CRaTER
Thermal-Vacuum
Test Procedure

Dwg. No. 32-06005.01

Revision B
September 21, 2007

S/N:_______ Date:_________
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Preface

Revision 01 is being released for general comment. The actual procedures for installing the instrument in the T/V chamber and running the thermal balance part of the procedure are more to be regarded as placeholders than finished products.

Revision A is released for testing of the flight hardware.

Revision B is released to incorporate comments received during Instrument PER, changing the control temperature to the external interface and reducing temperature excursions. Red and Yellow temperature limits have also been added. This revision does not address proposals for doing an actual Contamination Certification of the instrument, nor does it address the details necessary for implementing a revised plan for doing an expanded Thermal Balance test (involving shrouds, additional temperature monitors, etc.). These items will have to be picked up in a later revision.
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.

1.1 Activity Description

This procedure will provide a demonstration that

• the hardware meets its performance requirements within allowable tolerance when subjected to a thermal-vacuum environment representative of extreme operating conditions in flight;
• the hardware meets its performance requirements after being subjected to multiple thermal cycles in a vacuum environment;
• the thermal model faithfully represents the actual flight instrument.

Demonstration of hardware performance during the test is accomplished by use of the CRaTER Short Form (32-06003.02) and Long Form (32-06003.01) Functional Tests.

A graphical timeline of the activities described here is given by the TV Temperature Profiles (32-06005.0101 and 32-06005.0102)

1.2 Test Item Description

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 form a hextuple of 12-bit values that comprise the primary science data for a single event. The FPGA packs a series of these hextuples 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.

Six instrument temperatures are read out through the normal flight telemetry stream:

• telescope – this is a good representation of the TEP and detector temperatures
• analog board – the analog board has no point heat sources
• digital board – this is the temperature of the case of the hottest component (the 1553 transceiver)
• DC-DC converter – the case temperature of the hotter of the two converters
• bulkhead – the wall separating the electronics box from the telescope volume
• prt reference – located on the bulkhead adjacent to the above sensor

Note that the “prt reference” is normally read out by the spacecraft telemetry system; only in the stand-alone instrument test configuration is it read out in the instrument telemetry stream. The location of these sensors is shown in Appendix C – Temp Monitor Locations.
1.3 Support Item Description

1.3.1 Thermal-Vacuum Chamber
The Thermal-Vacuum Chamber is a 2’ x 2’ x 2’ chamber made of stainless steel. All walls are electropolished. The chamber baseplate is 3/8” thick copper, gold plated with temperature limits of -120°C to +125°C. The door gasket and baseplate feedthrough seals are viton. All other seals are conflat with copper gaskets. The vacuum system consists of a 4.5” OD Leybold turbo pump backed by a Tribudine dry rotary vane roughing pump.

1.3.2 TQCM
A Thermoelectric Quartz Crystal Microbalance (TQCM) is provided to assess the cleanliness of the instrument.

1.3.3 Radiation Source
A ⁶⁰Co gamma ray source is used to stimulate the thick detectors during parts of the Long Form Functional tests.

1.3.4 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 retrieved only 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.)

1.3.5 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.

1.3.6 Data Logger for Chamber Environment
The Chamber Data Logger acquires low time resolution data about chamber temperatures and pressure.

1.3.7 Computer Workstation
To support the monitoring of environment variables from the data logger in addition to the command and data interface to the instrument via the spacecraft simulator, a computer workstation is required. This workstation is also responsible for logging all data into standard LRO-format data files. Our software will run on UNIX, Mac, or Windows operating systems which support UDP network connections to the spacecraft simulator and data logger and have both Perl and TCL/Tk available to run the scripts.
2 Requirements

2.1 Verification Plan
This Procedure supports the Instrument Performance and Environmental Verification Plan (32-01206).

2.2 Temperature Limits – Thermal Balance
The test temperature requirements for Thermal Balance are taken from Table 2-1 of the LRO Thermal System Specification, 431-SPEC-000091, Rev C. These are not based on flight predicts of the internal reference temperatures but on the specified limits on the spacecraft side of the interface – in this case the plate to which the instrument under test is mounted.

- Hot balance: +25 C
- Cold balance: -30 C
- Survival balance: -40 C

2.3 Temperature Limits – Thermal Cycling
The test temperature requirements for Thermal Cycling are taken from Table 6-3 of the CRaTER Thermal Subsystem Specification, 431-SPEC-000091, Rev C. The temperatures refer to that measured at the external mounting surface.

- Hot Survival: +35 C
- Hot Qualification: +35 C
- Hot Operating: +25 C
- Cold Operating: -30 C
- Cold Qualification: -40 C
- Cold Survival: -40 C

To adequately screen for workmanship, we will envelope the requirements by doing the Hot Survival and Hot Qualification at +40C.

2.4 Temperature Tolerance
The tolerance on all test temperatures is ±2C.

2.5 Temperature Slew Rates
Thermal slews will be commanded to occur at a rate of 0.5C/min.

2.6 Order of Tests
The individual tests may be performed in any order which proves convenient.

2.7 Required Items
- Thermal-vacuum chamber
- TQCM
- 60Co radiation source
- Chamber data logger
- Spacecraft Simulator
- 28VDC Adjustable Power Supply
- Flight CRaTER Instrument
2.8 **Success Criteria – Thermal Cycling**

The success criteria for thermal cycling is that the instrument performance, as measured by the Long Form Functional tests, does not substantively change between the first and last LFF run at 0°C. The definition of “substantive” is given in the LFF procedure. (The various tests run at high and low temperature limits need to meet the general performance limits given in those tests.)

2.9 **Success Criteria – Thermal Balance**

There are no success criteria for the tests as performed by this procedure; we are merely collecting data here. Success is defined by the thermal model matching these results within tolerances defined by the model requirements.

2.10 **Documents to be on Hand**

- 32-03002.02 T/V Chamber Wiring Diagram
- 32-06003.01 Instrument Long Form Functional Test Procedure (4 copies)
- 32-06003.02 Instrument Short Form Functional Test Procedure (13 copies)
- 32-06003.05 Vacuum Pumpdown and Venting Procedure
- 32-06003.06 Instrument GN2 Purge Procedure
- Mate/Demate Log
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.

Only qualified personnel may install/remove the radiation source to/from the chamber. The activity level of the unshielded source is comparable to natural background at a distance of 3 feet.

The flight instrument shall be maintained in a clean environment per MIT 32-01203. In addition the thermal-vacuum chamber must be verified clean (using the TQCM) prior to installation of the instrument in the chamber.

The laboratory power supply shall be operated only within the range of 27 to 35 VDC.

A three-digit, calibrated digital voltmeter 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), the Chamber Data Logger, a computer workstation, and associated cabling.

The chamber baseplate is thermally isolated from the chamber walls and temperature controlled by a combination of heaters and LN2. The interface plate provides a hole pattern equivalent to the spacecraft mechanical interface. It is hard mounted to the chamber baseplate (and thus should follow the control temperature closely); the instrument and blanket (if used) are, in turn, mounted on the interface plate.

3.3 Test Configuration
The flight instrument with a representative thermal blanket is configured for test inside the thermal-vacuum chamber located at MIT Building NE80 with connections made through the chamber wall to the laboratory power supply and spacecraft simulator. (The thermal blanket is optional if only thermal cycling is to be performed.)

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
The instrument should be purged prior to returning the instrument to storage after testing; see the Instrument GN2 Purge Procedure (32-06003.06). Nominal completion of this procedure will result in that happening as part of the chamber vent cycle.
4 Procedures -- Initialization

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, 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. An example of this would be that the Thermal Balance dwells are done on only one flight unit and hence skipped on the alternate unit.

The pages of this section will be attached to the Test Report that is filed for each instrument on which this activity is conducted. That is also true of the as-run copies of the Short and Long Form Test Procedures. The telemetry data stream generated by the spacecraft simulator and chamber data logger is an integral part of the Test Report; that data is archived on crater.bu.edu.

4.1 Identification of Equipment and Personnel

Flight Instrument, 32-10000  S/N ____________
Spacecraft Simulator, 32-80201  S/N ____________

Principal Test Conductor

Other Test Conductors

QA Representative:

Other Individuals:

4.2 Data Logging

The general intent is to log the instrument and chamber data continuously for the duration of this test procedure. Since standard archive process date-stamps the file names, and every CCSDS data packet is time-tagged, we can, after the fact, stitch together a continuous archival record. The important point for the test conductor is not to terminate a data log archive at the conclusion of any short or long form functional test, but simply to let it run. (At maximum event rate we generated< about 1GB/day.)
4.3 **Baseline Chamber Cleanliness**
At some time prior to this test the chamber must be subjected to a “dry run” before the instrument and its thermal blanket are installed. With the interface plate held at +35°C and the TQCM held at –20°C, an empty-chamber cleanliness level must be established.

<table>
<thead>
<tr>
<th>TQCM Drift</th>
<th>Date of Test</th>
<th>Initial</th>
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4.4 **Install Instrument in Chamber**

4.4.1 **Prepare the Vacuum Chamber**
Clean room garment, hat, and clean latex gloves shall be worn during this operation.

1. Torque the ¼-20 SHCS (Qty 10) on the interface plate to 32 in-lbs.
2. Ensure RTD #7 is on the interface plate and RTD #8 is on the gold plated copper thermal plate near the cutout for the telescope and that the wires will not be pinched when CRaTER is installed.
3. Move Cables out of the way for installation.
4. Clean door gasket and interface surface with slightly damped 2-propanol clean Alpha 10 wipe. Visually inspect for particulates and clean with dry clean Alpha 10 wipe.
5. Close door. Remove latex gloves and put on clean ESD safe Nitrile gloves before continuing to install the instrument.

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<th>Date</th>
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4.4.2 **Install Instrument on Interface Plate**
ESD precautions must be met. Clean room attire shall warn: ESD-safe clean gloves, ESD clean room smock, ESD wrist strap, hair net must be worn.

1. Remove vent plug at the Nitrogen purge inlet.
2. Remove vent cover at the purge outlet, if applicable.
3. Place the CRaTER assembly onto Interface Plate being careful not to bump into the Blanket buttons. Ensure cables and RTD wires are clear.
4. Secure to Interface Plate with clean Silver plated 10-32 x .75” min SHCS. Torque to 28 in lbs.
5. Connect vacuum feedthru interface cables (1553, 1 Hz clock, power) to the instrument.
6. Place the $^{60}$Co gamma ray source above the nadir instrument aperture.

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4.5 **Check out the EGSE**
Connect the external 1553, 1Hz clock, and 28VDC power cables to the Spacecraft Simulator and run a Short Form Functional to demonstrate basic aliveness. **In addition to a normal Short Form, check out the alternate 1553 connection. The instrument should be left in a powered down state.**

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
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<tr>
<td>Off?</td>
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Connect the external cables to the Chamber Data Logger and verify that all environmental channels and the TQCM monitor are functioning properly.

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<th>Time</th>
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4.6 **Pump Down the Chamber**
Following the Vacuum Pumpdown Procedure, 32-06003.05, pump down the chamber for a minimum of 12 hours. Continue on to the next step when the pressure is less than $5 \times 10^{-5}$ torr.

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4.7 **Initial Outgassing Period**
Command the chamber baseplate to 45C. Continue on to the next step when the pressure is again less than $5 \times 10^{-5}$ torr (or when the Contamination Engineer feels we can proceed).

<table>
<thead>
<tr>
<th>Date</th>
<th>Chamber Pressure</th>
<th>Time</th>
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4.8 **Baseline Long Form Functional Test**
Command the chamber baseplate to 0C.

Wait for the Instrument Interface Temperature to reach between $-2$ and $+2$C; then run a full Long Form Functional Test, 32-06003.01. The Long Form will leave the instrument unpowered.

<table>
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<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Tbaseplate</th>
<th>Tref</th>
<th>Time</th>
<th>Initial</th>
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<tr>
<td>Off?</td>
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4.9 **General Instrument Monitoring**
As the instrument operates more or less continuously during this test, the test conductor must monitor the data to assure that nothing untoward – or even unusual – is happening between the benchmark test events. In particular both instrument and facility data should be monitored carefully during temperature transitions.
5 Procedures – Temperature Dwell

5.1 Hot Dwell #1 – Hot Turn On/Long Form
Command the chamber baseplate to +40C.

<table>
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<th>Date</th>
<th>Time</th>
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Wait for the Instrument Interface Temperature to reach the range or +38 to +42C.

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<th>Time</th>
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Now wait for (a minimum of) 2 hours with the instrument un-powered; then perform a Long Form Functional. The instrument should be powered off at the end of this procedure.

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<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
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<tbody>
<tr>
<td></td>
<td>Off?</td>
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</table>

Since the Long Form takes longer than 4 hours to complete, we can simply go on.

5.2 Cold Dwell #1 – Cold Survival Balance/Cold Turn On/Long Form
Command the chamber baseplate to -40C.

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<th>Date</th>
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Wait for the Instrument Interface Temperature to reach the range or -38 to -42C

<table>
<thead>
<tr>
<th>Time</th>
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</table>

Wait for a minimum of 2 hours with power off before proceeding.
5.2.1 Option for Cold Survival Balance

If doing a Cold Survival Balance, record at 30 minute intervals the instrument temperature data. Balance is achieved when, after a minimum of 5 hours, there is no change in any of the six instrument temperatures of more than 0.5 degree C in the previous 3 hours.

<table>
<thead>
<tr>
<th>Time</th>
<th>Telescope</th>
<th>Analog</th>
<th>Digital</th>
<th>Converter</th>
<th>Bulkhead</th>
<th>PRT</th>
<th>Interface Plate</th>
</tr>
</thead>
</table>

5.2.2 Cold Turn-on

Perform a Long Form Functional, stopping before para 4.16 Clean Up and Shut Down. When finished leave the instrument running in the state defined by para 4.7 Check Detector Noise Levels of the Short Form Functional.

<table>
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<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
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</table>

Since the Long Form takes longer than 4 hours to complete, we can simply go on.
5.3 **Hot Dwell #2**  
Command the chamber baseplate to +40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
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</table>

Wait for the Instrument Interface Temperature to reach a minimum of +38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
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</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
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5.4 **Cold Dwell #2**  
Command the chamber baseplate to -40C.

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<th>Date</th>
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Wait for the Instrument Interface Temperature to fall below –38C.

<table>
<thead>
<tr>
<th>Time</th>
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</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
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<tbody>
<tr>
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<td>On?</td>
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</table>
5.5 **Hot Dwell #3**

Command the chamber baseplate to +40°C.

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<tr>
<th>Date</th>
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<th>Initial</th>
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</table>

Wait for the Instrument Interface Temperature to reach a minimum of +38°C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
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</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
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5.6 **Cold Dwell #3**

Command the chamber baseplate to -40°C.

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<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
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Wait for the Instrument Interface Temperature to fall below –38°C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
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</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
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</table>
5.7 **Hot Dwell #4**

Command the chamber baseplate to +40C.

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<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
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Wait for the Instrument Interface Temperature to reach a minimum of +38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
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</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
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5.8 **Cold Dwell #4**

Command the chamber baseplate to -40C.

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<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
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Wait for the Instrument Interface Temperature to fall below –38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.9  **Hot Dwell #5**

Command the chamber baseplate to +40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to reach a minimum of +38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.10  **Cold Dwell #5**

Command the chamber baseplate to -40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to fall below –38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.11 Hot Dwell #6
Command the chamber baseplate to +40°C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to reach a minimum of +38°C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.12 Cold Dwell #6
Command the chamber baseplate to -40°C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to fall below –38°C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.13 Hot Dwell #7
Command the chamber baseplate to +40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to reach a minimum of +38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.14 Cold Dwell #7
Command the chamber baseplate to -40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to fall below –38C. (If the Reference Temperature fails to follow the baseplate temperature closely, some control adjustment to the baseplate temperature may be necessary.)

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.15 **Hot Dwell #8**

Command the chamber baseplate to +40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to reach a minimum of +38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.16 **Cold Dwell #8**

Command the chamber baseplate to -40C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to fall below –38C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Now wait for (a minimum of) 4 hours with the instrument operating; then perform a Short Form Functional, stopping at the conclusion of para 4.7 *Check Detector Noise Levels*. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If the Thermal Balance dwells are not being performed on this unit, proceed directly to section 6.1.
5.17 Hot Thermal Balance

Command the chamber baseplate to +25C. To measure blanket properties properly, we really want the chamber pressure below $1 \times 10^{-5}$ torr (which is why these balance tests have been moved to the end of the process), but we will continue on regardless.

<table>
<thead>
<tr>
<th>Date</th>
<th>Chamber Pressure</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

When the interface plate first reaches its target temperature (it is not necessary to wait for the whole instrument to stabilize), run a Short Form Functional, stopping at the conclusion of 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At 30 minute intervals record the instrument temperature data. Balance is achieved when, after a minimum of 5 hours, there is no change in any of the six instrument temperatures of more than 0.5 degree C in the previous 3 hours.

<table>
<thead>
<tr>
<th>Time</th>
<th>Telescope</th>
<th>Analog</th>
<th>Digital</th>
<th>Converter</th>
<th>Bulkhead</th>
<th>PRT</th>
<th>Interface Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
5.18 Cold Thermal Balance

Command the chamber baseplate to -30C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the interface plate first reaches its target temperature (it is not necessary to wait for the whole instrument to stabilize), run a Short Form Functional, stopping at the conclusion of para 4.7 Check Detector Noise Levels. This will leave the instrument running in its nominal on-orbit condition.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At 30 minute intervals record the instrument temperature data. Balance is achieved when, after a minimum of 5 hours, there is no change in any of the six instrument temperatures of more than 0.5 degree C in the previous 3 hours.

<table>
<thead>
<tr>
<th>Tiime</th>
<th>Telescope</th>
<th>Analog</th>
<th>Digital</th>
<th>Converter</th>
<th>Bulkhead</th>
<th>PRT</th>
<th>Interface Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>


6 Procedures – Wrap-up

6.1 Baseline Long Form Functional
Command the chamber baseplate to 0C.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Wait for the Instrument Interface Temperature to reach the range of -2 to +2C. Run a Long Form Functional, but leave the instrument in the state defined by the conclusion of para 4.7 Check Detector Noise Levels of the Short Form Functional. Compare the results to that obtain in the initial baseline functional.

<table>
<thead>
<tr>
<th>Pass/Fail</th>
<th>Instr. State</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>On?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.2 Cleanliness Monitor
Command the chamber baseplate to +35C

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

Turn on the TQCM (per Appendix A), setting the cooling loop to +10C and the sensor head to -20C. Record the TQCM readings every hour (for at least five hours) until the Contamination Engineer sees that a satisfactory evaluation of the instrument cleanliness has been achieved.
<table>
<thead>
<tr>
<th>Nominal Hours</th>
<th>Time</th>
<th>TQCM (Hz)</th>
<th>f Change (Hz/Hr)</th>
<th>Bulkhead (C)</th>
<th>Sensor (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td></td>
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<tr>
<td>3</td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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<td>5</td>
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<tr>
<td>9</td>
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<tr>
<td>10</td>
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<tr>
<td>11</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CC Engineer</th>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.3 **Power off Instrument**

Power off the instrument following para 4.8 *Clean Up and Shut Down* of the Short Form Functional.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

6.4 **Power off TQCM**

Raise the temperature of the sensor to +30°C. After the sensor has stabilized, turn off the TQCM.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

6.5 **Power off Thermal Control of the Chamber Baseplate**

Remove power from the chamber baseplate, leaving it drift at approximately +35°C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

6.6 **Vent the Thermal-Vacuum Chamber**

Vent the thermal-vacuum following the procedure of 32-06003.05.

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

6.7 **Remove Instrument from Chamber**

6.7.1 **Remove Instrument from Interface Plate**

ESD precautions must be met. Clean room attire shall warn: ESD-safe clean gloves, ESD clean room smock, ESD wrist strap, hair net must be worn.

1. Verify that the EGSE has been powered down.
2. Place Yellow dust cap over the TQCM.
3. Disconnect vacuum feedthru interface cables from the instrument (J1-J4)
4. Loosen and remove 10-32 hardware that secures CRaTER to the Interface Plate.
5. Lift CRaTER Assembly off of Interface Plate
6. Install vent plug at the instrument Nitrogen purge inlet
7. Install vent cover at the instrument purge outlet

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Initial</th>
</tr>
</thead>
</table>

6.7.2 **Secure the Vacuum Chamber**

We will not provide details here since what one does depends upon the following use of the chamber. Rely on the guidance of the Contamination Engineer.
7 In Case of Test Failure

7.1 Chamber Anomalies
In case of electrical power failure you must perform the steps in Section 2.5 of the Vacuum Pumpdown and Venting Procedure document. Note that the TQCM will have to be shut off if the chamber pressure rises above $1 \times 10^{-5}$ torr. The instrument should also be powered down if the pressure rises above this value. (The instrument bias supply does not like partial vacuum; normal atmospheric conditions are fine.)

7.2 Workstation Anomalies
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.)

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.

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

7.3 Spacecraft Simulator
The spacecraft simulator starts the CRaTER 1553 server (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 OmniBusBox.

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.

7.4 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.
7.5 Independence

Each dwell or balance in this procedure is really an independent test and, as such, can be executed separately from the rest if a procedural or GSE failure causes an interruption. One must only be careful that the final conditions of the previous test (e.g.: instrument power off) are met when picking up a test sequence in the middle.

A true test failure, on the other hand, will require that – after failure resolution – the test sequence is restarted from the beginning. Even here, however, the thermal balance, thermal cycling, and cleanliness monitoring are still separate entities, combined in this one procedure merely as a matter of convenience.
Appendix A -- TQCM Instructions

The Thermoelectric Quartz Crystal Microbalance (TQCM) provides an indication of the cleanliness level of the hardware in the Thermal-Vacuum chamber. It produces frequency data for the relative beat frequency of 2 crystals within the sensor head. This frequency increases with contamination deposition onto the surface of the exposed crystal surface.

There are two temperatures which are adjustable for the TQCM, that of the sensor and that of the cooling loop. The sensor temperature is set by a dial on the controller box. Running the sensor colder than the instrument under test causes the contamination to migrate to the sensing crystal surface. The sensor must be turned off during non-vacuum operating conditions and kept warmer than +10°C to avoid the risk of forming condensation and subsequent icing of the crystal.

The TQCM cooling loop temperature is controlled +10°C during sensor operation.

The TQCM requires a heat-cleaning cycle when its frequency exceeds 3,000 Hz. During heat-cleaning, raise the sensor temperature to 100°C for approximately 30 minutes. Do not be alarmed if the frequency drops to 0 during cleaning. It should reappear within the 30 minutes. Upon completion of the heat cycle, reset the TQCM sensor temperature to its pre-cleaning level.
### Appendix B – Red/Yellow Limits

#### Instrument Limits

<table>
<thead>
<tr>
<th>Monitor</th>
<th>Red Low</th>
<th>Yellow Low</th>
<th>Yellow High</th>
<th>Red High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope</td>
<td>-50</td>
<td>-45</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Analog Board</td>
<td>-50</td>
<td>-45</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Digital Board</td>
<td>-50</td>
<td>-45</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>Power Converter</td>
<td>-50</td>
<td>-45</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Bulkhead</td>
<td>-50</td>
<td>-45</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

#### Facility Limits

<table>
<thead>
<tr>
<th>Monitor</th>
<th>Red Low</th>
<th>Yellow Low</th>
<th>Yellow High</th>
<th>Red High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface Plate</td>
<td>-50</td>
<td>-45</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Control Base</td>
<td>-50</td>
<td>-45</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Plate</td>
<td>-50</td>
<td>-45</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>
Appendix C – Temp Monitor Locations

Reference Location

PRT on inner wall between electronics enclosure and telescope assembly
Telescope

AD590 on telescope preamp board
Analog Board
Digital Board

AD590 on 1553 Transceiver
Power Converter

PRT on bulkhead

AD590 on bulkhead

AD590 on power converter