## CRaTER Detector Specification

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<th>Rev.</th>
<th>ECO</th>
<th>Description</th>
<th>Author</th>
<th>Approved</th>
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<td>B. Crain</td>
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<td>Chg Fig 1, Fig3, Fig4A, Fig4B, Table 1, Table 2, Table 3, and Sec 3.1, 3.2, 3.4, 4.2, 5.4, 6.4, 7.1, 7.2, 7.4, 8.1</td>
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### CRaTER

Cosmic Ray Telescope for the Effects of Radiation

Detector Specification

Drawing Number: 32-05001

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1 Scope
This document shall serve as the procurement specification for the CRaTER detectors and shall take precedence over detector descriptions found in other documents and prior quotations.

2 Detector Supplier
Micron Semiconductor Ltd, whose contact information is provided below, shall be named as the sole source supplier for the CRaTER detectors. The CRaTER program was awarded in large part due to the heritage of Micron’s detectors obtained from other NASA and DOD programs including POLAR/CEPPAD, WIND, ACE, IMAGE, STEREO, and HiLET.

2.1 Contact Information
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UK

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Email: microndirect@btconnect.com
Website: www.micronsemiconductor.co.uk

2.2 Initial Quotation
During the proposal phase of the CRaTER project, Micron prepared a detector quotation (No. 5455A). The detectors for CRaTER utilize the same mask designs as the COMPASS detectors (MSD035) used as a baseline for the original proposal. While there have been NO changes to the detector silicon design and technical proposal, some additional information on its design and operation have been included in this document. Therefore, this Detector Specification document shall take precedence over the specifications found in the former quotation and a new quotation shall be prepared by Micron.
3 Points-of-Contact

3.1 Procurements and Quality Assurance POC
The point-of-contact for the procurement is Boston University. Rick Foster, CRaTER project manager, is affiliated with Boston University but maintains the CRaTER project office at MIT.

3.1.1 Funding
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Fax: 310-336-1636 Fax: 310-336-1636
Bill.Crain@aero.org Albert.Y.Lin@aero.org
Detector Overview

3.3 Detector Description
There are two detector types being requested from Micron that shall be referred to as the thin detector (140um) and thick detector (1,000um). Both detectors are ion implanted totally depleted structures formed from an N-type substrate. The Phosphorous-implanted N-type substrate is referred to as the ohmic side of the detector and the Boron-implanted P-side is referred to as the junction. These implants require lower energy and result in low implant depths of ~0.3 um.

Figure 1 depicts a simplified detector cross-section. Both detectors are circular, have thin junction and ohmic windows, and have fast timing capability (i.e., although fast timing is not critical for CRaTER, it is desired to have the metallization made in such a fashion to reduce surface resistivity). There is a guard ring (Gd) around the active junction to improve edge uniformity and a neighboring field plate (FP) ring to aid discharge of oxide stray charge. Each thin and thick detector is mounted to its own small passive PCB and connected to the electronics board by shielded wire.

3.4 Electronics Description
The external electronics (not the responsibility of Micron) will be an Amptek Charge Preamplifier A250 device with external JFET selected for low noise and high transconductance. These electronics reside on a separate printed circuit board, called the Telescope board, within the CRaTER Telescope assembly. The Telescope board connects to each Micron Detector PCB via small gauge wire. There are no electronics on the Detector board. All active and passive electronic components are located on the Aerospace Telescope board.

The JFET on the Telescope board will be AC coupled to the detector junction contact, enabling collection of holes and thus positive current flow into the preamplifier. The ohmic side of the detector will be biased positively through a resistor sized to provide minimal drift in bias over the mission and contribute minimal noise. The junction will be grounded through a current monitoring network. To avoid charge collection in the guard
region, the guard will be grounded independently with a dedicated resistor chosen to match the operating voltage of the junction. Figure 2 illustrates the detector interface circuit (for reference) being designed.

![Diagram of detector interface circuit](image)

**Figure 2: Detector Interface Circuit (for reference only)**

Table 1 summarizes the main detector specifications. Table 1 is to be used as a quick reference and not meant to supersede the actual specification text found in the body of this document.

**Table 1: Primary Design and Performance Specifications Summary (for reference only)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active area</td>
<td>9.6 cm² circular - Reference</td>
</tr>
<tr>
<td>Active dimension</td>
<td>35 mm</td>
</tr>
<tr>
<td>Active dimension tolerance</td>
<td>+/- 0.1 mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>Thin = 140 um, Thick = 1000 um</td>
</tr>
<tr>
<td>Thickness tolerance</td>
<td>+/- 10 um thin, +/- 25 um thick</td>
</tr>
<tr>
<td>Thickness uniformity</td>
<td>+/- 10 um</td>
</tr>
<tr>
<td>Window</td>
<td>0.1 um ohmic, 0.1 um junction</td>
</tr>
<tr>
<td>Metalization</td>
<td>Ohmic surface and junction grid 3000 Å +/- 1000 Å</td>
</tr>
<tr>
<td>Full depletion (FD)</td>
<td>Thin = 20 – 40V, Thick = 150 – 200V</td>
</tr>
<tr>
<td>Operating voltage max</td>
<td>Thin = 2 x FD, Thick = FD + 30V</td>
</tr>
<tr>
<td>Capacitance</td>
<td>Thin = 700 pF, Thick = 100 pF</td>
</tr>
<tr>
<td>Leakage current max (20C)</td>
<td>Thin = 300 nA junction, 200 nA guard</td>
</tr>
<tr>
<td>Drift (max leakage @ 40C)</td>
<td>Thic = 1,000 nA junction, 700 nA guard</td>
</tr>
<tr>
<td>Stability</td>
<td>1% Ileak @ 40C for 168 hours</td>
</tr>
<tr>
<td>Alpha resolution</td>
<td>Thin = 3%, Thick = 1.5%</td>
</tr>
</tbody>
</table>
4 Detector Design Specifications

4.1 Silicon Resistivity

4.1.1 Thin
The thin detector shall be constructed from an N-type silicon wafer whose resistivity is in the range 5K to 10Kohm-cm.

4.1.2 Thick
The thick detector shall be constructed from an N-type silicon wafer whose resistivity is in the range 20K to 30Kohm-cm.

4.2 Active Area
Both thin and thick detectors will be circular with a nominal active area of 9.6 cm². The active dimension (diameter) shall be 35mm.

4.3 Active Dimension Tolerance
The diameter tolerance and uniformity around the circumference shall be within +/- 0.1 mm.

4.4 Thickness

4.4.1 Thin
The thin detector shall have a nominal thickness of 140 um +/- 10 um. The anticipated tolerance of the wafer prior to implantation and other processing is +/- 5 um according to Micron.

4.4.2 Thick
The thick detector shall have a nominal thickness of 1,000 um +/- 25 um. The anticipated tolerance of the wafer prior to implantation and other processing is +/- 5 um according to Micron.

4.5 Thickness Tolerance
See Section 4.4 for tolerance on detector thicknesses.

4.6 Thickness Uniformity
The uniformity of the thickness of the thin and thick detectors over the active area shall be within +/- 10 um. The anticipated tolerance is +/- 1um according to Micron.

4.7 Window

4.7.1 Ohmic side
The ohmic window shall be 0.1 um (Type 7M – see metallization Section 4.8.1).
4.7.2 Junction side
The junction implant window shall be 0.1 μm (Type 7G – see metallization Section 4.8.2).

4.8 Metallization

4.8.1 Ohmic side
Metallization on the ohmic side shall be uniform Aluminum at 3000 Å +/- 1000 Å in thickness and shall cover the entire area of the detector within manufacturing tolerance.

4.8.2 Junction side
Metallization on the junction side shall be 3% grid of Aluminum with thickness 3000 Å +/- 1000 Å.

4.9 Solar Blindness
There will be NO solar blind features required on either the thin or thick detector.

4.10 Guard Ring
A multi-guard ring shall be incorporated around the active junction in the space between the edge of the active area and the chip edge per Micron standard processing. A separate connection to the electronics shall be provided by Micron for the guard ring.

*Note on implementation: The guard ring will be biased by the external electronics at the same operating voltage as the active detector area. It is CRaTER’s understanding that the thin detector guard may be floated without degradation in performance whereas floating the thick detector guard will result in double pulsing.*

4.11 Cover Layer
A protective layer of oxide with nominal thickness of 1 μm shall be grown on the junction and ohmic sides of each detector for protection against environmental contaminants per Micron standard processing.

4.12 Field Plate
A field plate ring shall be incorporated on the junction side in the space between the edge of the guard ring and the chip edge per Micron standard processing. The field plate is used to aid the discharging of the oxide. The field plate will not be connected externally.

4.13 Cutting
Detector chips will be cut with a diamond edge saw. There will be no passivation after cutting, just high resistivity silicon on the edge surface.
5 Detector Performance Specifications

5.1 Full Depletion (FD)

5.1.1 Thin
The thin detector FD voltage shall be typically 20V but no greater than 40V.

5.1.2 Thick
The thick detector FD voltage shall be typically 150V but no greater than 200V.

5.2 Operating Voltage
The operating voltage supplied by the electronics will be larger than the full depletion voltage so that good uniformity of the electric field inside the active volume is obtained.

5.2.1 Thin
The minimum operating voltage of the thin detector shall be its full depletion voltage (FD). The maximum safe operating voltage (i.e., the voltage that is at least 10 volts below the knee in the I-V characteristic) shall be at least 2 x FD.

5.2.2 Thick
The minimum operating voltage of the thick detector shall be its full depletion voltage (FD). The maximum safe operating voltage (i.e., the voltage that is at least 10 volts below the knee in the I-V characteristic) shall be at least FD + 30V.

5.3 Capacitance
The detector capacitance is determined by the thickness, active area, dielectric constant of the silicon, detector mount, and parasitics.

5.3.1 Thin
The capacitance of the thin detector will be nominally 700 pF and shall not exceed 770 pF (i.e., 110% of nominal), not including cable capacitance, at the FD voltage.

5.3.2 Thick
The capacitance of the thick detector will be nominally 100 pF and shall not exceed 120 pF (i.e., 120% of nominal), not including cable capacitance, at the FD voltage.

5.4 Leakage Current

5.4.1 Thin
The leakage current drawn through the active junction of the thin detector at 20 deg C shall not exceed 300 nA (i.e., note - typical is 150 nA) at the maximum operating voltage of 2xFD. The leakage current drawn through the guard ring of the thin detector at 20 deg C shall not exceed 200 nA at the maximum operating voltage of 2xFD.
5.4.2 Thick
The leakage current drawn through the active junction of the thick detector at 20 deg C shall not exceed 1,000 nA (i.e., note - typical is 500 nA) at the maximum operating voltage of FD+30V. The leakage current drawn through the guard ring of the thick detector at 20 deg C shall not exceed 700 nA at the maximum operating voltage of FD+30V.

5.4.3 Drift
The leakage current at 40 deg C shall not exceed six times the leakage current at 20 deg C for each detector. This is based on the knowledge that leakage current will increase by about a factor of 2 for every 8 deg C rise in temperature. For example, a thin detector whose leakage at 20 deg C is measured at 150 nA shall have a measured leakage at 40 deg C of no more than 6x150nA = 900 nA. The leakage current at 20 deg C and 40 deg C shall be measured for all detectors.

5.4.4 Stability
The stability of DC leakage current for each thin and thick detector at the maximum safe operating voltage shall be within 1 % at 40 deg C over 168 hours of continuous bias.

5.4.5 Radiation – For Information Only
Radiation damage will result in an increase in leakage current. The CRaTER project, not Micron, will be responsible for testing a subset of detectors to determine the relationship between proton/heavy ion dose and leakage current.

5.5 Alpha Resolution

5.5.1 Thin
The measured pulse-height distribution due to an alpha source located in front of the junction side of the thin detector shall not exceed 3% (FWHM/Line) at the optimum shaping time for the test system at 20 deg C. The same requirement applies for an alpha source located in front of the ohmic side.

5.5.2 Thick
The measured pulse-height distribution due to an alpha source located in front of the junction side of the thick detector shall not exceed 1.5% (FWHM/Line) at the optimum shaping time for the test system at 20 deg C. The same requirement applies for an alpha source located in front of the ohmic side.
6 Detector Mount Specifications

Conceptual drawings of the detector pcb is shown in Figures 3, 4A, and 4B. Micron will provide the detailed PCB design drawings, and changes to the dimensions given in this document are anticipated during the detailed design process. Nevertheless, changes must be communicated in writing to the technical point of contact. Also, a PCB design review shall be held with the technical point of contact prior to Micron manufacture of the detector boards.

![Diagram of Detector Mounting Concept](image)

**Figure 3: Detector Mounting Concept (for reference only)**

6.1 Detector PCB

Each thin and thick detector shall be mounted to their own small Polyimide PCB. The dimensions of this PCB are specified in Figure 4A (shown with detector) and 4B (shown without detector).

All conductive surfaces shall be plated with soft Gold on 1oz Copper. PCBs shall have NO solder resist.

The front side of the mount will contain the detector-mounting shelf. Since two detectors will be stacked in the CRaTER telescope (similar to COMPASS design), the PCB depth
on the backside shall be routed around the rim of the detector to provide room for the rear bond wires and a path for out-gassing.

The front and back sides of the PCB shall have a ground plane. A jumper on the ohmic side of the pcb shall be incorporated in the design between the ohmic detector connection and pcb ground. See Section 6.4 for information on PCB connections.

6.1.1 PCB Design Specification
The PCB design shall conform to the following IPC specifications. The PCB shall be reviewed by the CRaTER project prior to manufacture.
- *IPC-2221 – Generic Standard On Printed Board Design (Class 3, Level A)*
- *IPC-2222 – Sectional Standard on Rigid PWB Design (Class 3, Level A)*

6.1.2 PCB Manufacture Specification
The PCB manufacturing shall conform to the following IPC specifications.
- *IPC-6011 – Generic Performance Specification for Printed Boards (Class 3, Level A)*

6.1.3 Coupons
The PCB manufacturer shall attach coupons per the IPC specification. Coupons shall be sent to MIT for testing immediately after manufacture. Micron shall NOT perform any assembly of the detector boards until written approval is received from MIT stating that the coupon testing passed.

6.2 Detector Attachment
The detector shall be attached to the substrate around the entire circumference with an appropriate adhesive. The adhesive will be chosen to provide necessary compliance and pliability to mitigate thermal mismatch of the PCB and detector, and to dampen mechanical resonances at the detector interface.

6.2.1 Outgassing
Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% may be used.

6.2.2 Polymeric Materials
Polymeric materials used in space flight hardware must be documented and submitted to MIT/CSR for the Materials Identification and Usage List (MIUL).
6.3 Bond Wires
There shall be 3 bond wires per contact. The bond wires will be Aluminum, 25 um diameter. An ultrasonic process will be used to make the bond.

6.4 Connections
Detectors shall be delivered with four 20 cm-long AWG28 wires: one for the junction, one for the guard, one for the ohmic connection, and one for the detector PCB ground plane.

These wires will be cut to the proper length by the CRaTER project during the CRaTER telescope assembly.

6.5 Connector
The CRaTER project will cut the detector wires to the proper length and will install the connector that mates the detector wires to the Telescope board. This will be done at The Aerospace Corporation.

6.6 Housing
The CRaTER project will design and manufacture the metallic housing for the detectors. This will be done at The Aerospace Corporation. The critical dimensions for the PCB are based on the CRaTER Telescope design.
Figure 4A: Detector Mount Detail Illustration A
Figure 4B: Detect Mount Detail Illustration B
7 Screening

7.1 Performance Tests
Performance tests shall be performed on each detector. The matrix of Table 3 specifies the methods for demonstrating that the detector performance specifications are satisfied. The verification method is classified as demonstration (D), inspection (I), analysis (A), or test (T).

The matrix also specifies whether each requirement is verified before or after environmental tests (see next section). In some cases, verification is required both before and after environmental tests.

7.2 Environmental Tests
Each detector shall be subjected to the screening tests described in this section. A specific order for these tests is not required by the project and left to Micron’s discretion.

7.2.1.1 Non-destructive Wire Bond Pull Test
Each wire bond (100%) shall undergo a non-destructive wire bond test in accordance with MIL-STD-883, Method 2023.5.

7.2.1.2 Random Vibration
All detectors shall be subjected to the random vibration environment shown in Table 2. The overall amplitude of vibration shall be 14.1 g-rms over a duration of 60 seconds. All three axes shall be tested.

Table 2. Random Vibration Environmental Test Specification

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Acceleration Spectral Density (g²/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.026</td>
</tr>
<tr>
<td>20 – 50</td>
<td>+6dB/octave</td>
</tr>
<tr>
<td>50-800</td>
<td>0.16</td>
</tr>
<tr>
<td>800 – 2000</td>
<td>-6dB/octave</td>
</tr>
<tr>
<td>2000</td>
<td>0.013</td>
</tr>
</tbody>
</table>

7.2.1.3 Thermal Cycling
A thermal cycling test shall be performed on all flight detectors for 10 cycles at –40 C to + 40 C and biased at the maximum safe operating voltage. One additional cycle shall be performed with zero bias on the detector over the range –50 C to + 60 C.

7.2.1.4 Thermal Vacuum
A thermal vacuum test shall be performed on the thick detectors. All thick detectors shall be subjected to 21 days at +40C at a pressure of 1x10⁻⁷ Torr. Vacuum pumps must be non oil vapor. The detectors shall be biased at the maximum safe operating voltage and
leakage current shall be monitored. A successful thermal-vac test must demonstrate leakage current stability in a vacuum environment per section 5.4.4.

No thermal vacuum is required on the thin detectors. The stability test on thin detectors will be performed in nitrogen.

7.3 Acceptance Data Package
Final acceptance of detectors shall include documentation of inspection and test results proving compliance to the specifications according to the methods described in the verification matrix of Table 3.
Table 3: Verification Matrix

<table>
<thead>
<tr>
<th>Ref</th>
<th>Description</th>
<th>D</th>
<th>I</th>
<th>A</th>
<th>T</th>
<th>Method</th>
<th>Pre-EnvTest</th>
<th>Post-EnvTest</th>
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<tbody>
<tr>
<td>4.1.1</td>
<td>Silicon Resistivity - Thin</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Procurement source does inspection</td>
<td>X</td>
<td></td>
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<tr>
<td>4.1.2</td>
<td>Silicon Resistivity - Thick</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Procurement source does inspection</td>
<td>X</td>
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<td>4.2</td>
<td>Active Area</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Measurement of diameter at 45-deg angles</td>
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<td>4.3</td>
<td>Active Area Tolerance</td>
<td>X</td>
<td></td>
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<td></td>
<td>Measurement of diameter at 45-deg angles</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4.4.1</td>
<td>Thickness - Thin</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Micrometer measurement of off-samples</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Thickness - Thick</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Micrometer measurement of off-samples</td>
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<td>Leakage Current Drift</td>
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<td>Measurement at 40C in Nitrogen at FD</td>
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<td>5.4.4</td>
<td>Leakage Current Stability</td>
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<td>Measure over 168 hours at 40C in Nitrogen at FD for thin detectors and same in vacuum for thick detectors</td>
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<td>Alpha Resolution - Thin</td>
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<td>Measurement using Amptek preamp system, low noise FET, and optimum shaping times. Test conditions and parameters to be reported.</td>
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<td>Alpha Resolution - Thick</td>
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<td>Measurement using Amptek preamp system, low noise FET, and optimum shaping times. Test conditions and parameters to be reported.</td>
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<td>5.5</td>
<td>Pulse Noise Test</td>
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<td>Pulser injected into preamp with biased detectors at FD. Measure FWHM of pulse-height distribution and record for each detector.</td>
<td>X</td>
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</table>
8 Quality Assurance Requirements
The detectors shall be built in accordance with ISO9001. The CRaTER QAM (Quality Assurance Manager) shall be given a tour of the facility prior to acceptance of deliverables and preferably prior to start of manufacturing. This is to be in compliance with NASA Mission Assurance Requirements.

8.1 Failure Reporting
Failure of a detector in performance or environmental testing requires review by the CRaTER project team. Micron shall notify The Aerospace Corporation technical point-of-contact within 72 hours of failure confirmation.

8.2 Traceability
Forward and backward traceability shall be maintained on all detectors from diffusion and metallization to each individual printed circuit board. All detectors shall be serialized and batch travelers shall be maintained. Test documentation shall be maintained for each detector containing test results and graphs.
9 Statement of Work Overview

Micron will purchase the silicon wafers, fabricate the detectors, develop detailed design drawings of the detector PCB, manufacture the detector PCB, purchase and install interface wiring, attach detectors to PCBs, and perform functional and environmental testing as required by the grade of detectors being procured.

Micron will provide a suitable shipping container for each detector shipment.

Micron will supply test documentation and batch travelers upon delivery of the detectors.

Micron will perform these duties according to the technical requirements specified in this document.

Micron will provide PCB design drawings for review prior to manufacture.