Rev.	ECO	Description	Author	Approved	Date
01	32-200	Initial Release for comment	RFGoeke		1/24/07
02	32-207	Update base on first full run	RFGoeke		4/2/07
03	32-216	Incorporate new software packages	RFGoeke		5/4/07
A	32-223	Release for flight testing	RFGoeke		6/26/07
B	32-246	Add stability criteria; lf_ecal test	RFGoeke		9/21/07
C	32-257	Measure bus voltage at GSE supply	RFGoeke		11/14/07

CRaTER
Long Form Functional
Test Procedure

Dwg. No. 32-06003.01

Revision C
November 8, 2007

S/N: ______ Date: _______________

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Preface

The Long Form Test is not run often, for a variety of reasons, and some of its components yield data that must be evaluated by an observer familiar with the idiosyncrasies of particle detectors in general and the characteristics of this instrument in particular. Similarly, some data analysis involves EGSE procedures that are only sketchily described here. It is intended that only the Project Scientist, Project Engineer, or Project Test Engineer run the Long Form Test.

Rev. 01 is released for general comment.

Rev. 02 is an update based on the experience of the first full run on S/N 10.

Rev. 03 added Echo commands to mark test boundaries and incorporated new test software.

Rev. A had implemented packet checking of test mode plus minor procedural changes.

Rev. B added a range of internal cal signal data plus success criteria for assuring stable instrument operation over time (see Section 4.18). The Purge Flow test was deleted (tracking a hardware deletion!). An internal calibration sweep test was added. A criteria for the stability of the regulated power supplies over a range of input voltages was added.

Rev. C made power measurements at the GSE power supply rather than the now removed internal telemetry points.

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 as many of its performance requirements as can be tested within a laboratory environment. In particular all functional modes, including redundant operations, will be exercised.

1.2 Test Item Description

See para. 1.2 of the Short Form Functional Test Procedure (32-06003.02).

1.3 Support Item Description

See para. 1.3 of the Short Form Functional Test Procedure (32-06003.02).

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

See para. 2.2 of the Short Form Functional Test Procedure (32-06003.02).

3 Configuration

3.1 General Constraints

See para. 3.1 of the Short Form Functional Test Procedure (32-06003.02).

3.2 Test Configurations

Same as para. 3.2 of the Short Form Functional Test Procedure (32-06003.02) except that here two MIL-STD-1553 dual-coax cables connect the spacecraft simulator to the instrument 1553 connector.

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/demaite 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.*

4 Procedures

Space is provided for the recording of information of particular significance in the conduct this test. Where a value simply needs to be verified, as opposed to recorded, 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 complexities of running this test makes it difficult for the novice test conductor to achieve a satisfactory result. At the time of initial controlled release of this document, only Bob Goeke and Dorothy Gordon are qualified for this effort.

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 Accumulated Operating Time

Record the current reading of the cumulative operating time for this instrument by using a web browser to interrogate the spacecraft simulator at http://csr-dyn-94.mit.edu (or whatever net address the simulator resides on for this test).

EGSE S/N	Time in hours:minutes	Initial

4.4 Short Form Functional Test

Perform the CRaTER Short Form Functional Test (32-06003.02) and attach the as-run copy to this report. Do not terminate the **sf_log** archive program at the end of the test (or, if you did, restart it now!).

Pass	Fail	Time	Initial

This simple test demonstrates most of the functionality of the instrument (as well as ensuring that the Instrument GSE is functioning properly). The remaining tests pick up specialized and redundant functions. We are using the echo command to place markers in the data stream so that we can go back and review individual tests.

4.5 Echo Command Function

Command	Function	Value
	Echo	0x1234

Read, record, and verify the following

		From command.tcl		
Group	Measurement	Value	Expected	OK?
System	Echo		2 : 0x1234	

4.6 Bus Power Variations

Command	Function	Value
	Echo	0x4600
	HV Bias	On

With the GSE power supply set at 31±0.5 VDC, read and record the following

From GSE Power Supply			
Measurement	Value	Expected	OK?
Voltage		31±0.5 volts	
Current		0.15-0.25 amps	
Calculated Power		6-8 watts	

Adjust the GSE power supply to 27±0.5 VDC, then read and record the following

From house.tcl				
Group	Measurement	Value	Expected	OK?
Bus Voltages	+5 Digital		5.0±0.1	
	+5 Analog		5.0±0.1	
	-5 Analog		5.0±0.1	
Time Display	hh:mm:ss		Wall time	

From GSE Power Supply			
Measurement	Value	Expected	OK?
Voltage		27±0.5 volts	
Current		0.15-0.25 amps	
Calculated Power		6-8 watts	

Command	Function	Value
	Echo	0x4601

Adjust the GSE power supply to 35±0.5 VDC, then read and record the following. Note that for the regulated voltages, we are interested in the change from the previous condition being minimal.

From house.tcl				
Group	Measurement	Value	Expected	OK?
Bus Voltages	+5 Digital		Δ < 12mv	
	+5 Analog			
	-5 Analog			
Time Display	hh:mm:ss		Wall time	

From GSE Power Supply			
Measurement	Value	Expected	OK?
Voltage		27±0.5 volts	
Current		0.15-0.25 amps	
Calculated Power		6-8 watts	

Command	Function	Value
	Echo	0x4602

Adjust the GSE power supply to 31±0.5 VDC and proceed to the next section/

Time Completed	Initial

4.7 Interrupt 1 Hz Tick

Command	Function	Value
	Echo	0x4700
	1 Hz Tick off	(none)

Observe that the /One Hertz/ message appears preceding the time display.

/One Hertz/ message displayed?	Initial

Command	Function	Value
	Echo	0x4701
	1 Hz Tick on	(none)

Observe that the /One Hertz/ message has disappeared.

/One Hertz/ message absent?	Initial

4.8 Interrupt 1553 Functions

Command	Function	Value
	Echo	0x4800
	1553 Side B	(none)

Verify that the time display continues to run properly on the B side bus of the 1553 interface.

.

From house.tcl				
Group	Measurement	Value	Expected	OK?
Time Display	1 sec ticks		Wall time	

Command	Function	Value
	Echo	0x4801
	1553 Side A	(none)

Verify that the time display is back running properly on the A side.

From house.tcl				
Group	Measurement	Value	Expected	OK?
Time Display	1 sec ticks		Wall time	

4.9 Test Mode

Command	Function	Value
	Echo	0x4900
	Echo	8
	Data Test	(none)

The Test Mode starts a science telemetry pattern generator within the digital section of the instrument. (The preceding "echo 8" instructs the system to run the entire suite of tests.) Run **CData** to verify that the test mode flag is set to "1" and test data is filling the science packets. (The Data Test button on the display also changes state here.)

Data Field	Expected	OK?
Test Mode Flag	1	

Wait a minimum of 2 minutes before proceeding. (The only way to exit Test Mode is to Reset the Instrument.)

Command	Function	Value
	Reset	(none)
	HV Bias	On

	From house.tcl			
Group	Measurement	Value	Expected	OK?
Bias Voltage	Thin		75±10	
	Thick		220±10	

We check the results of the Data Test (plus do a number of other consistency checks on the normal data packets) by running the following on the running data archive file starting in the initial Short Form test.

rtlm-x <archive_file | craterCheck

The desired outcome is to have no errors – though you will see messages reporting the clock outage we commanded back in Section 4.7. See Appendix A -- craterCheck man page for the details.

Data	Expected	OK?
craterCheck output	No errors	

4.10 Detector Noise Thresholds

We now enable a single detector channel at a time; the noise threshold is determined by walking the appropriate LLD up from 64 (or approximately 0 mv) until the number of reported Good Events is less than 20. When a measurement is completed, reset the LLD to 128. Record the threshold setting, not the feedback voltage.

Command	Function	Value
	Echo	0x4A00

Command	Function	LLD Thin Threshold	LLD Thick Threshold	OK?
	Process D1 Only			
	Process D2 Only			
	Process D3 Only			
	Process D4 Only			
	Process D5 Only			
	Process D6 Only			

4.11 Detector Zero Crossing

Command	Function	Value
	Echo	0x4B00

Run the **`lf_zero`** script. This will use the low range internal cal signal to draw a line between two points and calculate the ADU count of that line when it crosses zero (input).

	D1	D2	D3	D4	D5	D6
High						
Low						
Zero						

4.12 Internal Cal Signal Sweep

This test is run purely to gather data which would be used by the science team to cross-calibrate instrument performance in case of on-orbit anomalies. The internal calibration source is run in both low and high amplitude modes, stepping 8 (command) LSBs and collecting a few thousand events at each step.

Command	Function	Value
	Echo	0x4C00

Run the **lf_ecal** script.

Time Completed	Success?

4.13 Coincidence Mask Test

Command	Function	Value
	Echo	0x4D00

This is a test which, for all combinations of detector processing enable, verifies that one and only one coincidence mask bit allows good events to be recorded. Since the test involves 2^6 processing combinations and the same number of coincidence mask bits, it takes at least $3 * 2^{12}$ seconds (3.4 hours) to complete. (We do not attempt to test all combinations of the coincidence mask, even for a single processing case; that would take 10^{12} years.)

Run the **lf_mask** script.

Time Completed	Cases Run	Success?

4.14 Cobalt-60 Radiation Test

Command	Function	Value
	Echo	0x4E00

This test works best with a 5 microcurie source held just in front of the telescope aperture (effectively about 1 cm from the closest thick detector). A stronger source held at a greater distance would do as well. With some of our older sources one must take into account the 5.3 year half-life in establishing the effective strength.

Run the "**lf_cobalt 60**" script (it will take 60 minutes worth of data) and compare the plots to the reference data in Appendix B. (The example is from a 13 hour run!)

Time Completed	Max Counts D1,3,5	Max Counts D2,4,6	Success?

4.15 Dosimeter Tests

The dosimeter does not respond to commonly available radiation sources. There is no test available once the instrument is buttoned up.

4.16 Clean Up and Shut Down

We intentionally use the "clear" command here to exercise that function; the "reset" command used elsewhere is a more general instruction which affects most of the internal logic states.

Command	Function	Value
	Clear	(none)

Read, record, and verify the following

	From house.tcl			
Group	Measurement	Value	Expected	OK?
Bias Voltage	Thin		3±1	
	Thick		3±1	

Turn off GSE 28VDC power supply and Spacecraft Simulator if no further testing is to be performed immediately.

Close the archive data file by closing the window opened by **sf_log** .

Time Completed	Initial

4.17 Accumulated Operating Time

Record the current reading of the cumulative operating time for this instrument by using a web browser to interrogate the spacecraft simulator at http://csr-dyn-94.mit.edu (or whatever net address the simulator resides on for this test).

EGSE S/N	Time in hours:minutes	Initial

4.18 Deviation from Baseline Performance

Where applicable, test limits have been defined in this procedure and the accompanying Short Form Functional. These limits are intended to encompass all operating conditions. Additionally, we want to assure that the operation of instrument remains stable. To that end we calculate here – when appropriate – the deviation of various parameters from their baseline values. (The nominal, ambient temperature and pressure baseline is available from the CRaTER database under the 32-06001 heading.)

Date of Baseline or Database Ref. Number	Initial

Test Ref	Parameter	#/LSB	Baseline	This Test	Delta	Limit	OK?
SFF 4.4	+5 Digital	2mv				10mv	
	+5 Analog						
	-5 Analog						
	Bulkhead	0.1C					
	ΔTelescope					2.0C	
	ΔAnalog						
	ΔDigital						
	ΔDC-DC						
SFF 4.5	Power	30mw				0.2w	
	Bias V, Thin	0.1v				0.5v	
	Bias V, Thick	0.1v					
	D1 bias I	0.5μa, 12%/C				greater of 25% or 2.5μa	
	D3 bias I						
	D5 bias I						
	D2 bias I	5μa, 12%/C				Greater of 25% or 25μa	
	D4 bias I						
	D6 bias I						

NB: Temperature data is entered here as differences between the monitored value and the temperature of the bulkhead, instrument reference. The bulk temperature of the instrument depends upon the environment; to a first order the internal deltas should not.

The Primary Science data is recorded here in ADU. For reference, the thick detectors have a scale of approximately 20KeV/LSB; the thin detectors approximately 60KeV/LSB.

Test Ref	Parameter	Baseline	This Test	Delta	Limit	OK?
SFF 4.7	D1 Cal Amp				5	
	D2 Cal Amp					
	D3 Cal Amp					
	D4 Cal Amp					
	D5 Cal Amp					
	D6 Cal Amp					
	D1 Noise				0.3	
	D2 Noise					
	D3 Noise					
	D4 Noise					
	D5 Noise					
	D6 Noise					
LFF 4.11	D1 Zero Cross				0.3	
	D2 Zero Cross					
	D3 Zero Cross					
	D4 Zero Cross					
	D5 Zero Cross					
	D6 Zero Cross					

Appendix A -- craterCheck man page

```
NAME
    craterCheck -- Search for errors in CRaTER packets in test mode

  USAGE
        craterCheck        # For use on SUN Solaris machines
        craterCheck.mac    # For use on Mac OS X machines
        craterCheck.exe    # For use on Windows machines
        craterCheck.c      # Source code

  FLAGS
        (none)
        Uses only STDIN and STDOUT

  DESCRIPTION
    This program verifies the data integrity of the CraterInstrument, as
    well as the operation of the SRAM and 1553 bus subsystems. Although
    useful for looking at packets emitted by the intrument in normal mode,
    running the intrument in "text" mode provides a more thorough
    diagnostic. First set up a data archiving process. Then the commands

      echo 8
      test

    sent to the instrument will start a cycle of internal diagnostics whch
    should be allowed to continue for at least 2 minutes.

        rtlm-x <archive_data | craterCheck

    will process the data.

  DATA OUTPUT DESCRIPTION
    PS - Primary Science SS - Secondary Science HK - Housekeeping SSCnt -
    Source Sequence Count

    ApIDErr - Encountered an illegal Application Process ID (not equal to
    120, 121 or 122)

    HdrBitCorr - Corruption encountered at the beginning of the packet
    header (check includes Version Number, Type and Secondary Header Flag)

    PLen - indicates that the packet length field does not match the
    expected value.

    SSCnt - (Source Sequence Counter) errors are listed for each ApID This
    error count is non-zero if the detected SSCnt is non-consecutive.
    Special cases were added to handle potential GSE problems: Drop1
    indicates one dropped packet. Repeat1 indicates a duplicate packet.

    Testmode data integrity checking is continued if the Drop1 or Repeat1
    error is found. The program resynchs when a more serious PS SSCnt error
    is encountered.

    Data Errors apply only to the PS Telemetry when the system is in
    TestMode. They indicate a test-mode pattern mismatch in the data portion
    of the packet. Data Errors are tabulated on a per packet basis and
    accumlated for all Testmode packets. If more than four errors are found
    in one packet, the MultErrs count is incremented and the system
    "resynchs".

  BUGS
    The program will only work if provided the output of an rtlm -x process,
    with or without a 64-byte file header. The program is very intolerant of
    variations in input format and has only been used with an rtlm feed.

  SEE ALSO
        rtlm-x.c, verify
```

Appendix B -- Sample Cobalt-60 data