Rev.	ECO	Description	Author	Approved	Date
01	32-042	Initial Release	B. Crain		
02	32-045	Chg Sec 2, 4.1, 5.4, 5.5, 5.6, 5.7, 5.8, 5.10, 5.13, 6.2, 6.4, 6.5, 8	B. Crain		8/1/05
03	32-061	Incorporated team review comments from 10/12/05	B. Crain		10/13/05
A	32-065	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	B. Crain		11/28/05
B	32-069	Chg 4.7.1, 4.7.2, 4.8, 5.5, 6, 6.3, 6.4, 7.2.1.4 Table 1, Table 3	B. Crain		12/15/05
C	32-071	Chg 2., 2.1, 3.3, Table 1, 4.1, 4.10, 4.11, 5.1, 5.2, 5.2.1, 5.3, 5.4.4, 6.1, 6.2, 6.2.2, 6.4, 7.2.1.4,	B. Crain		12/22/05
D	32-173	Structural changes	B. Crain		10/9/06
E	32-181	Changes after Micron review	B. Crain		10/13/06

CRaTER

Cosmic Ray Telescope for the Effects of Radiation

Detector Specification

Drawing Number: 32-05001

Revision E

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

Micron Semiconductor Limited
1 Royal Buildings
Marlborough Road
Lancing
Sussex
BN15 8SJ
UK

Telephone: (011 44) 01903 755252
Fax: (011 44) 01903 754155
Email: direct@micronsemiconductor.co.uk
Website: www.micronsemiconductor.co.uk

2.2 Baseline Information

The detectors for CRaTER utilize the same mask designs as the COMPASS detectors (MSD035), supplied to the Belgian Space Agency.

3 Points-of-Contact

3.1 Procurements and Mission Assurance POC

The point-of-contact for the procurement is:

Brian Klatt (Mission Assurance Manager)
MIT Kavli Institute for Astrophysics and Space Research
NE80-6063 1 Hampshire Street
Cambridge, MA 02139
Tel: 617-253-7555 Fax: 617-253-8084
bk@space.mit.edu

3.2 Technical POC

3.2.1 Detector Physics and Requirements

Bern Blake (M/S M2-259)
The Aerospace Corporation
2350 E. El Segundo Blvd.
El Segundo, CA 90245
M/S M2-259
Tel: 310-336-7078
Fax: 310-336-1636
JBernard.Blake@aero.org

Joe Mazur
The Aerospace Corporation
15049 Conference Center Drive,
CH3/210
Chantilly, VA 20151
Tel: 703-324-8915
Fax: 703-324-0135
Joseph.E.Mazur@aero.org

3.2.2 Engineering

Bill Crain (Electrical)
The Aerospace Corporation
2350 E. El Segundo Blvd.
El Segundo, CA 90245
M/S M2-255
Tel: 310-336-8530
Fax: 310-336-1636
Bill.Crain@aero.org

Albert Lin (Mechanical)
The Aerospace Corporation
2350 E. El Segundo Blvd.
El Segundo, CA 90245
M/S M2-255
Tel: 310-336-1023
Fax: 310-336-1636
Albert.Y.Lin@aero.org

4 Detector Overview

4.1 Detector Description

There are two circular detector types being requested from Micron, using the MSD035 mask set, 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 Boron-implanted P-side of the substrate is referred to as the junction and the Phosphorous-implanted N-type side of the substrate is referred to as the ohmic side. 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.

4.2 CRATER Implementation

The detectors will be used in a space application whose mission is to characterize the effects of radiation on humans working on the moon. There will be a stack of three pairs of thin/thick detectors; each pair separated by tissue equivalent plastic (TEP) and housed in an aluminum light-tight enclosure. The electronics will utilize an Amptek front-end charge amplifier system with external JFET. The detector signal will be taken from the junction contact, preamplified, and shaped with ~ 800 nsec peaking time (~ 1 usec FWHM). A peak-hold ADC will produce an energy measurement after a modest coincidence timing (~ 1 usec) gate is satisfied from two or more detectors. The guard contact will be biased at the same voltage as the junction, but the signal from the guard will be shunted to ground.

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

Requirement	Specification
Active area	9.6 cm^2 circular - Reference
Active diameter	35 mm
Active diameter tolerance	+/- 0.1 mm
Thickness (detector)	Thin = 140 um, Thick = 1000 um
Thickness tolerance	+/- 10 um thin, +/- 35 um thick
Thickness uniformity	+/- 10 um
Window implantation	5 um each ohmic and junction
Metallization - junction	3% grid of 3000 Å +/- 1000 Å
Metallization - ohmic	100% surface coverage; 3000 Å +/- 1000 Å
Full depletion (FD)	Thin = 10 – 60V, Thick = 100 – 200V
Operating voltage	Thin = Thick = FD + 30V
Capacitance (typical)	Thin = 700 pF, Thick = 100 pF
Leakage current max (20C)	Thin = 300 nA junction, 200 nA guard Thick = 2,000 nA junction, 2000 nA guard
Drift (max leakage @ 40C)	8 x Ileak @ 20C
Stability	Thin = 1% Ileak @ 40C for 168 hours in Nitrogen Thick = 1% Ileak @ 40C for 21 days in vacuum
Alpha resolution (^{241}Am) - junction	Thin = 3%, Thick = 1.5% (line width)
Alpha resolution (^{241}Am) - ohmic	Thin = 3%, Thick = 1.5% (line width)

5 Detector Design Specifications

5.1 Silicon Resistivity

The silicon resistivity will be selected by Micron to meet the depletion and operating voltage requirements per this specification for the thin and thick detectors.

5.2 Active Area

Both thin and thick detectors shall be circular with a nominal active area of 9.6 cm^2 and a diameter of 35mm +/- 0.1mm.

This requirement shall be verified by the MSD035 mask inspection described in 8.1.4.

5.3 Detector Thickness

The thin detector shall have a nominal thickness of 140 um +/- 10 um.
The thick detector shall have a nominal thickness of 1,000 um +/-35 um.

This requirement shall be verified by Micrometer Measurements described in 8.1.5.

5.4 Detector Thickness Uniformity

The detector design thickness over the active area shall be within +/- 2 um.

5.5 Window Depth and Metallization

The ohmic and junction dead layer, including the metallization and the un-implanted depth, shall be no greater than 1 um thick each. Metallization on the ohmic side shall be Type 7M (Aluminum with thickness of 3000 Å +/- 1000 Å) and shall cover the entire area of the detector within manufacturing tolerance. Metallization on the junction side shall be Type 7G (Aluminum grid covering 3% total area with thickness of 3000 Å +/- 1000 Å.).

This requirement shall be verified by inspection of the MSD035 mask drawing described in 8.1.4.

5.6 Solar Blindness

There will be no solar blind features required on either the thin or thick detector.

5.7 Guard Ring

A 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.

This requirement shall be verified by the MSD035 mask inspection described in 8.1.4.

5.8 Field Oxide

A field oxide with nominal thickness of 1 um shall be grown on the junction and ohmic sides of each detector.

5.9 Field Plate

Per MSD035 mask drawing, 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.

5.10 Cutting

Detector chips shall be cut from the wafers on the saw line shown on the MSD035 mask drawing. There will be sixteen flats and the flat-to-flat saw dimension will be 39mm. There will be no passivation after cutting, just high resistivity silicon on the edge surface.

This requirement shall be verified by the inspection of the completed MSD035 batch traveler described in section 8.4.1.

6 Detector Performance Specifications

6.1 Full Depletion (FD)

The thin detector FD voltage shall be minimum 10V and no greater than 60V.
The thick detector FD voltage shall be minimum 100V and no greater than 200V.

This requirement shall be verified by the Depletion Plot specified in 8.3.1.

6.2 Operating Voltage

The minimum operating voltage of the thin and 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.

This requirement shall be verified by the Leakage Current vs. Bias Measurements specified in 8.3.3.

6.3 Capacitance

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.

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.

This requirement shall be verified by the Depletion Plot specified in 8.3.1.

6.4 Leakage Current

The leakage current drawn through the active junction at +20 deg C shall not exceed 300 nA for the thin detector and 2,000 nA for the thick detector at an operating voltage of FD+30V.

The leakage current drawn through the guard ring at +20 deg C shall not exceed 200 nA for the thin detector and 2000 nA for the thick detector at an operating voltage of FD+30V.

This requirement shall be verified by the Leakage Current vs. Bias Measurements specified in 8.3.3.

6.4.1 Leakage vs. Temperature

The junction leakage current at +40 deg C shall not exceed eight times the leakage current at +20 deg C for each detector.

This requirement shall be verified by the Thermal Cycle test specified in 8.2.2.

6.4.2 Leakage Stability

The stability of junction leakage current for each thin and thick detector at the maximum safe operating voltage shall deviate no more than 1%.

This requirement shall be verified by the Burn-In test for the thin detectors and by the Thermal Vacuum test for the thick detectors specified in 8.2.3 and 8.2.4, respectively.

6.4.3 Long-term Leakage Stability

The long-term leakage stability of the thick detectors shall be demonstrated over 21 days in 10E-6 Torr vacuum at +40C. The thick detectors shall have a constant plateau of leakage current within 5% and with no evidence of breakdown or resistive slope development.

6.5 Alpha Resolution (^{241}Am 5.48 MeV)

The measured pulse-height distribution due to an alpha source located in front of either the junction side or ohmic side at +20 deg C shall not exceed 3% (FWHM/Line) for the thin detectors and 1.5% (FWHM/Line) for the thick detectors, using a 1 usec FWHM shaping time for both.

This requirement shall be verified by the Resolution Plot specified in 8.3.2.

7 Detector Mount Specifications

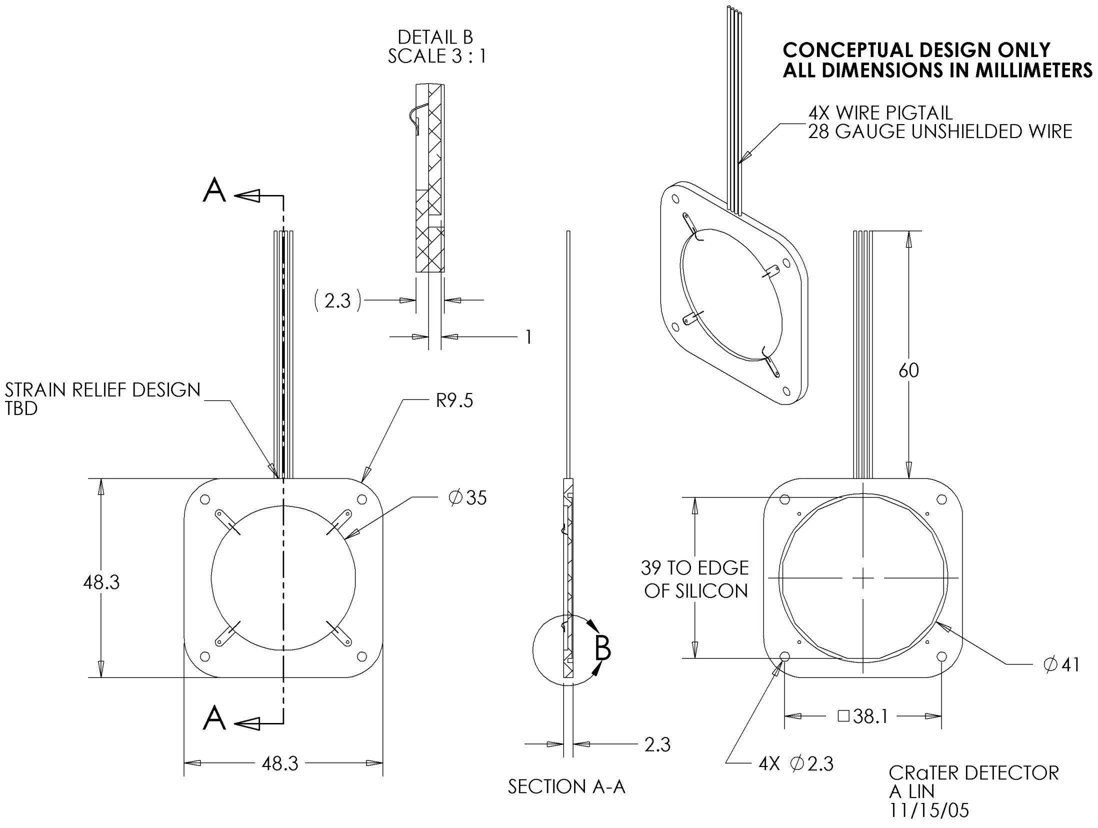

Figure 3: Detector Mounting Concept (for reference only)

7.1 Detector PCB

A conceptual drawing of the detector PCB is shown in Figure 3.

7.1.1 Design Requirements

The front and back sides of the PCB shall have a ground plane. This ground plane shall be relieved from the edge of the board by 0.05 inch. Mounting holes shall be connected to the ground plane and be plated through, excluding the cover layers.

A jumper shall be incorporated in the design between the ohmic detector connection and PCB ground.

The PCB design shall conform to the following IPC specifications.

- *IPC-2221 –Generic Standard On Printed Board Design (Class 3, Level A)*
- *IPC-2222 – Sectional Standard on Rigid PWB Design (Class 3, Level A)*

Design requirements shall be verified by the PCB design review described in 8.1.1

7.1.2 Manufacturing Requirements

All conductive surfaces shall be plated with soft Gold on 1oz Copper.

PCBs shall have no solder resist.

The PCB manufacturing shall conform to the following IPC specifications.

- *IPC-6011 – Generic Performance Specification for Printed Boards (Class 3, Level A))*
- *IPC-6012 – Qualification and Performance Specification for Rigid Printed Boards (Flight Applications supplemented with: IPC-6012B "Performance Specification Sheet for Space and Military Avionics") Boards (Class 3, Level A)*

Manufacturing requirements shall be verified by PCB Inspection and PCB Electrical Test described in 8.1.2 and 8.1.3, respectively.

7.1.3 Coupon Requirements

The PCB manufacturer shall deliver a minimum of two sets of coupons per the IPC specification in section 7.1.1. 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 has passed.

7.2 Detector Attachment

7.2.1 Adhesive

Micron shall submit to the CRaTER project the documented procedure for mounting the detector to the PCB, including adhesive of choice, curing temperature, curing time, mix ratios, test sample preparation, and rationale for deviations from any manufacturer specifications in the use of adhesive.

A cure sample of the adhesive shall be retained for hardness testing. This sample should be about 0.5 cm thick and be of the same mix and cure batch as used in the flight hardware. The sample shall be available for three years.

Micron must receive written approval from the CRaTER project for this procedure prior to detector attachment.

The Batch Traveler shall contain all the indicated steps for adhesive preparation and application.

7.2.2 Out-gassing

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. Material must receive approval from CRaTER project.

7.2.3 Polymeric Materials

Polymeric materials used in space flight hardware must be documented and submitted to CRaTER mission assurance for approval and for inclusion in the Materials Identification and Usage List (MIUL).

7.3 Bond Wires

The junction and guard ring connections shall have 2 bond wires minimum per contact. The bond wires will be Aluminum of 25um diameter.

The ohmic side of the detector shall have 2 bond wires per contact, and shall have 4 contact areas around the perimeter of the detector.

Each wire bond (100%) shall undergo a non-destructive wire bond pull test in accordance with MIL-STD-883, Method 2023.5.

There shall be no bond heels on the detector side of the bond wires.

This requirement shall be verified by inspection of the Batch Traveler described in 8.4.1 and Final Inspection described in 8.1.6.

7.4 Connections

Detectors shall be delivered with four independently colored 20 cm-long AWG28 wires: one for the junction (black), one for the guard ring (blue), one for the ohmic connection (red), and one for the detector PCB ground plane (white). These wires will be cut to the proper length by the CRaTER project during the CRaTER telescope assembly.

PCB connections shall be soldered per NASA-STD-8739.3 or a micron equivalent documented procedure. All solder joints (100%) shall be inspected by the CRaTER Mission Assurance Manager.

This requirement shall be verified by the PCB Inspection as described in 8.1.2.

8 Verification and Acceptance

8.1 Design and Manufacturing Verification

8.1.1 PCB Design Review

A PCB design review shall be held between Micron and the technical points of contact including the CRaTER system engineer, CRaTER telescope designers (technical points of contact), and CRaTER mission assurance manager prior to the manufacture of the detector boards. The review shall also include details of the shipping holder.

8.1.2 PCB Inspection

The inspection of all (100%) of the PCBs and solder joints shall be performed by the CRaTER Mission Assurance Manager prior to detector assembly. Micron shall prepare one sample board with soldered connections and send to CRaTER mission assurance manager in advance in order to verify the manufacturing process.

8.1.3 PCB Electrical Test

The PCB electrical test shall be performed by Micron and consist of electrical isolation and voltage standoff tests for each board prior to detector assembly. This step shall be noted on the Batch Traveler.

8.1.4 MSD035 Inspection

Verification of the detector active area, diameter, saw line, metallization mask, and guard ring shall be in accordance with the MSD035 mask drawing.

8.1.5 Micrometer Measurements

Verification of the detector thickness and uniformity shall be performed with a minimum of four micrometer measurements around the perimeter of each detector wafer in the areas between the saw line and the active area. This step can be performed prior to sawing.

8.1.6 Final Inspection

A final inspection of the detectors shall be performed prior to shipment. The inspection shall document overall appearance, cleanliness, number and appearance of bond wires, solder joints, strain relief integrity, and adhesive appearance around edge of detector. The CRATER mission assurance manager shall have access to Micron to witness assembly, test, and/or verifications of flight hardware.

8.2 Environmental Screening Tests

Each detector shall be subjected to the screening tests described in this section. Acceptance tests outlined in the next section shall be performed after random vibration and either before or after thermal cycle testing at Micron's discretion. Pre-environmental testing may be performed by Micron at their discretion.

8.2.1 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. Levels shall be verified by the use of an accelerometer placed near the detectors.

Table 2. Random Vibration Environmental Test Specification

Frequency (Hz)	Acceleration Spectral Density (g^2/Hz)
20	0.026
20 – 50	+6dB/octave
50-800	0.16
800 – 2000	-6dB/octave
2000	0.013

8.2.2 Thermal Cycling

A thermal cycling test shall be performed on all detectors for 10 cycles at –40 C to + 40 C and biased at the maximum safe operating voltage. Junction leakage currents shall be measured and documented on each hot and cold cycle. One additional cycle shall be performed with zero bias on the detector over the range –50 C to + 60 C.

8.2.3 Burn-In Test

A table of leakage current versus time shall be prepared for each detector showing the junction leakage current over a minimum of 168 hours measured periodically at +40C in Nitrogen. Temperature shall be stable within 1 degree Celsius, monitored, and reported at each data point.

8.2.4 Thermal Vacuum

All thick detectors shall be subjected to 21 days at +40C at a pressure of $1x10^{-6}$ Torr or better. Vacuum pumps must be non-oil vapor.

The detectors shall be biased at the maximum safe operating voltage and leakage current shall be monitored. Acceptance criteria requires a constant plateau of leakage current with no evidence of breakdown or resistive slope development as per section 6.4.2.

No thermal vacuum is required on the thin detectors.

8.3 Acceptance Tests

The following acceptance tests shall be executed after completion of random vibration test.

8.3.1 Depletion Measurement

A plot of detector capacitance versus voltage bias shall be prepared for each detector. The calculated depletion voltage shall be documented on the plot. Capacitance shall be measured at 1 MHz. The plot shall also include breakdown voltage and forward voltage measurements for verification as follows.

V_{BR} at 10uA: Thin > 90V; Thick > 200V
V_F at 10uA: Thin and thick < 0.8V

8.3.2 Resolution Measurement

A resolution plot shall be prepared for each detector showing two peaks: one for a test pulser (system) and one with an alpha source (detector line). The plot shall indicate the FWHM for both under the measured bias and leakage current conditions. The calculated detector resolution shall be obtained using the subtraction in quadrature of the system FWHM from the detector line FWHM.

8.3.3 Leakage Current vs. Bias

A table of measured leakage currents for the junction and guard shall be prepared for each detector showing the leakage at the depletion voltage and the leakage at the maximum safe operating voltage. Reverse bias voltage measurements shall also be made for the point at which the thin detector leakage is 100 nA and the thick detector leakage is 10 uA. A measurement of the forward voltage drop shall also be made at 10 mA for both detectors.

8.4 Acceptance Data Package

Final acceptance of detectors shall include documentation of inspection and test results proving compliance to the requirements in this document. This shall include the following:

8.4.1 Assembly Batch Traveler

A separate traveler shall be maintained for each detector and shall include the process executed, date of completion, end result, operator initials, and Micron quality assurance sign-off for each step performed.

The traveler shall include:

- Wafer type, wafer number, wafer thickness, and PCB serial number
- Wafer preparation steps including sawing, cleaning, and edge inspection with documented results
- PCB coupon approval and date
- PCB preparation including cleaning of bare PCB, wire soldering, inspection, and electrical isolation and standoff test prior to detector attachment
- Detector electrical test before assembly including leakage current and breakdown voltage
- Visual inspection after assembly
- Detector attachment including resin type, lot date code, mix ratios, cure temperature, and cure time. Any deviations from resin manufacturer’s instructions shall have been given prior review by CRATER project team and noted as such on traveler. An adhesive cure sample shall be prepared at the same time the detectors are attached to the PCB.

- Wire bonding data including size, number, and type of bond and non-destructive pull test value performed on each.
- Final testing including all performance tests and environmental tests specified in section 8.2.
- Final visual inspection
- Packing approval including verification that detectors are firmly held in shipping container and that wires are without strain
- Final signoff by Micron Quality Assurance and CRATER mission assurance.
- Final signoff by CRaTER Mission Assurance will approve hardware and documentation for shipment.

8.4.2 Environmental Test Results

The acceptance data package shall include the vibration test results and accelerometer data, thermal cycle temperatures and test results, burn-in test results, and thermal-vacuum test results.

8.4.3 Acceptance Test Results

The acceptance data package shall include the results of all tests described in 8.3.

8.4.4 Certificate of Conformance

The detector certificate of conformance shall be included in the acceptance data package.

8.5 Quality Assurance

8.5.1 General

The detectors shall be built in accordance with the intent of ISO9001. All critical processes must be documented in detailed procedures that show step-by-step instructions for each process. Ion implant, metal deposition, masking, soldering, wire bonding, adhesive preparation, and detector mounting are some of the critical processes.

8.5.2 Oversight

The CRaTER mission assurance manager shall be given access to Micron facility for purposes of monitoring, witnessing, and inspection during fabrication, assembly, and test/verification phases. This is to be in compliance with NASA mission assurance requirements.

8.5.3 Failure Reporting

Failure of a detector in acceptance testing requires review by the CRaTER project team. Micron shall notify the CRATER quality assurance manager within 72 hours of failure confirmation.

8.5.4 Traceability

Forward and backward traceability shall be maintained on all detectors from wafer sawing to final PCB assembly. All detectors shall be serialized and batch travelers shall be maintained.

8.5.5 Packaging for Shipment

Micron shall provide a shipping container that protects the detector assembly, including silicon, PCB mount, and lead wires, during transportation by common carrier. Shock, vibration, temperature change, pressure change, ESD, and contamination are some of the hazards during shipment.