3.5 Instrument Purge**

It is not necessary to maintain a continuous GN2 purge of the instrument unless an ambient pressure thermal test is being performed. It is prudent to perform a purge prior to returning the instrument to storage after testing.



## 4 Procedures

Space is provided for the recording of information of particular significance in the conduct of this test. Where a value simply needs to be verified, as opposed to recorded – or an instruction to send a command acknowledged -- a simple check mark √ will suffice. In addition the Test Conductor may redline the procedure to more accurately document the actual flow of events, both routine and anomalous.

The pages of this section will be attached to the Test Report that is filed each time this activity is conducted. The telemetry data stream generated by the spacecraft simulator is also an integral part of the Test Report; that data is archived on crater.bu.edu.

### 4.1 Identification of Test Environment

Procedure requiring this test: \_\_\_\_\_

\_\_\_\_\_

Location of Test Environment \_\_\_\_\_

Date: \_\_\_\_\_

### 4.2 Identification of Equipment and Personnel

Flight Instrument, 32-10000 S/N \_\_\_\_\_

Spacecraft Simulator, 32-80201 S/N \_\_\_\_\_

Test Conductor \_\_\_\_\_

QA Representative: \_\_\_\_\_

Other Individuals: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

### 4.3 Configure the EGSE

#### 4.3.1 Connect Test Cables

Using external DVM set DC power supply to 31VDC nominal – or other voltage if governing procedure calls for a specific value; then turn off supply.

Value in VDC	Time	Initial

The Spacecraft Simulator (aka OmniBusBox) is connected to the adjacent Interface box – two connectors on the Simulator go to four input connectors on the Interface box. They are usually left permanently connected.

Connect the power cable to instrument J2, the 1 Hz cable from the Interface box to J1, and the two MIL-STD-1553 cables from the Interface box to J3 and J4. (For a simple Short Form test, only one – and it doesn't matter which one – of the 1553 cables is required. Only in the Long Form test are both required. To power up Spacecraft Simulator simply turn the power switch ON; the system boots up in under 10 seconds.

#### 4.3.2 Log onto Workstation

*Although it is possible to run the underlying programs from standalone Windows, Macintosh, or Linux boxes, the instructions here assume a UNIX workstation connected to the MKI network.*

Log in to the workstation as user: **jennyg** (see a guru for the password).

Two TCL display windows will be required; start the following

```
CHouse &  
CCmd &
```

A primary science data window will show statistics

```
sf_noise &
```

Finally, we want to log the telemetry data for posterity

```
sf_log &
```

#### 4.4 Verify Initial Instrument State

Turn on DC power supply and verify proper instrument initialization as follows; or, if the instrument has been left on from a previous test issue, do

Command	Function	Value	Sent?
	Reset Instrument	n/a	

Verify that the time displayed in either the “CRaTER Analog House” and “CRaTER Command” widows is consistent with wall time and is incrementing every second.

Time and Date displayed	Initial

Verify that the time string displayed is not preceded by “/One Hertz/”, which would indicate a failure of the instrument to receive the 1 Hz tick from the spacecraft simulator on J1.

Check absence of /One Hertz/ display	Initial

Record the serial number of the unit under test, as displayed at the CRaTER Command window.

Instrument Serial Number	Initial

Read, record, and verify the state of the instrument command tell-tales (the current state is highlighted in the display).

Group	From command.tcl			
	Command	Value	Expected	OK?
HV Bias	On/Off		Off	
Calibrate	Low		Off	
	High		Off	
	Rate		8 Hz	
Processing	D1		On	
	D2		On	
	D3		On	
	D4		On	
	D5		On	
	D6		On	

Read, record, and verify the nominal housekeeping values recorded by the instrument.

From house.tcl					
Group	Measurement	Value	Units	Expected	OK?
Bus Voltages	+5 Digital		volts	5.0±0.1	
	+5 Analog			5.0±0.1	
	-5 Analog			-5.0±0.1	
Bias Current	D1		µamps	<0.1	
	D3				
	D5				
	D2			<0.40 at 25C	
	D4				
	D6				
Bias Voltage	Thin		volts	2.5±1	
	Thick			2.5±1	
Thresholds	Cal Amplitude		volts	<0.01	
	Thin LLD			0.048±0.001	
	Thick LLD			0.048±0.001	
Temperatures	Telescope		C	Ambient	
	Analog Board			Ambient	
	Digital Board			Ambient	
	DC-DC Supply			Ambient	
	Bulkhead			Ambient	
Dosimeter	Low		mRad	<0.1	
	Medium		mRad	<0.1	
	High		Rad	<0.1	
Ground Test	PRT Temp.		C	Ambient	

From GSE Power Supply			
Measurement	Value	Expected	OK?
Voltage		27-35	
Current		0.15-0.25 amps	

#### 4.5 Turn Detector Bias On

Command	Function	Value	Sent?
	HV Bias	ON	

Read, record, and verify the following. Note that, with the detector bias on, we are detecting the occasional cosmic ray, which is why the particle counts are not always zero.

From command.tcl					
Group	Command	Value	Units	Expected	OK?
HV Bias	On/Off		na	On	
	Voltage Thin		volts	75±10	
	Voltage Thick			220±10	
	Current D1		µamps	<0.1 at 25C	
	Current D3				
	Current D5				
	Current D2			<3.0 at 25C	
	Current D4				
	Current D6				
System	Echo		na	3 : 0x1000	
Singles Rates	D1		na	<5	
	D2				
	D3				
	D4				
	D5				
	D6				
Particle Counts	Good		na	<4	
	Reject			0	
	Total			<4	

From GSE Power Supply			
Measurement	Value	Expected	OK?
Voltage		27-35	
Current		0.15-0.25 amps	

#### 4.6 Initiate the Internal Calibration Signal

Command	Function	Value	Sent?
	Cal Amplitude	128	

Read, record, and verify the following

From command.tcl				
Group	Command	Value	Expected	OK?
Calibrate	Amplitude		2.048±0.024	

Command	Function	Value	Sent?
	Cal Low	ON	

Read, record, and verify the following. Again note that we see occasional cosmic ray hits which cause occasional reading 1 – 3 counts above the nominal calibration rates. **We are recording the minimum observed value here.**

From command.tcl				
Group	Item	Min. Value	Expected	OK?
Singles Rates	D1		8	
	D2		8	
	D3		8	
	D4		8	
	D5		8	
	D6		8	
Particle Counts	Good		8	
	Reject		0	
	Total		8	

#### 4.7 Check Detector Noise Levels

Command	Function	Value	Sent?
	Cal Rate	2KHz	

Read, record, and verify the following using the program **sf\_noise**

From Statistics window					
Detector	Mean	Expected	Sigma	Expected	OK?
D1		216±16		<2	
D2					
D3					
D4					
D5					
D6					

#### 4.8 Clean Up and Shut Down

If the instrument is to be left running

Command	Function	Value	Sent?
	Cal Rate	8Hz	

and the procedure ends here. **Otherwise**, we continue with

Command	Function	Value	Sent?
	Reset Instrument	n/a	

Read, record, and verify the following

From house.tcl				
Group	Measurement	Value	Expected	OK?
HV Bias	Voltage Thin		2.5±1	
	Voltage Thick		2.5±1	

Only if no further testing is to be performed immediately

- Turn off GSE 28VDC power supply and Spacecraft Simulator
- Close the telemetry archive file and upload the file to the CRaTER engineering web site: <http://snebulos.mit.edu/project/crater/>

Time Completed	Initial

## 5 In Case of Test Failure

### 5.1 Workstation Anomalies

If you have trouble logging in as “jennyg”, an alternative might be to log in as your own persona, and then enter the command

```
source /nfs/acis/a1/crater/etc/config
```

which should allow you to proceed with the CHouse, CCmd, *etc.* commands.

Note that if the power is cycled to the Spacecraft Simulator, any current invocations of CHouse, CCmd, *etc.* will have to be closed and the programs restarted. (Each application program makes a specific request to the Simulator for a data feed, and these requests do not persist over a power cycle.)

Most other workstation problems will probably require the assistance of a guru.

### 5.2 Spacecraft Simulator

The spacecraft simulator starts the CRaTER 1553 software (omniserver) and packet distribution program (pdist) automatically upon power-on boot. A healthy Ethernet connection is indicated by the blinking green status light on the front of the Omnibox.

The 1553 server defaults to using the A side 1553 bus (only) on power up. The server can be commanded (button on lower left of the workstation command window) to use the B side. All command and telemetry will operate normally in this mode, and all test procedures may be run in this condition without modification.

The spacecraft simulator also generates the 1 Hz tick. This signal may be commanded ON/OFF by a button on the lower left of the workstation command window (it will be ON by default on power up.)

Lacking success, there is little more the casual user can do but recheck the cables and cycle the power.

### 5.3 General Procedure Errors

A time stamp is generated by the spacecraft simulator once per second, converted into LRO-standard Mission Elapsed Time and sent to the Instrument in a 1553 data packet. That time stamp is then attached to each CCSDS telemetry packet returned by the Instrument. The GSE displays unpack those MET timestamps and convert them back into standard wall-clock format. The end result: if the GSE time displays are incrementing once per second, the entire end-to-end command-instrument-telemetry system is working. And, if not, there is no sense in proceeding on until that problem is solved.

Note that the spacecraft normally reads the RTD internal to the CRaTER instrument. In our usual test set-up we do not bring those two leads out; rather, they are looped back on the J1 connector that is part of the test cable, allowing the internal housekeeping circuitry to read its value. Where the loopback is not available, one needs to read the resistance of the RTD with an ohm meter and record the result in the space given. (The nominal resistance is 2000 ohm at 0 C, varying approximately 8 ohms/C.)



In general all failures of a telemetry value to be within expected limits are meaningful. The test should generally be terminated at that point in the procedure, though it will not cause harm to the instrument to continue and seek guidance after the fact. It is possible, of course, that operator error has occurred. Simply resending a command is perfectly acceptable; none of the CRATER commands are sensitive to instrument state. It is also acceptable to simply send a RESET command and restart the procedure from the top (paragraph 4.4 in this procedure), although this should be considered as a troubleshooting exercise – and a fresh copy of the procedure used when the test problems have been solved.