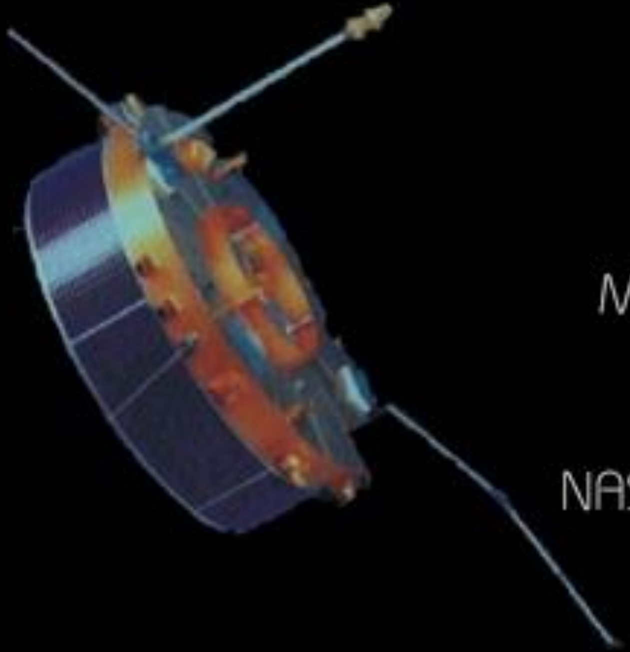
Micron Semiconductor Ltd

Silicon Detectors in Space

September 2011- Colin D Wilburn Director (direct@micronsemiconductor.co.uk)

SILICON DETECTORS FOR SATELLITES SPACE BASED ASTROPHYSICS



1990-Present

UO SAT 5
CRRES
WIND
LEMT-ANTI
EPACT
MICROSAT
CLUSTER
CEPPAD
POEMS
ACE
IMAGE
IMEX
MESSENGER
STEREO
HNX
NASDA-NASUDA
RBSP
GOES
FEEPS
WINDSAT

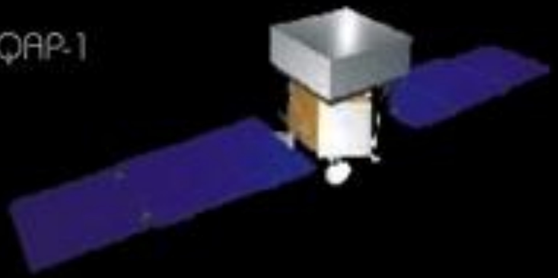
DETECTORS INTEGRATED WITH VLSI ELECTRONICS

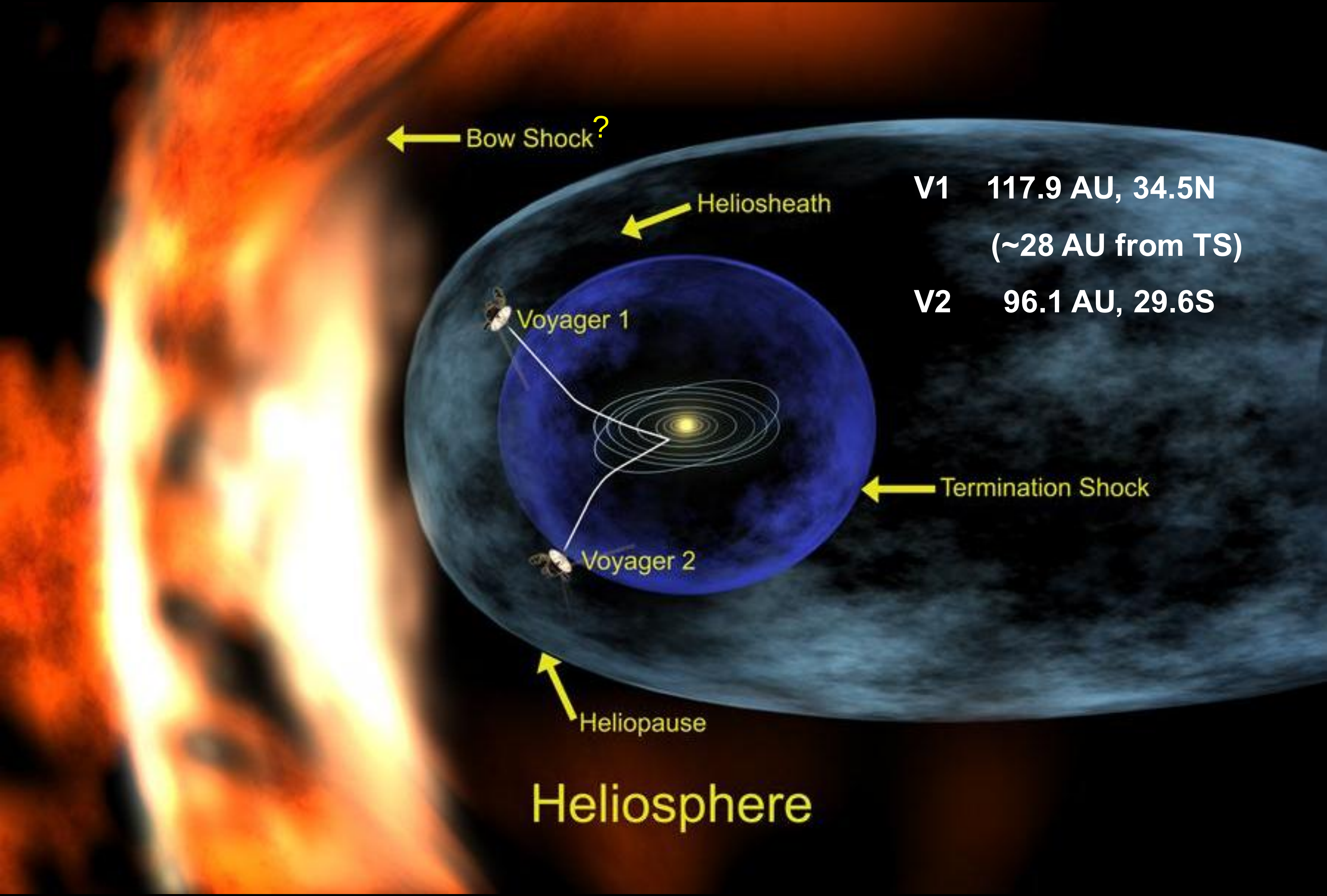
DOUBLE SIDED MICROSTRIP DETECTORS
FOR X-RAY INSTRUMENTS
3 INCH, 4 INCH AND 6 INCH TECHNOLOGY
FULL DEPLETION THICKNESS RANGE: 30 µm TO 1500 µm

SILICON LARGE AREA PAD DETECTORS
DETECTORS TO 65 cm^2 x 100 µm/ 250 µm/
500 µm/ 1000 µm/ 1500 µm

MULTI ELEMENT LINEAR ARRAY DETECTORS
ULTRA THIN WINDOW
ULTRA LOW CROSS TALK
ULTRA LOW LEAKAGE CURRENT
THICKNESS RANGE: 10 µm TO 1500 µm
SPACE QUALIFIED: RANDOM VIBRATION / TEMPERATURE CYCLING

Quality Control: ISO9001, AQAP-1



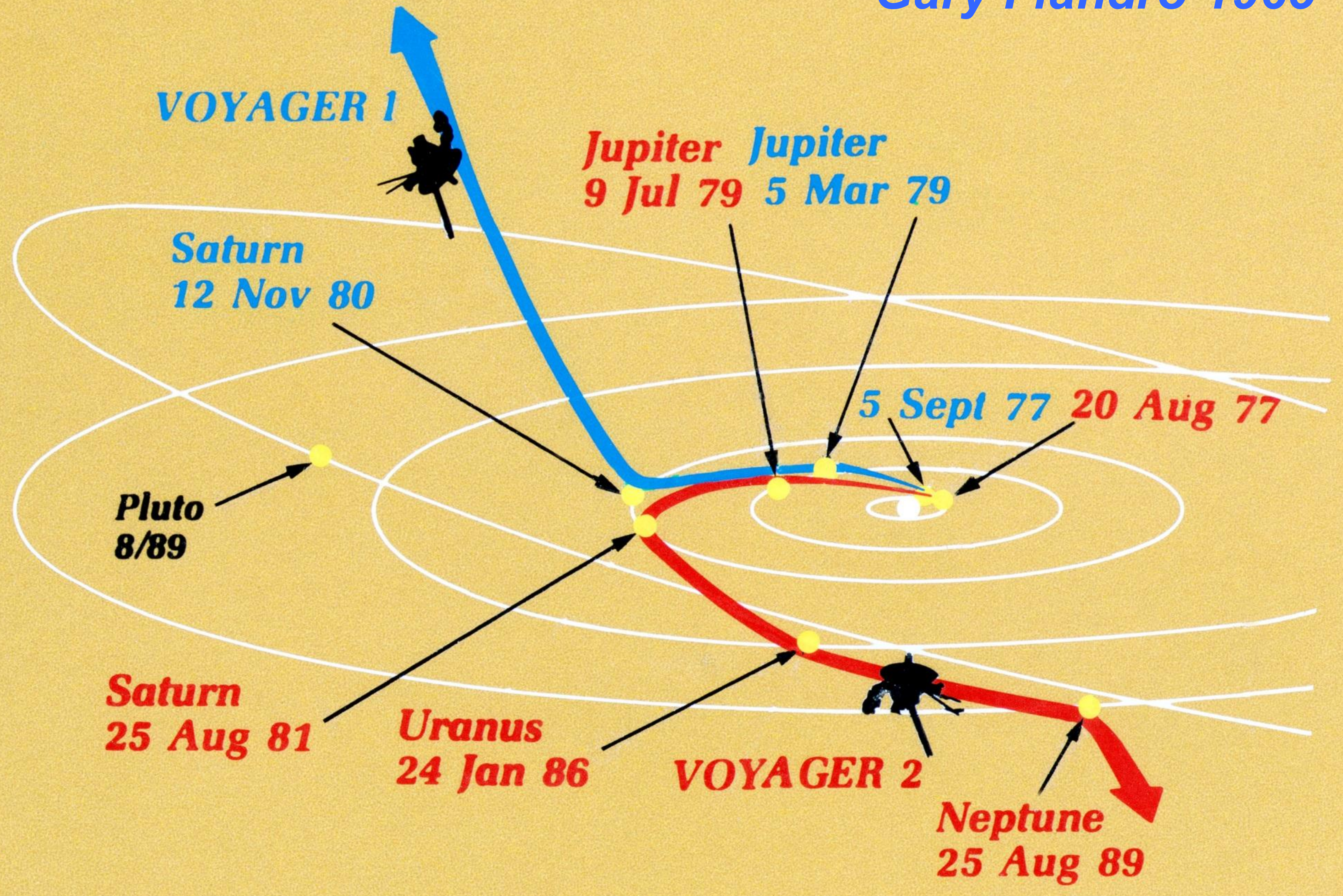


V1 117.9 AU, 34.5N

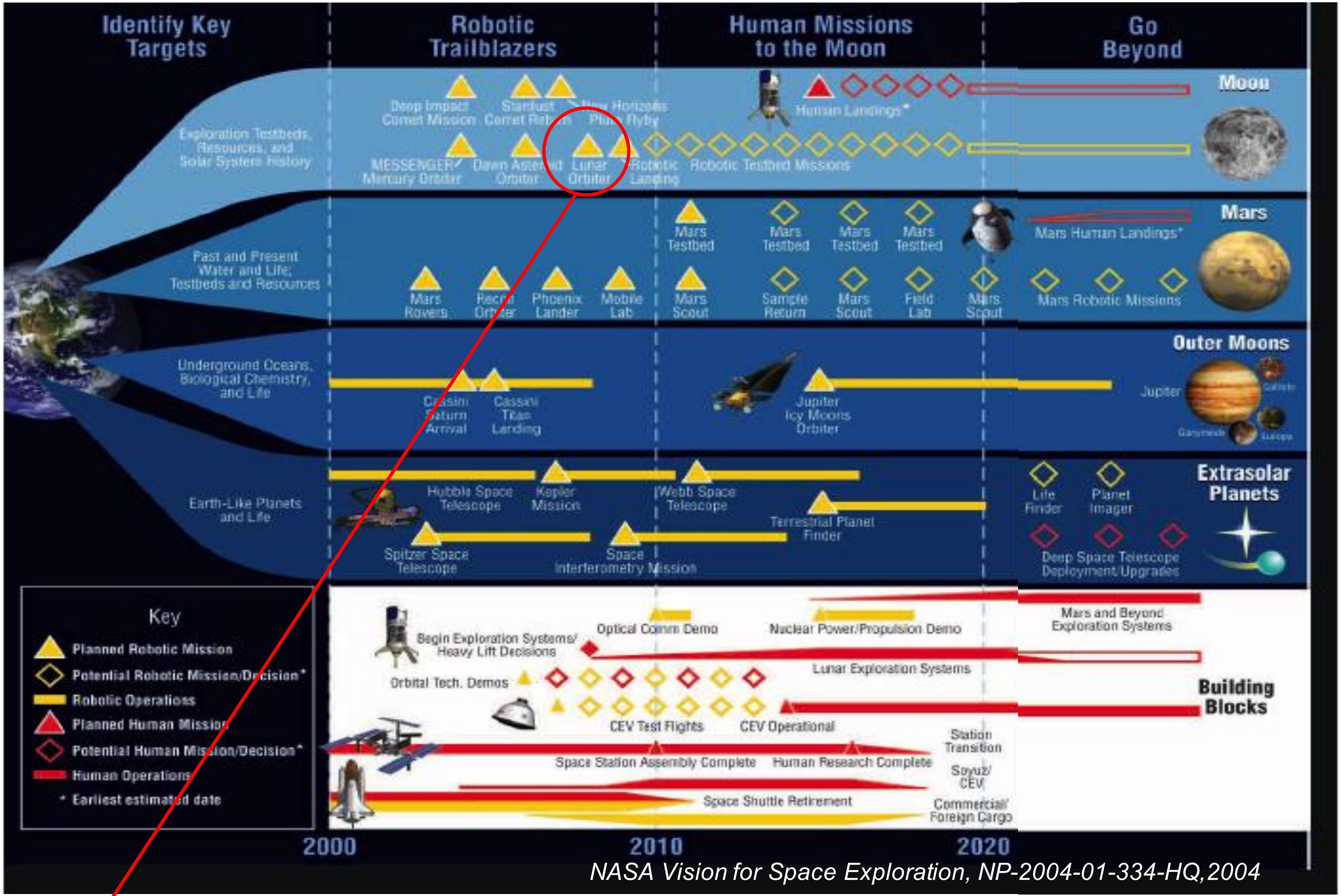
(~28 AU from TS)

V2 96.1 AU, 29.6S

Gary Flandro 1965



NASA's Vision for Space Exploration: February 2004



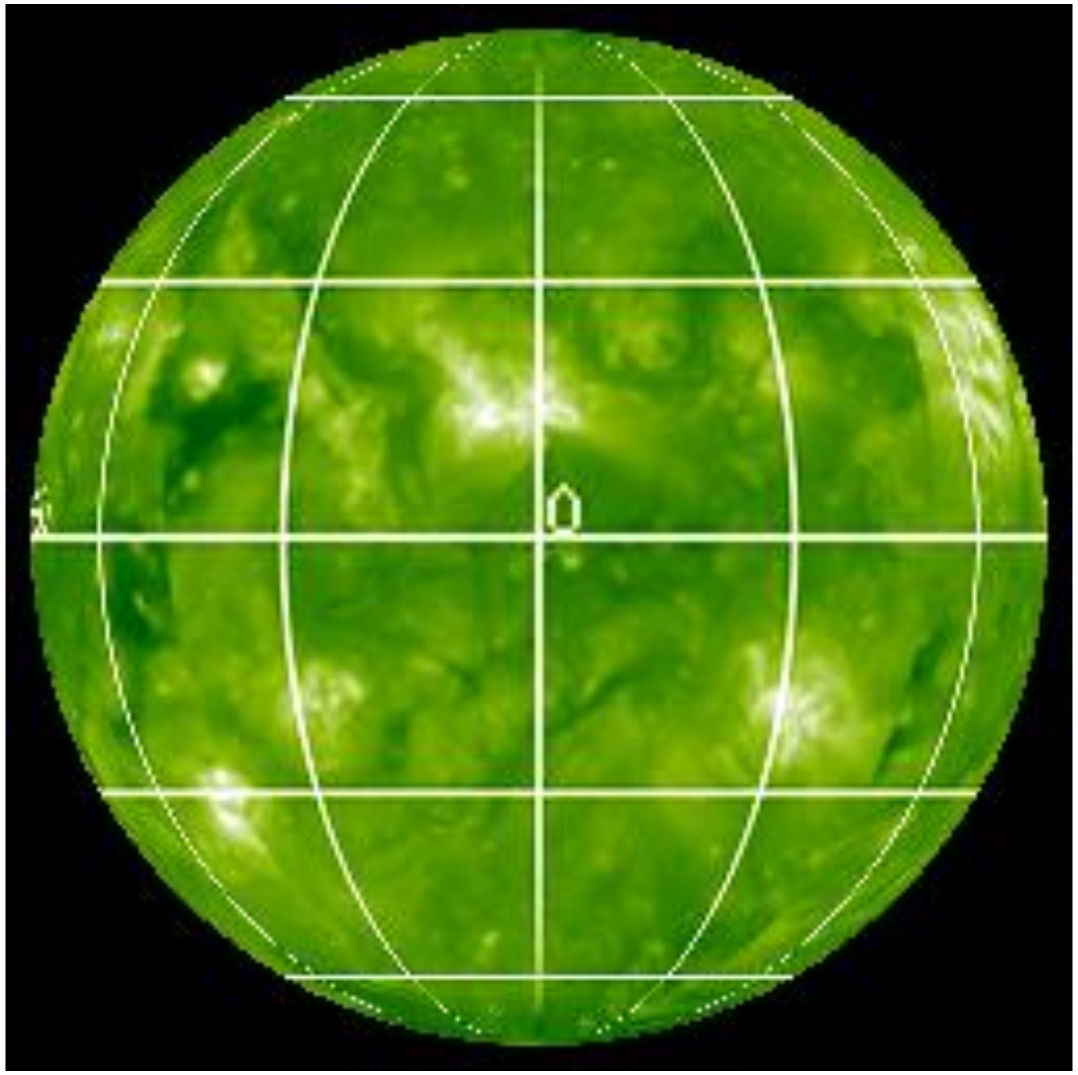
NASA Vision for Space Exploration, NP-2004-01-334-HQ,2004

LRO was to be the first of many robotic missions to the moon in the VSE architecture

STEREO Mission

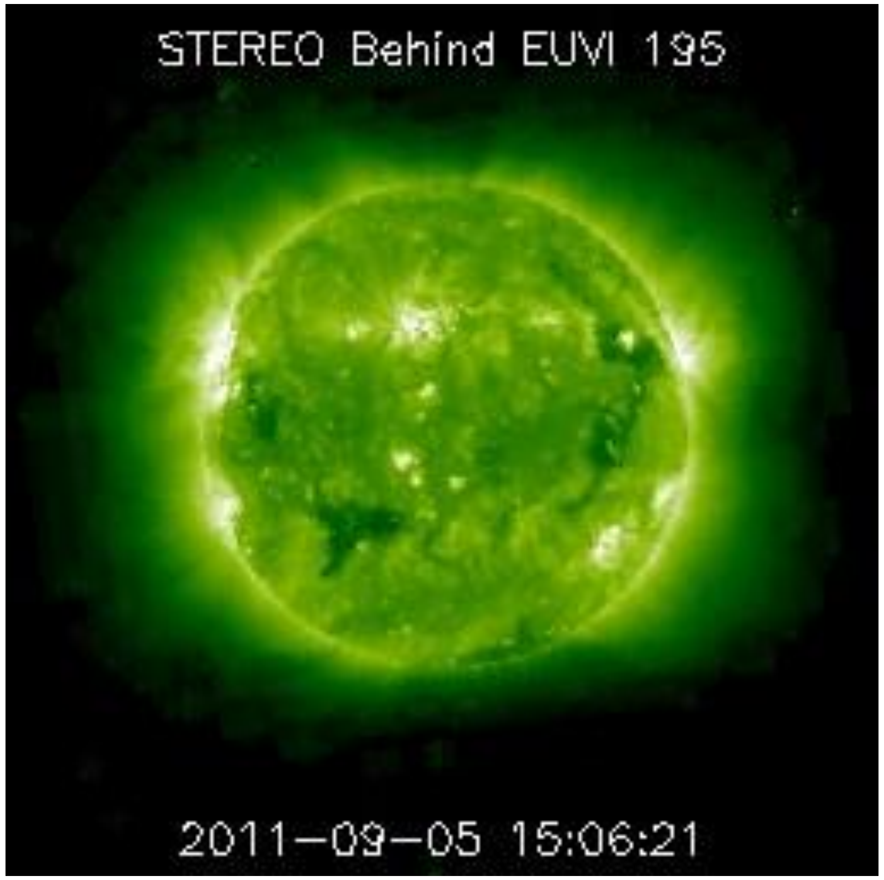
STEREO consists of two space-based observatories - one ahead of Earth in its orbit, the other trailing behind. With this new pair of viewpoints, scientists will be able to see the structure and evolution of solar storms as they blast from the Sun and move out through space

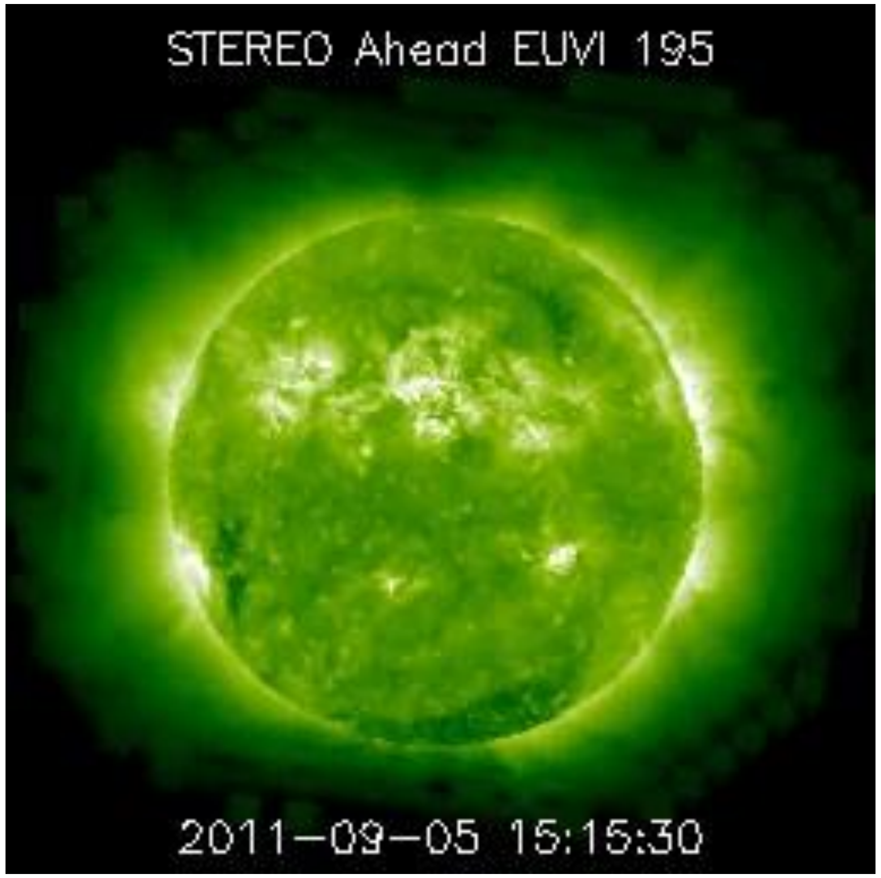
Image shows spherical map of the Sun as it currently appears, formed from a combination of the latest STEREO Ahead and Behind beacon images, along with an SDO/AIA image in between.



STEREO Mission

Latest EUVI images





STEREO Mission

CORONA

STEREO's SECCHI imaging suite shows us the corona in two ways. Its coronagraphs imitate a solar eclipse in space by covering the disk of the Sun with an occulting disk, so that we can see scattered light from the corona. The SECCHI Extreme-Ultraviolet Imager (EUVI) lets us observe the ultraviolet light produced by the corona.

Solar Winds

The STEREO PLASTIC and IMPACT instruments sample the solar wind as it passes by the two spacecraft.

STEREO Mission

CORONAL MASS EJECTION (CME)

A billion tons of matter traveling at a million miles an hour, these giant magnetic structures blast off the Sun into the solar system and can create major disturbances in Earth's magnetic field, resulting in the beautiful aurora but also problems with spacecraft and power systems.

One of is one of the chief goals of the STEREO mission if Understanding what causes CMEs and how they move through the solar system.

STEREO Mission

SOLAR FLARES

Solar flares are bright, explosive events that take place in the Sun's lower corona. They can be associated with CMEs, but are not the same thing. Scientists will use the SECCHI imaging instruments aboard STEREO to improve our understanding of how flares are related to CMEs.

Although most of what is called a solar flare occurs relatively low in the Sun's atmosphere, flares do release charged particles which travel along the magnetic field lines of the interplanetary magnetic field (IMF). Electrons emitted in this way by flares produce radio waves detected by the SWAVES instruments and allow researchers to map the IMF.

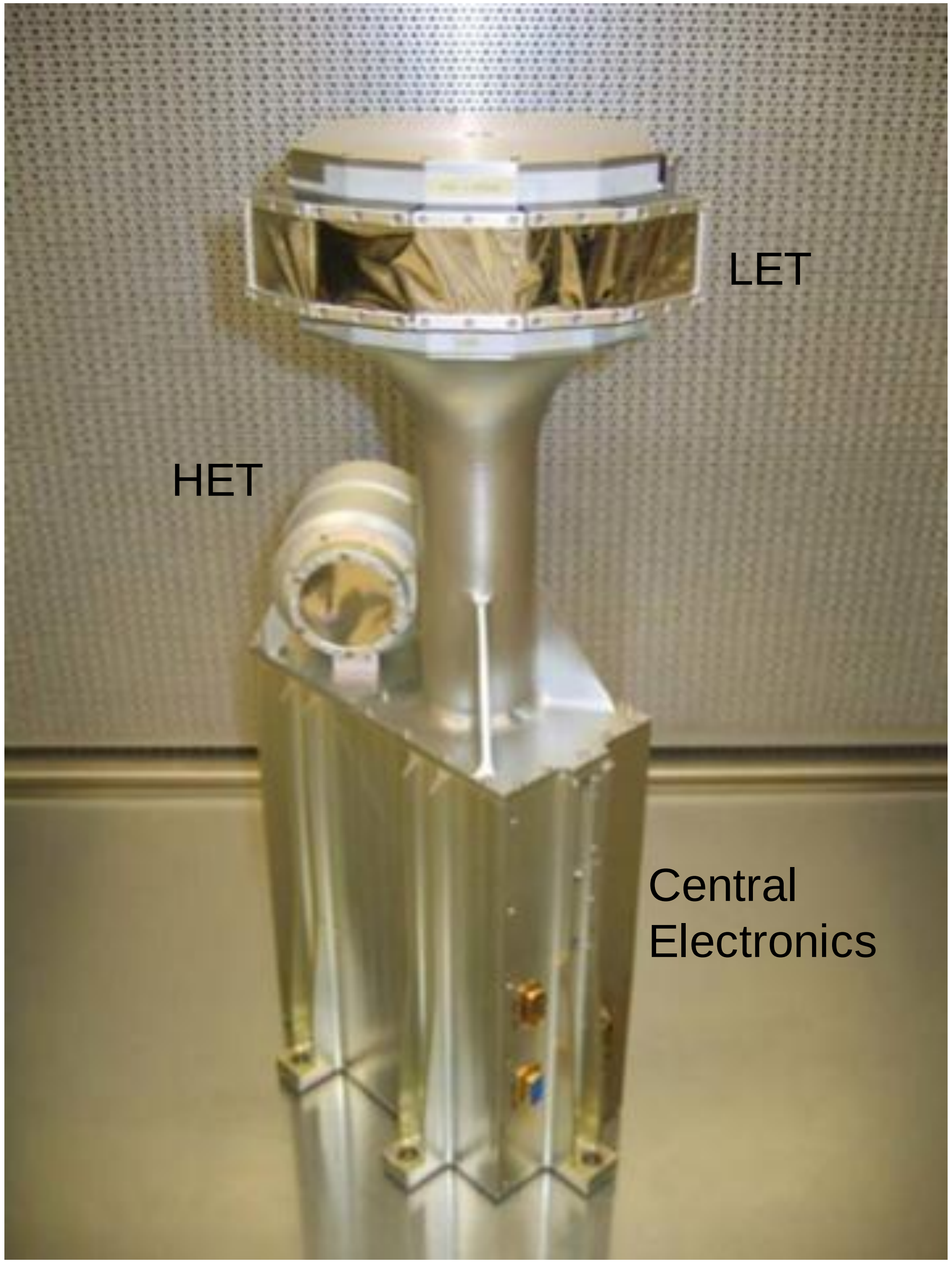
Sometimes these charged particles may be high enough in energy to qualify as solar energetic particles (SEPs). SEPs along with the X-rays and gamma-rays produced by flares can be harmful to astronauts.

STEREO Mission

SPACE WEATHER

Space Weather describes changes in the solar system environment caused by variations in the Sun and Solar Wind. These include, coronal mass ejections and solar flares, and changes in the interplanetary magnetic field due to solar surface features like coronal holes. Space weather phenomena cause the beautiful aurora (northern and southern lights) and can also affect communications, power systems, aviation, and spacecraft. Some space weather occurrences, such as solar energetic particles can present grave dangers to astronauts.

Like Earth weather, space weather varies substantially in space and time. A CME headed towards Earth may completely miss Mars or Venus and vice versa. Spacecraft deployed around the solar system, like STEREO, will give us a better, solar system wide view of what is happening.


LET
HET
Central Electronics

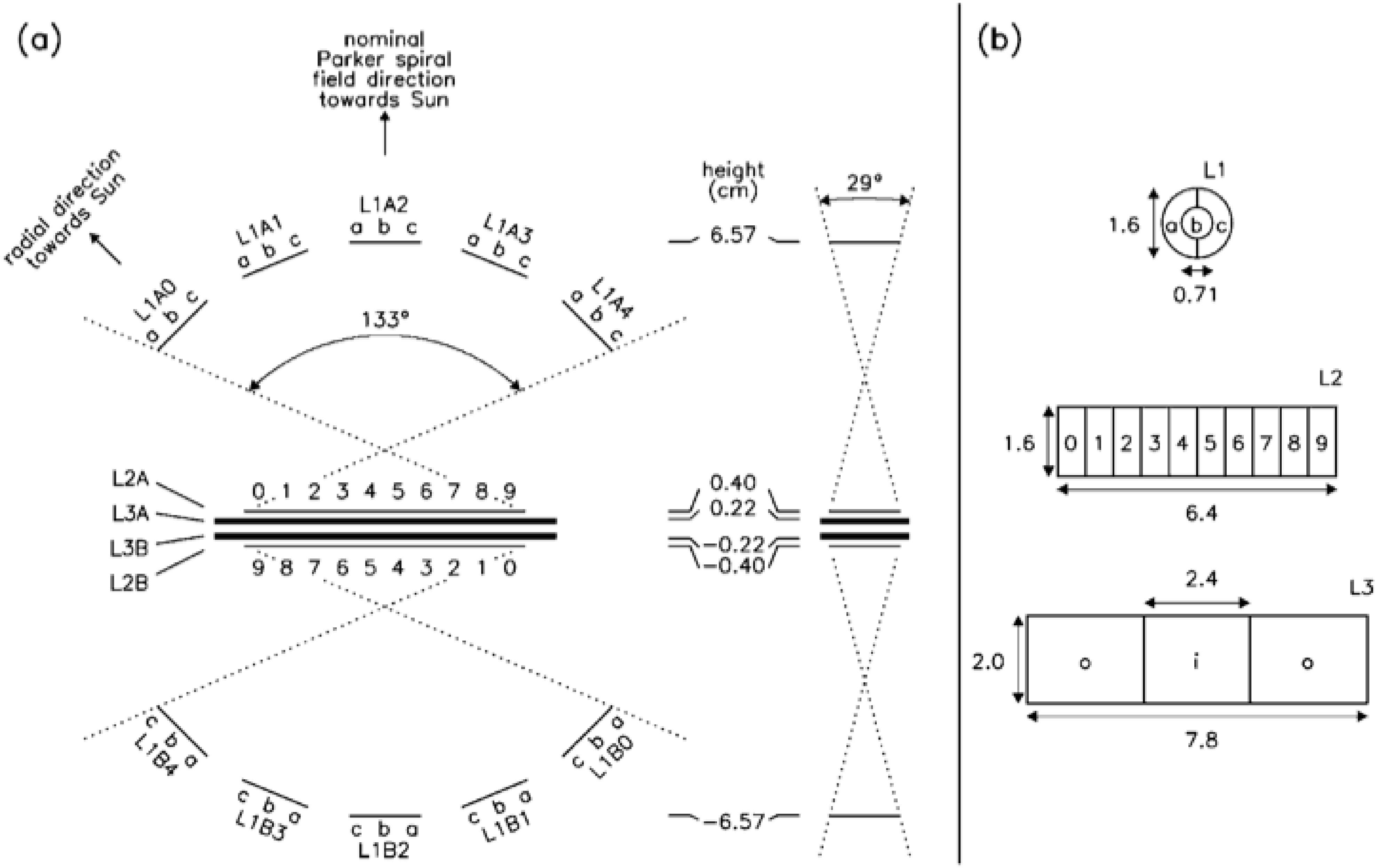


Fig. 20 Panel (**a**) shows a cross-sectional view of the LET detector system together with the limits of the field of view. The L1A2 detector is oriented generally sunward along the nominal direction of the Parker spiral magnetic field on both spacecraft. On the Ahead spacecraft the L1A0 points radially towards the Sun, as shown in the figure. On the Behind spacecraft L1A4 lies along the radial direction towards the Sun. Panel (**b**) illustrates the sizes and segmentation of the LET detectors. Each of the three segments on the L1 detectors and the 10 segments on the L2 detectors is individually pulse height analyzed. The L3 detector signals are processed with two pulse height analyzers, one for the inner segment (i) and the other for the combination of the two outer segments (o)

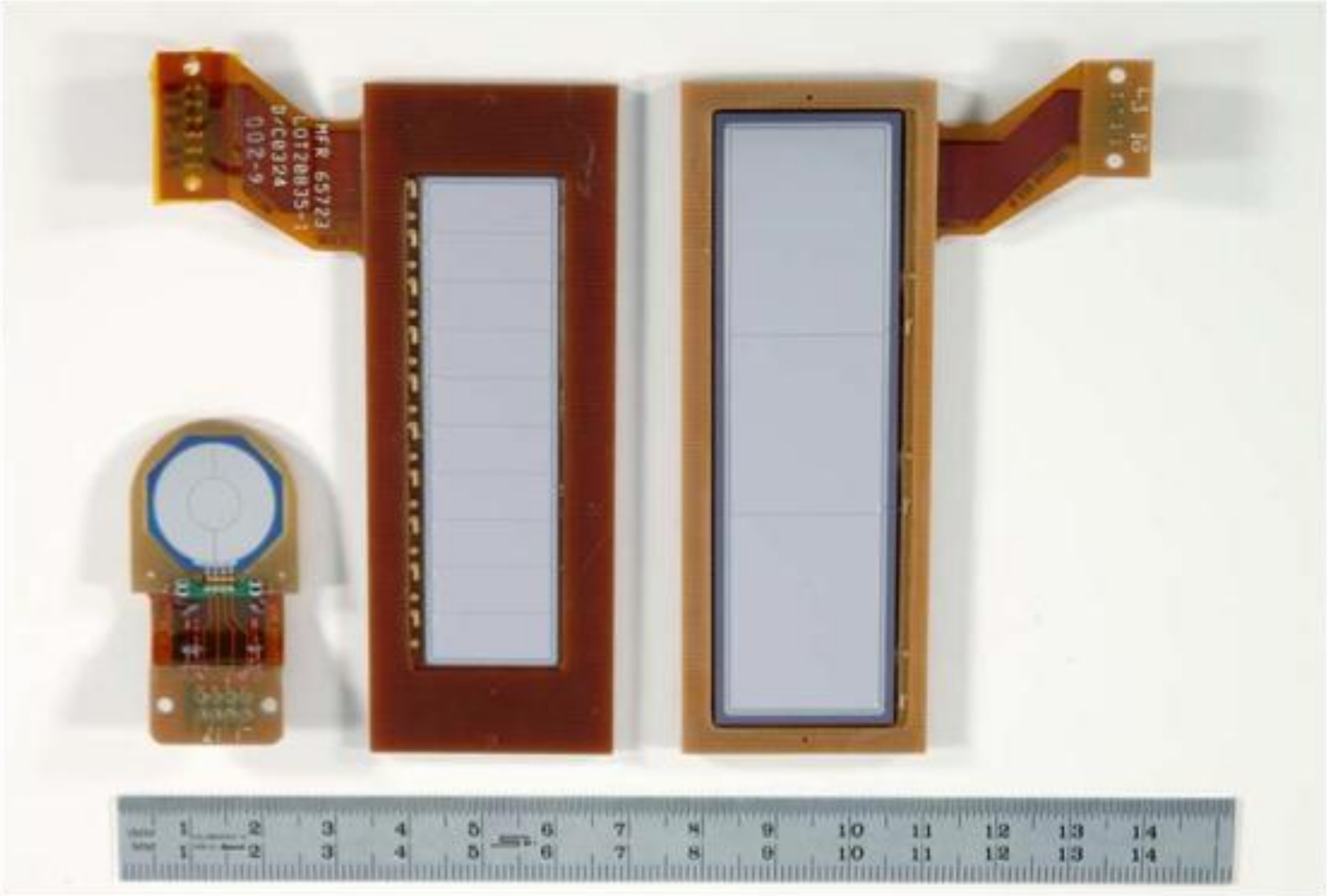


Fig. 23 Photographs showing (from left to right) examples of L1, L2, and L3 detectors. These views from the junction surfaces of the detectors show the segmentation into multiple active areas. The opposite (ohmic) surfaces consist of a single, full-area contact in each detector design. Detectors are installed by the manufacturer in multilayer circuit board mounts with flexible metallized Kapton strips for making electrical connections to the LET bias and pulse height analysis circuitry

Fe

Si

O

C

He

H

STEREO/LET Data from 5 Dec 2006 Solar Energetic Particle Event

Fig. 9 Shows a HET stack detector (junction side)

Solar Isotope Spectrometer (SIS) on the Advanced Composition Explorer (ACE)
Operating continually since launch on 25 August 1997

Figure 1. Photograph of the SIS instrument with the acoustic covers open. The dimensions of the housing are 30.0 × 41.9 × 27.5 cm.

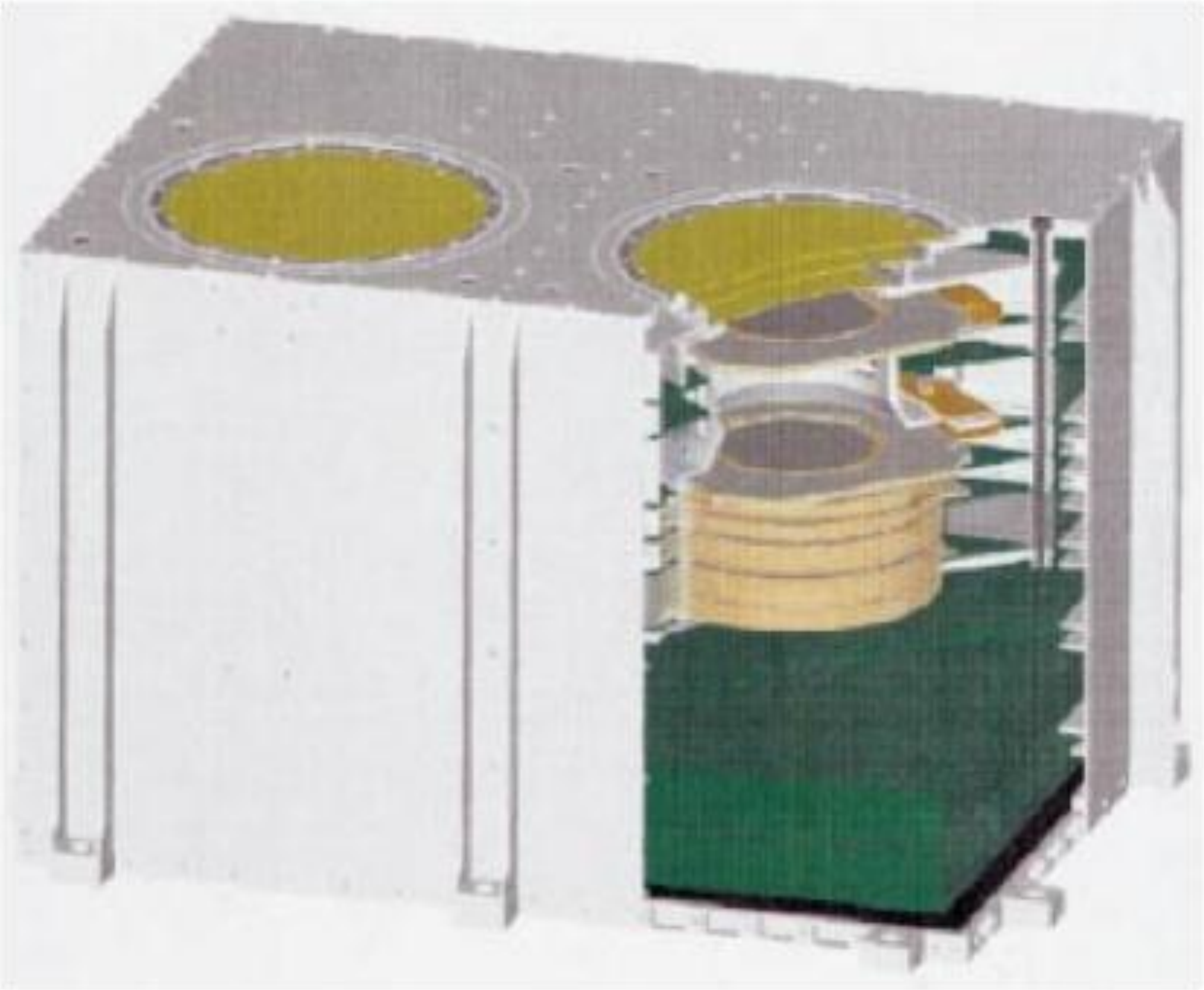


Figure 16. Cut-away view of SIS, showing one of the two SIS telescopes. At the top of the cut-away section, one can see three entrance foils supported by the entrance collimator. Below are two matrix detectors followed by the four modules which hold T1+T2, T3+T4, T5+T6, and T7+T8. The modules are cut away to show the detectors. The power supply appears below the telescope. The acoustic doors, shown in Figure 1, are not included here.

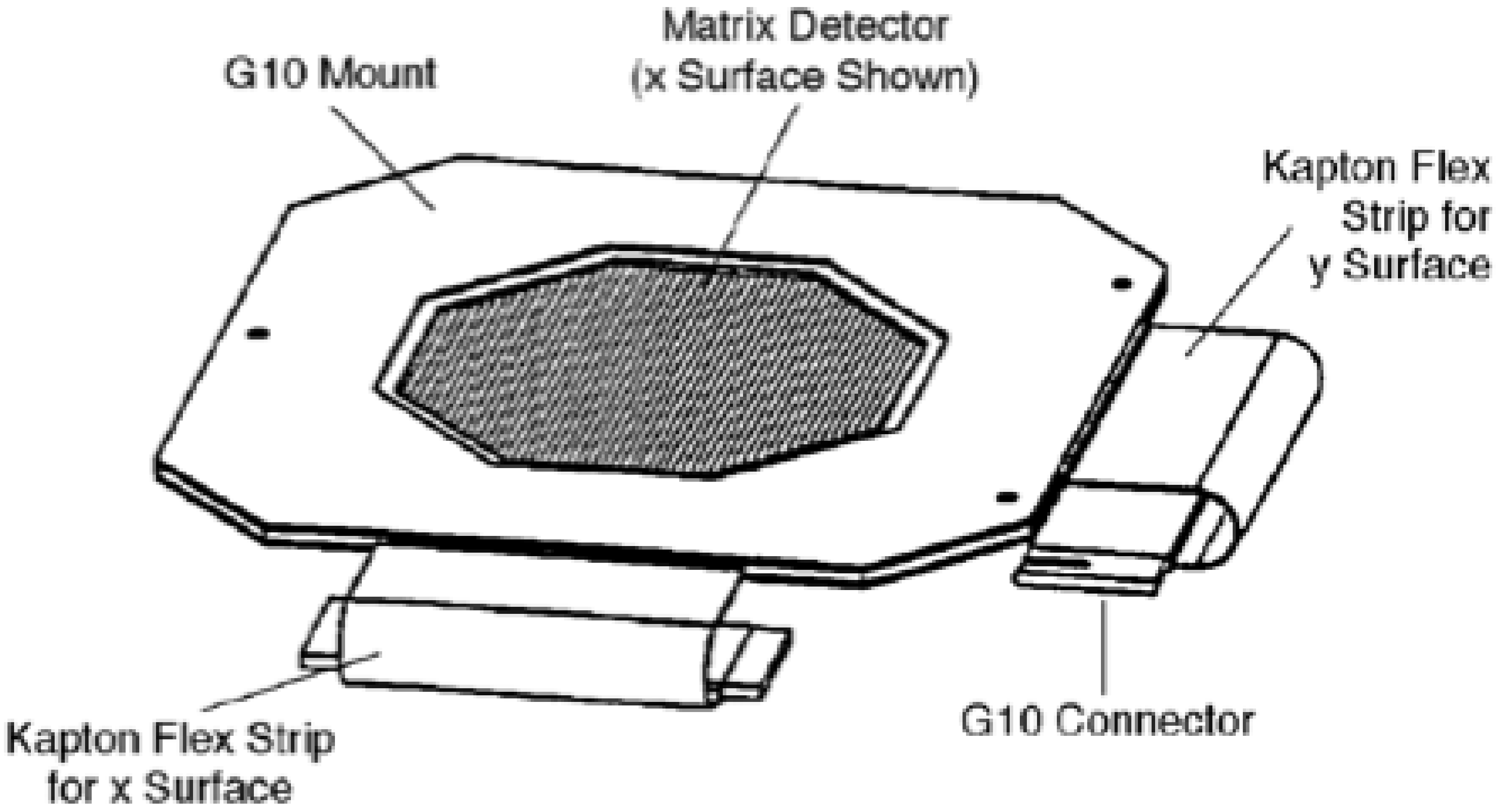


Figure 12. Schematic of a SIS matrix detector in its mount. Each surface of the detector has 64 metallized strips. The X-surface strips are orthogonal to the Y-surface strips and all strips are individually pulse-height analyzed.

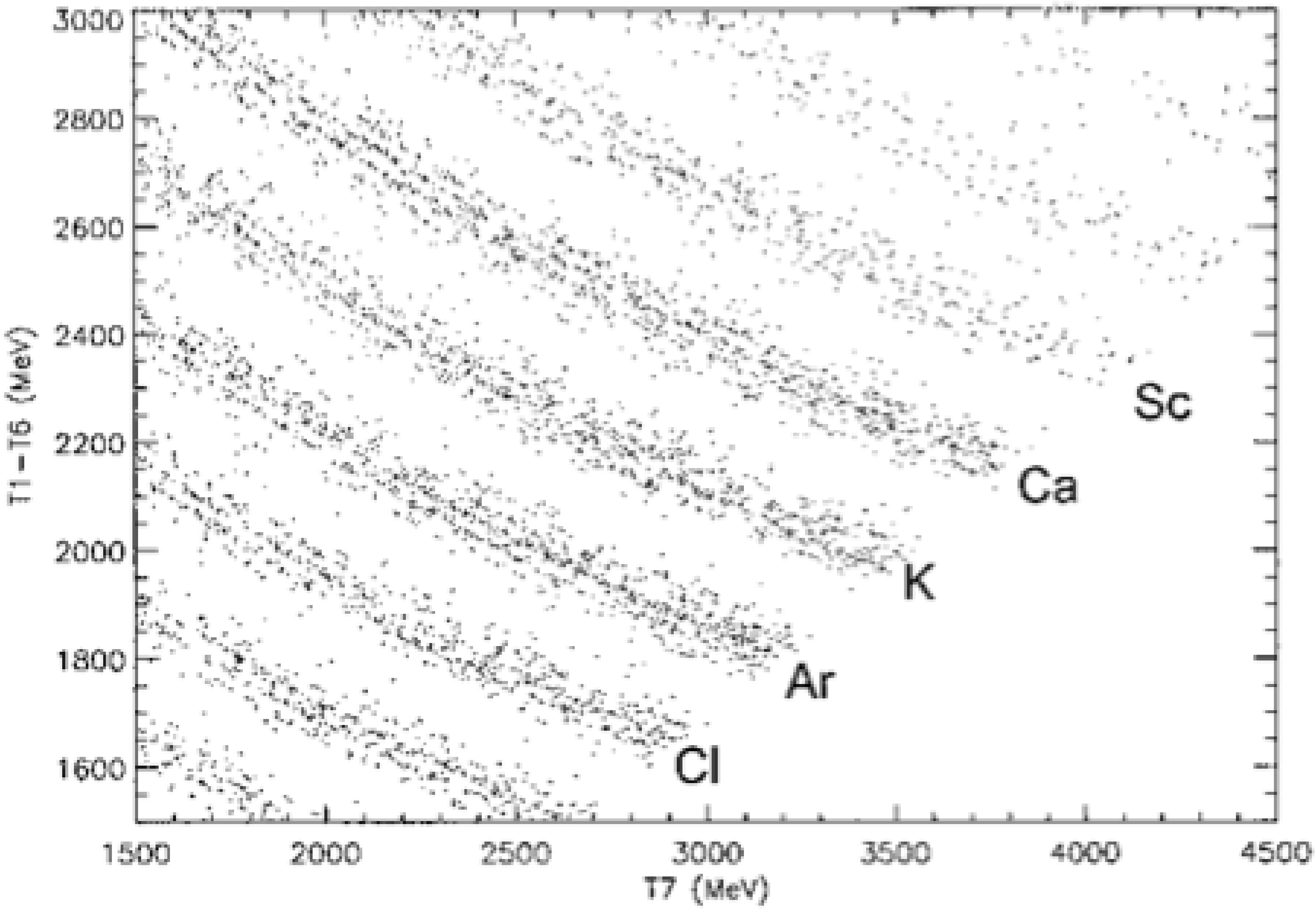


Figure 18. Scatter plot of ΔE vs E' for events collected in a SIS accelerator calibration run at the GSI accelerator in Darmstadt, Germany. The data that are plotted were collected for heavy nuclei that stopped in T7 (used as E') and the sum of the signals from T1 through T6 is used as ΔE. In this run a primary beam of ^{56}Fe at 500 MeV nucl^{-1} incident a 5° was allowed to fragment in a target. Data are shown for elements near $Z = 20$. Tracks corresponding to a number of isotopes of each element are clearly visible in these data.

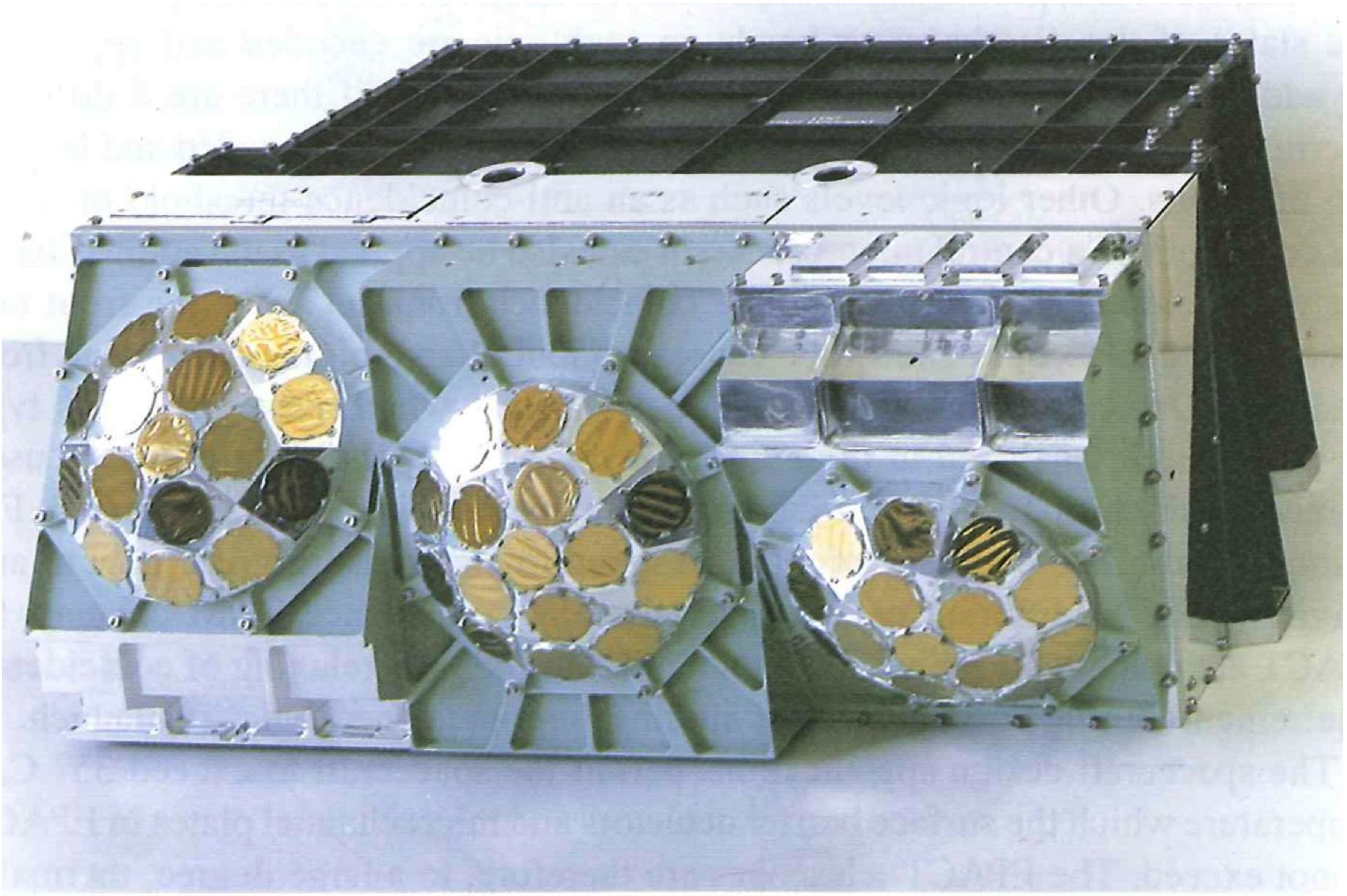


Fig. 3.2-1. Picture of the assembled LEMT system.

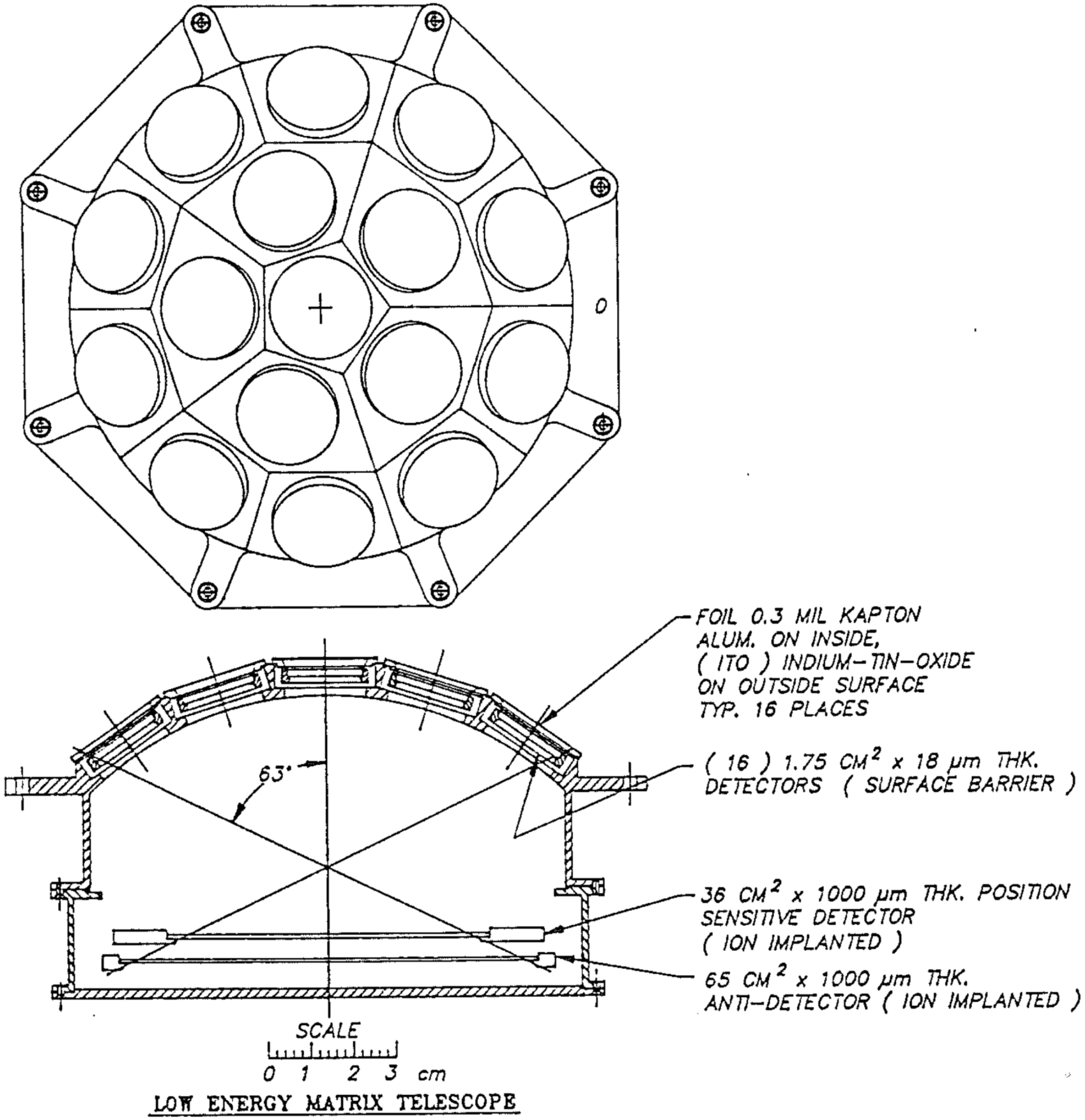


Fig. 3.2-2. Schematic cross-section and front view of a LEMT telescope.

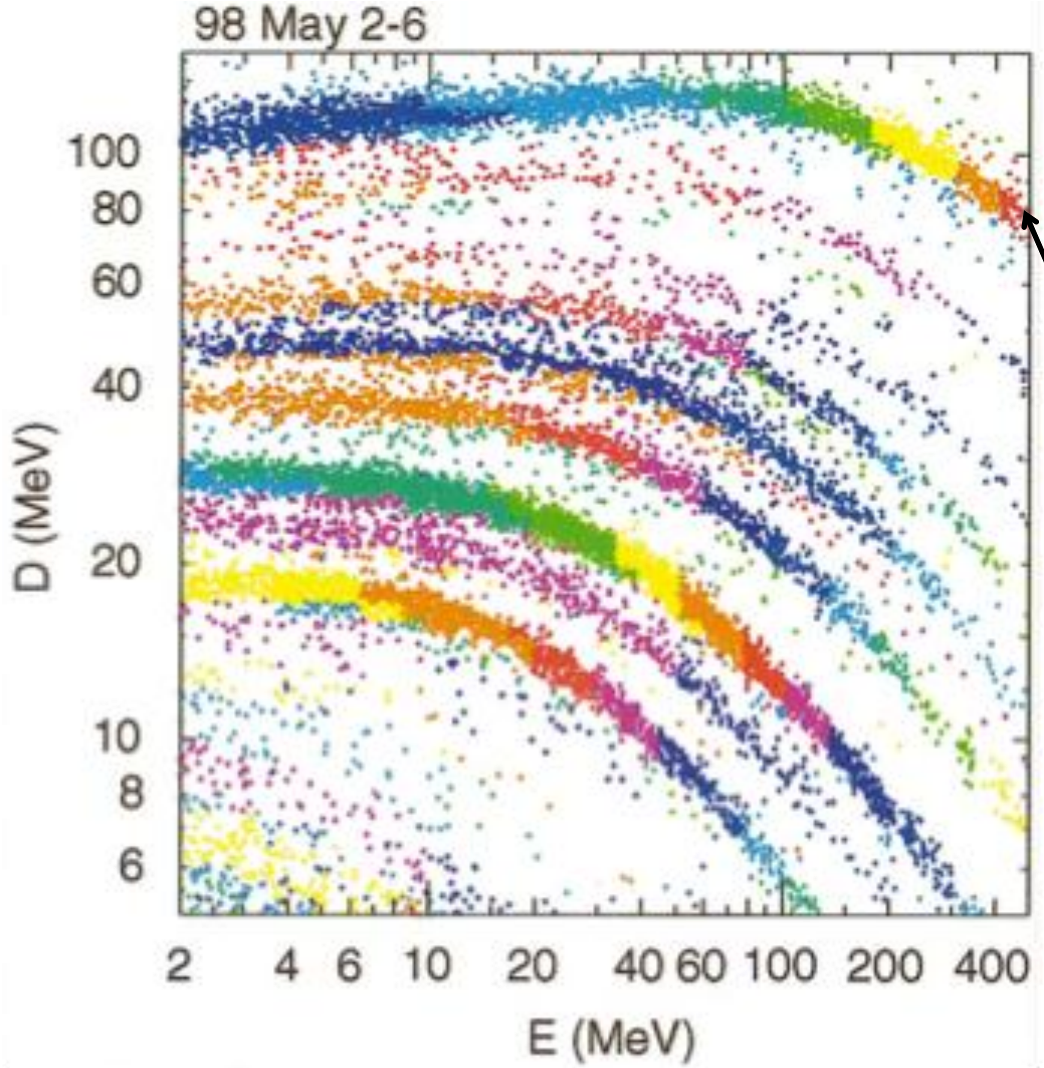


FIG. 1—Onboard bins of particle species and energy identification are indicated with a rotating pattern of colors in a D vs. E pulse-height plot from the LEMT telescope on the *Wind* spacecraft. Onboard identification allows formation of angular distributions for well-identified species and energy intervals.

Fe

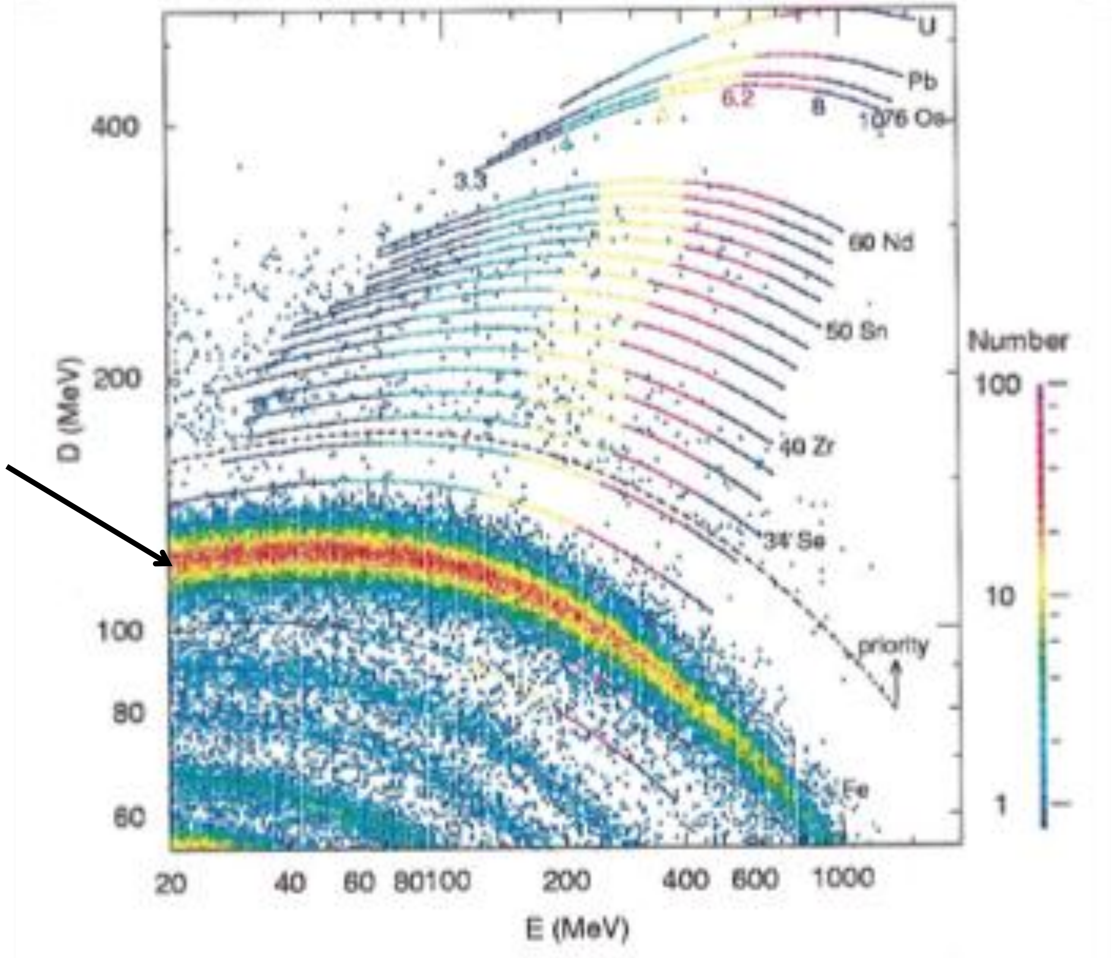


FIG. 1.—Distribution of particles with energy deposited in the dome (D) detector vs. that in the energy (E) detector of the LEMT telescope for the first 5.5 years of the *Wind* mission. Calibration curves identify selected elements.

GOES R

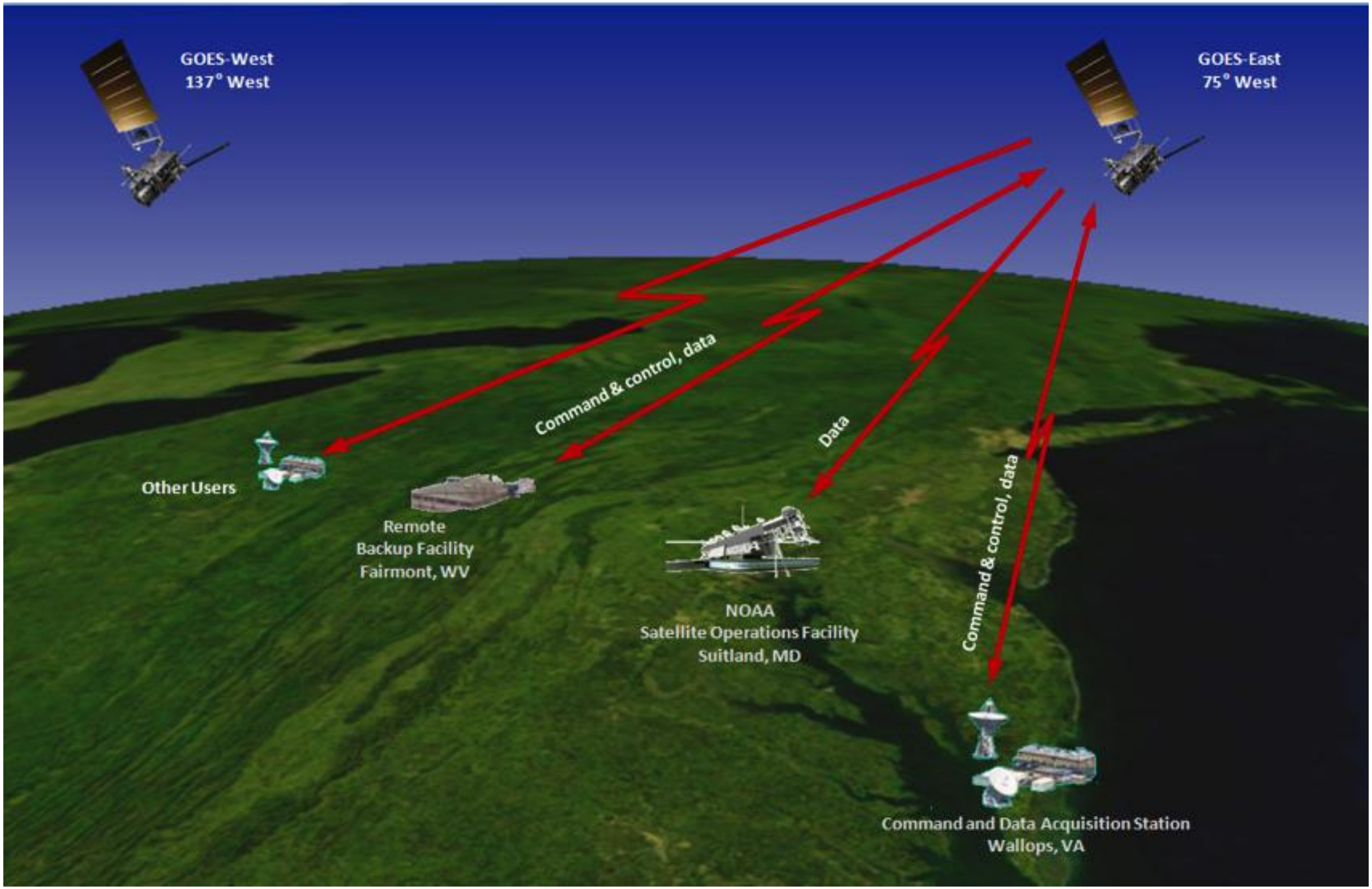
The Geostationary Operational Environmental Satellite – R Series (GOES-R) program is a key element to meeting the **National Oceanic and Atmospheric Administration (NOAA)** mission.

The advanced spacecraft and instrument technology used on the GOES-R series will result in more timely and accurate weather forecasts.

It will improve support for the detection and observations of meteorological phenomena and directly affect public safety, protection of property, and ultimately, economic health and development.

The first launch of the GOES-R series satellite is scheduled for 2015.

GOES R


GOES-West
137° West
GOES-East
75° West
Command & control, data
Data
Command & control, data
Other Users
Remote
Backup Facility
Fairmont, WV
NOAA
Satellite Operations Facility
Suitland, MD
Command and Data Acquisition Station
Wallops, VA

GOES R

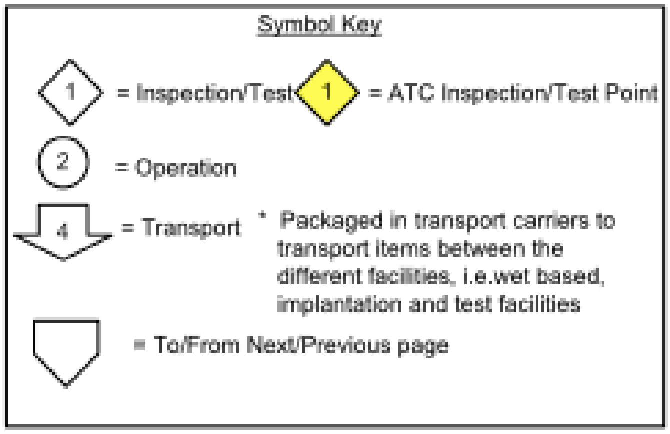
The GOES-R satellite will provide continuous imagery and atmospheric measurements of Earth’s Western Hemisphere and space weather monitoring. It will be the primary tool for the detection and tracking of hurricanes and severe weather and provide new and improved applications and products for fulfilling NOAA’s goals of Water and Weather, Climate, Commerce, and Ecosystem.

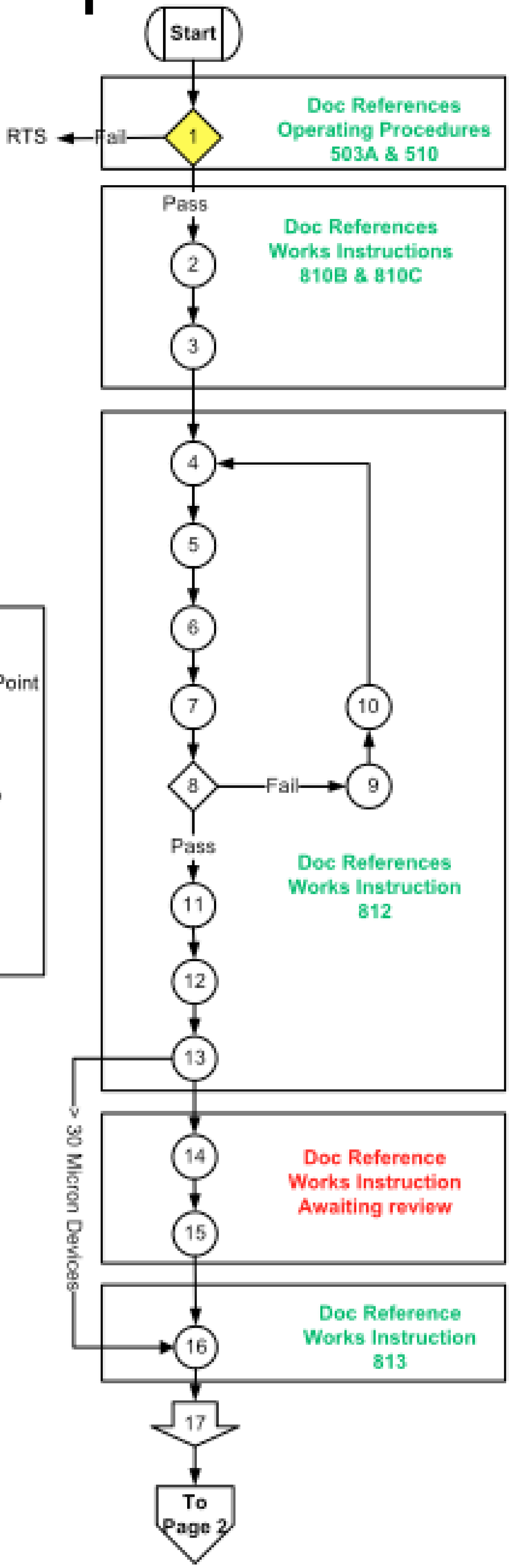
The GOES-R **Space Segment** is comprised of the **spacecraft bus**, **instruments**, **auxiliary communications payloads**, and the Launch Vehicle (LV). The spacecraft bus supports numerous subsystems. The instrument suite consists of Earth sensing, solar imaging, and space environment measurement payloads. The auxiliary communications payload contains the antennae, transmitters, receivers, and transponders to relay processed imagery data and provide the auxiliary communications services.

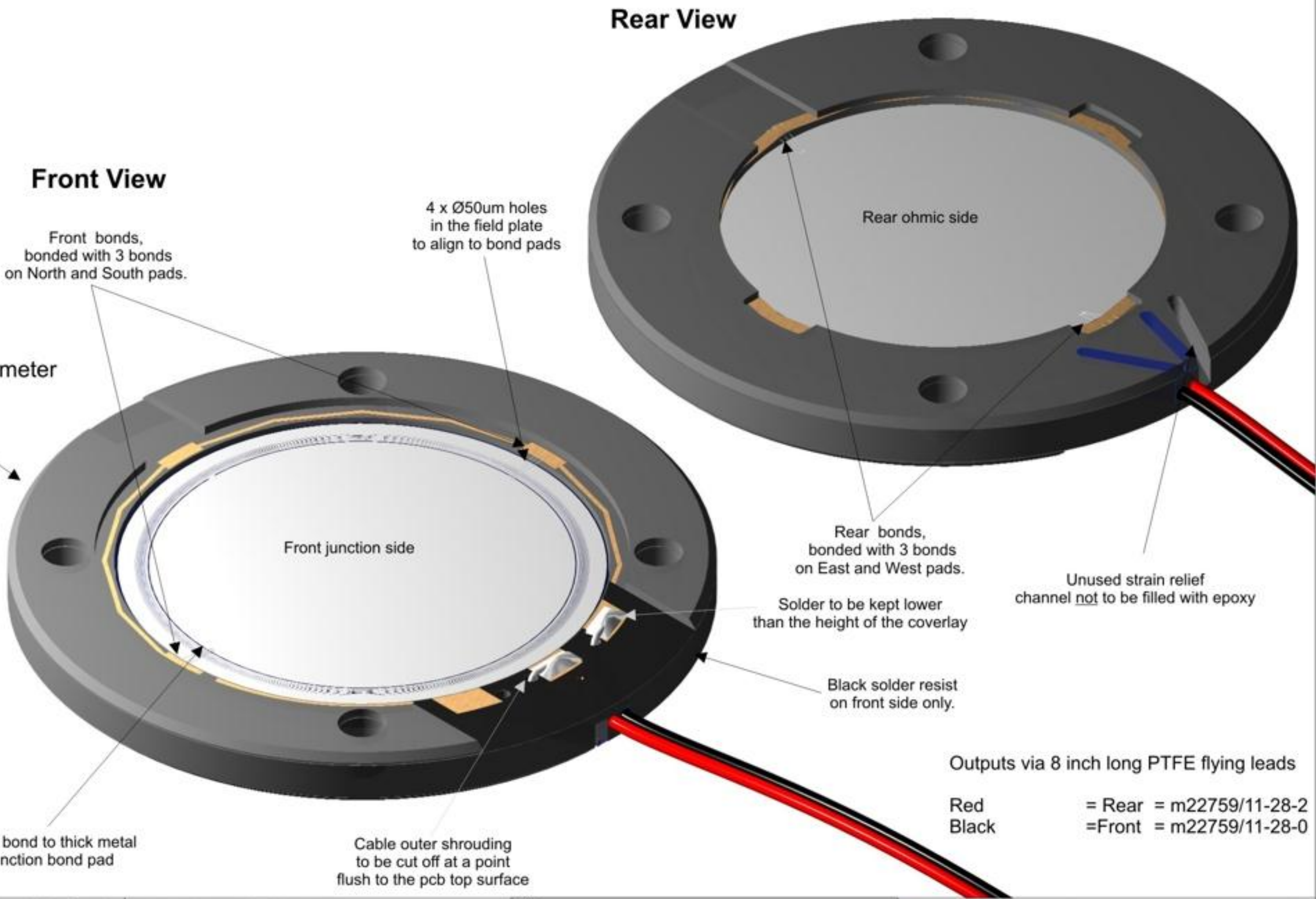
Manufacturing Process Example for Space Detectors to NASA standards

Operation Key

1. Goods Inwards Verification of silicon
2. Pre thermal oxidation cleaning of wafers
3. Thermal Oxide
4. Application of UV sensitive film
5. Soft bake of photo resist
6. 1st stage lithographic imaging
7. Developing of photo resist
8. Visual Inspection of image
9. Strip photo resist
10. Clean wafers
11. Hard bake of photo resist
12. Etch 1st stage of thermal oxide
13. Resist strip and wafers cleaned
14. Substrate thinning to 20 or 30 microns
15. Clean
16. Thin thermal oxide applied
17. Transport to Metal Deposition facility







Outputs via 8 inch long PTFE flying leads

Red = Rear = m22759/11-28-2
Black =Front = m22759/11-28-0

Date	Tolerances Unless Stated	Outputs Via: 8 inch long PTFE flying leads.
18/07/2007	Package O/D ± 0.1mm	Mating Connector: N/A
	Package Hole ± 0.05mm	Potted Wire Bonds: No
	Package Hole Pos'n ± 0.1mm	Substrate Number: A-3288
	Detector O/D ± 20.0μm	Substrate Material: 3.6mm Thick black FR4 PCB Material
	Total thickness tolerance ± 0.2mm	Connector Orientation: N/A

Title.

MSD026-1500
Type A1-1 PCB.
3D Assembly.
Front and Rear View.

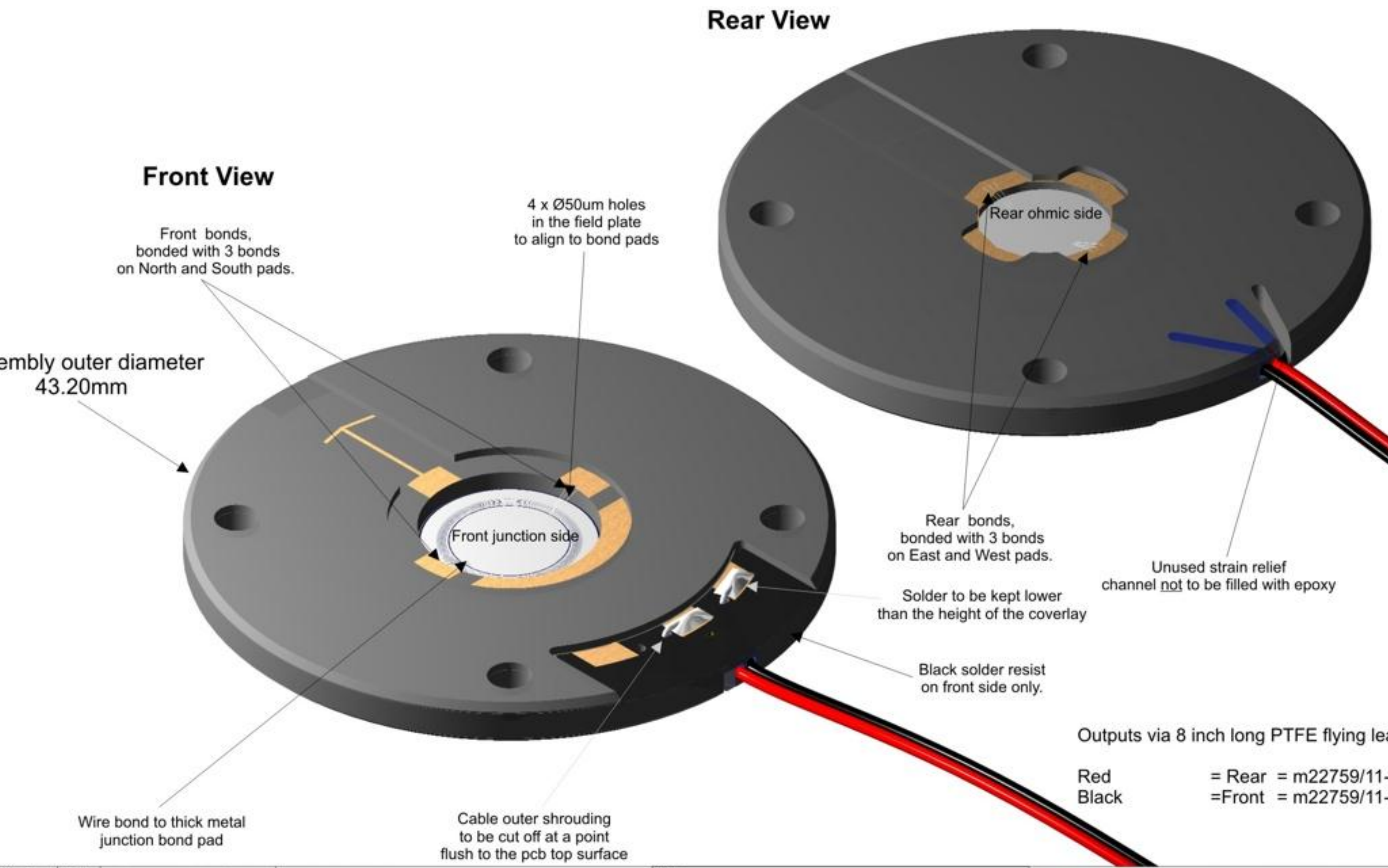
MICRON SEMICONDUCTOR LIMITED

THIS DOCUMENT IS THE PROPERTY OF MICRON SEMICONDUCTOR LTD AND IS COMMERCIAL IN CONFIDENCE

graphics@micronsemiconductor.co.uk

Scale N/A | Dims In. mm | Drg No A-3307

-3349



Outputs via 8 inch long PTFE flying lea

Red = Rear = m22759/11-
Black =Front = m22759/11-

Checked	Date	Tolerances Unless Stated	Outputs Via: 8 inch long PTFE flying leads.
S.W	18/07/200	Package O/D ± 0.1mm	Mating Connector: N/A
		Package Hole ± 0.05mm	Potted Wire Bonds: No
		Package Hole Pos'n ± 0.1mm	Substrate Number: A-3290
		Detector O/D ± 20.0μm	Substrate Material: 3.2mm Thick black FR4 PCB Material

Title.

MSD008-100
Type B1-1 PCB.
3D Assembly.
Front and Rear View.

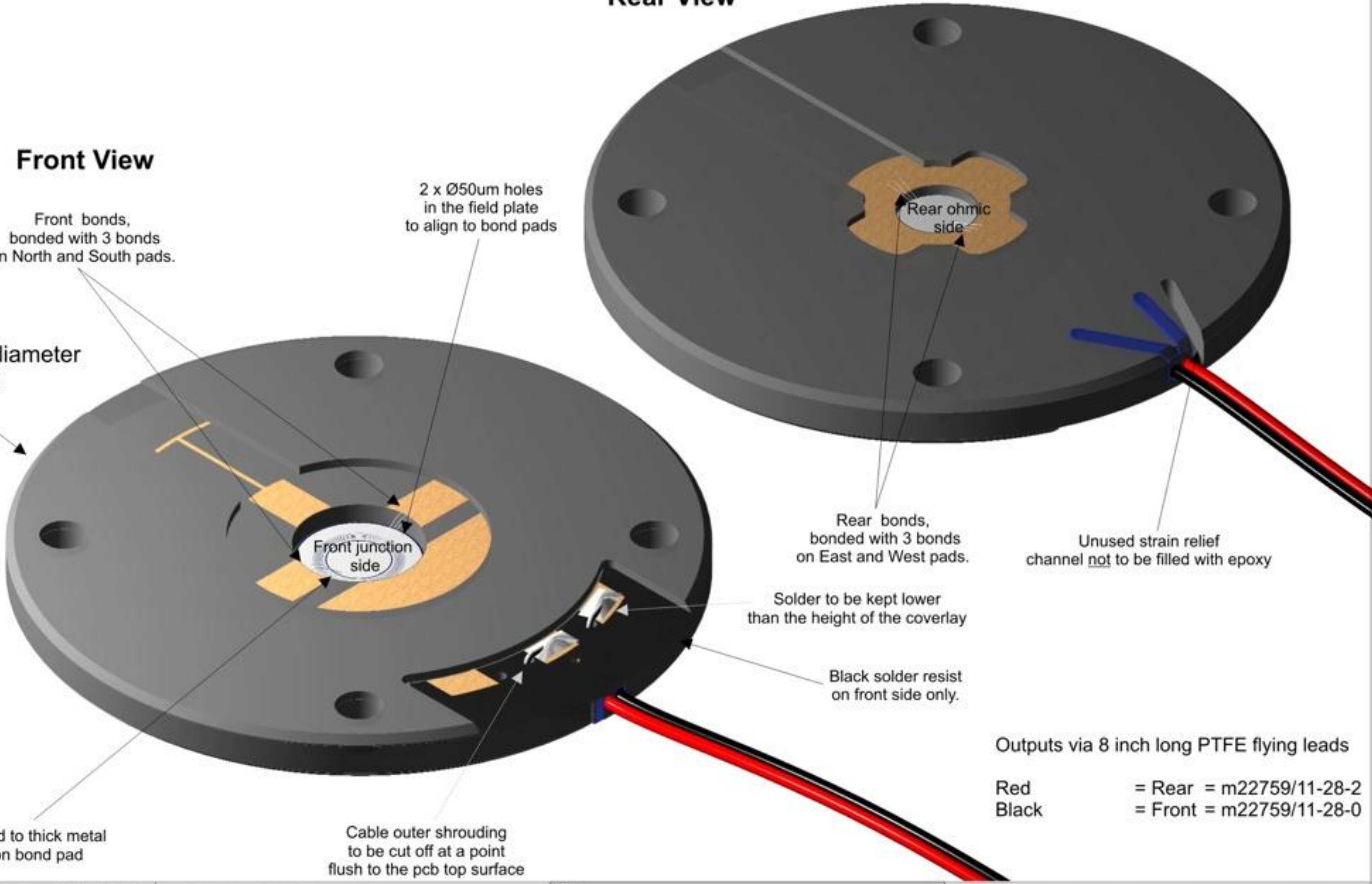
MICRON SEMICONDUCTOR LI

graphics@micronsemiconductor.co.uk

57

Front View

Rear View



outer diameter
.20mm

Front bonds,
bonded with 3 bonds
on North and South pads.

2 x Ø50um holes
in the field plate
to align to bond pads

Rear bonds,
bonded with 3 bonds
on East and West pads.

Unused strain relief
channel <u>not</u> to be filled with epoxy

Solder to be kept lower
than the height of the coverlay

Black solder resist
on front side only.

Outputs via 8 inch long PTFE flying leads

Red = Rear = m22759/11-28-2
Black = Front = m22759/11-28-0

Wire bond to thick metal
junction bond pad

Cable outer shrouding
to be cut off at a point
flush to the pcb top surface

Date	Tolerances Unless Stated	Outputs Via: 8 inch long PTFE flying leads.
18/07/200	Package O/D ± 0.1mm	Mating Connector: N/A
	Package Hole ± 0.05mm	Potted Wire Bonds: No
	Package Hole Pos'n ± 0.1mm	Substrate Number: A-3292
	Detector O/D ± 20.0µm	Substrate Material: 3.2mm Thick black FR4 PCB Material

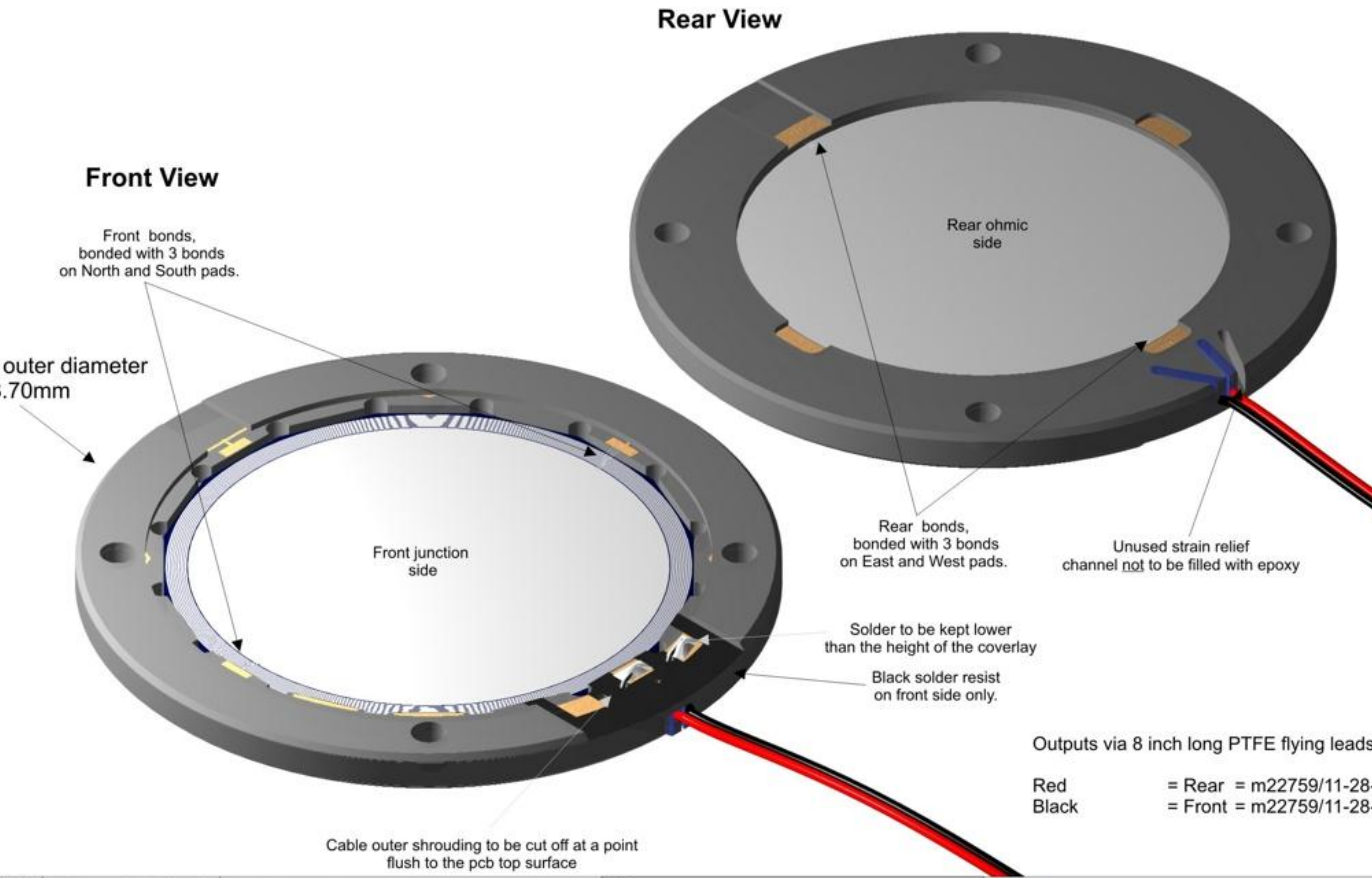
Title.

MSD004-20
Type F3-1 PCB.
3D Assembly.
Front and Rear View.

MICRON SEMICONDUCTOR LIMITED

graphics@micronsemiconductor.co.uk

359



Outputs via 8 inch long PTFE flying leads

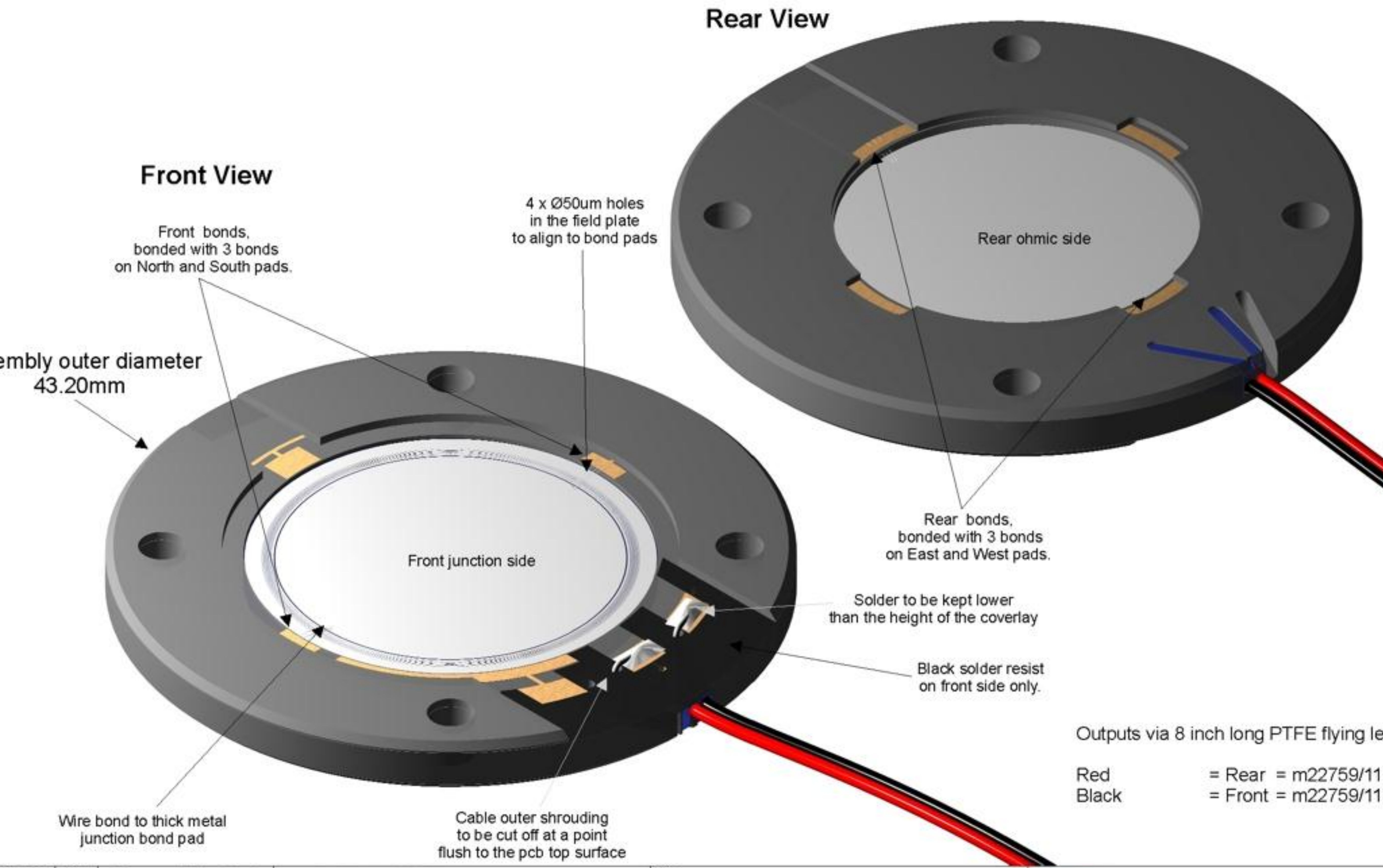
Red	= Rear	= m22759/11-28
Black	= Front	= m22759/11-28

cked	Date	Tolerances Unless Stated	Outputs Via: 8 inch long PTFE flying leads.
W	18/07/2	Package O/D ± 0.1mm	Mating Connector: N/A
		Package Hole ± 0.05mm	Potted Wire Bonds: No
		Package Hole Pos'n ± 0.1mm	Substrate Number: A-3298

Title.

MSD040-1500
Type H1-1 PCB.
3D Assembly.
Front and Rear View

MICRON SEMICONDUCTOR LIMIT



Front bonds,
bonded with 3 bonds
on North and South pads.

4 x Ø50um holes
in the field plate
to align to bond pads

embly outer diameter
43.20mm

Rear bonds,
bonded with 3 bonds
on East and West pads.

Solder to be kept lower
than the height of the coverlay

Black solder resist
on front side only.

Outputs via 8 inch long PTFE flying le

Red = Rear = m22759/11
Black = Front = m22759/11

Wire bond to thick metal
junction bond pad

Cable outer shrouding
to be cut off at a point
flush to the pcb top surface

Checked	Date	Tolerances Unless Stated	Outputs Via: 8 inch long PTFE flying leads.	Title.
S.W	26/10/2009	Package O/D ± 0.1mm	Mating Connector: N/A	MSD022-1500. 3D Assembly. Front and Rear View with White PTFE Cable Removed
		Package Hole ± 0.05mm	Potted Wire Bonds: No	
		Package Hole Pos'n ± 0.1mm	Substrate Number: A-3293	
		Detector O/D ± 20.0µm	Substrate Material: 3.6mm Thick black FR4 PCB Material	
		Total thickness tolerance ± 0.2mm	Connector Orientation: N/A	

MICRON SEMICONDUCTOR LI

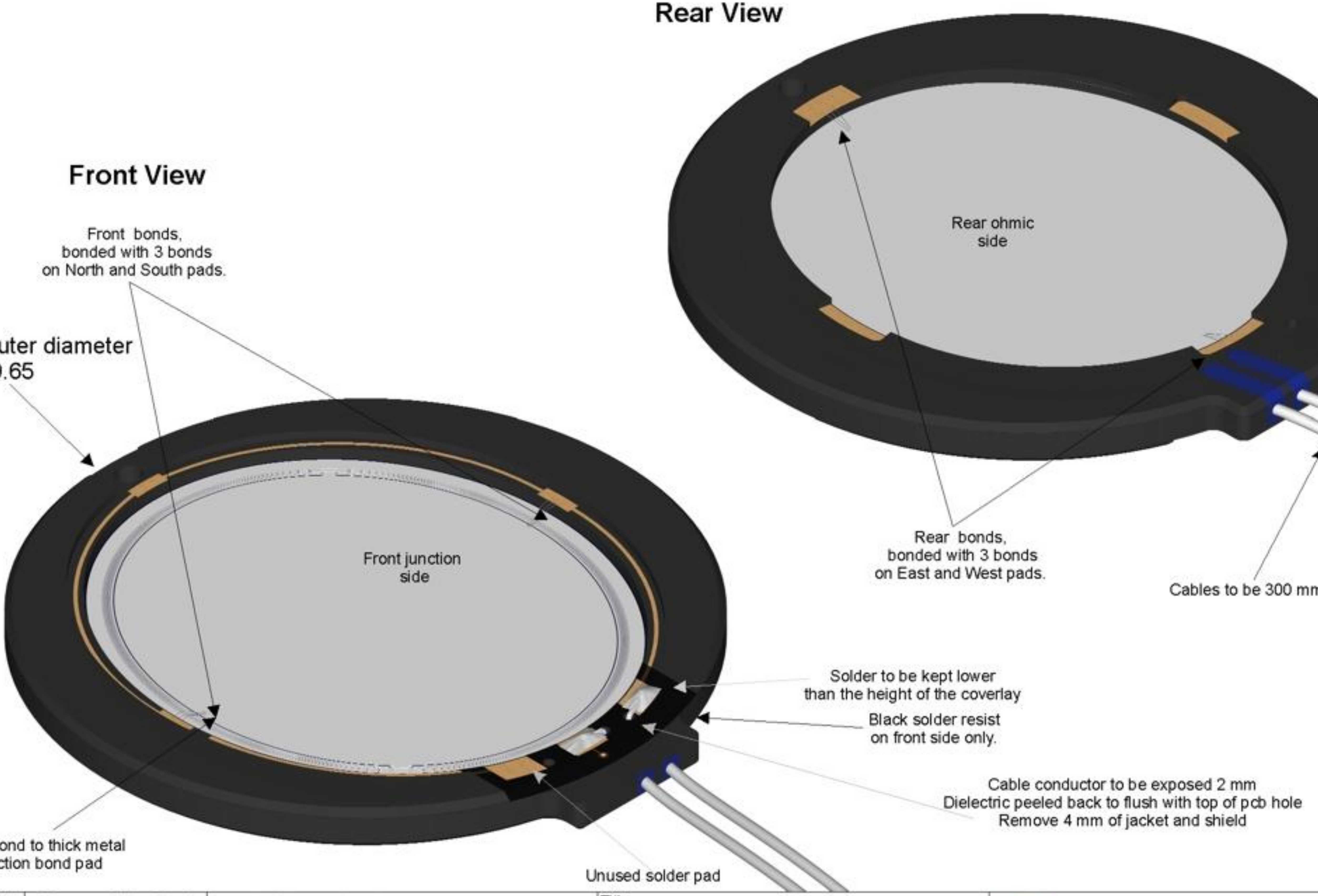
graphics@micronsemiconductor.co.u

Scale N/A	Dims In. mm	Drg No A-3

rg.
o A-3716

Rear View

Front View



Rear ohmic
side

Front bonds,
bonded with 3 bonds
on North and South pads.

Assembly outer diameter
49.65

Front junction
side

Rear bonds,
bonded with 3 bonds
on East and West pads.

Cables to be 300 m

Solder to be kept lower
than the height of the coverlay

Black solder resist
on front side only.

Cable conductor to be exposed 2 mm
Dielectric peeled back to flush with top of pcb hole
Remove 4 mm of jacket and shield

Wire bond to thick metal
junction bond pad

Unused solder pad

rawn	Checked	Date	Tolerances Unless Stated	Outputs Via: 300 mm long Co-Axial leads.
N.W	S.W	29/10/200	Package O/D ± 0.1mm	Mating Connector: N/A
Des.			Package Hole ± 0.05mm	Potted Wire Bonds: No
ppd.			Package Hole Pos'n ± 0.1mm	Substrate Number: A-3691
stomer			Detector O/D ± 20.0µm	Substrate Material: 3.2mm Thick black FR4 PCB Material

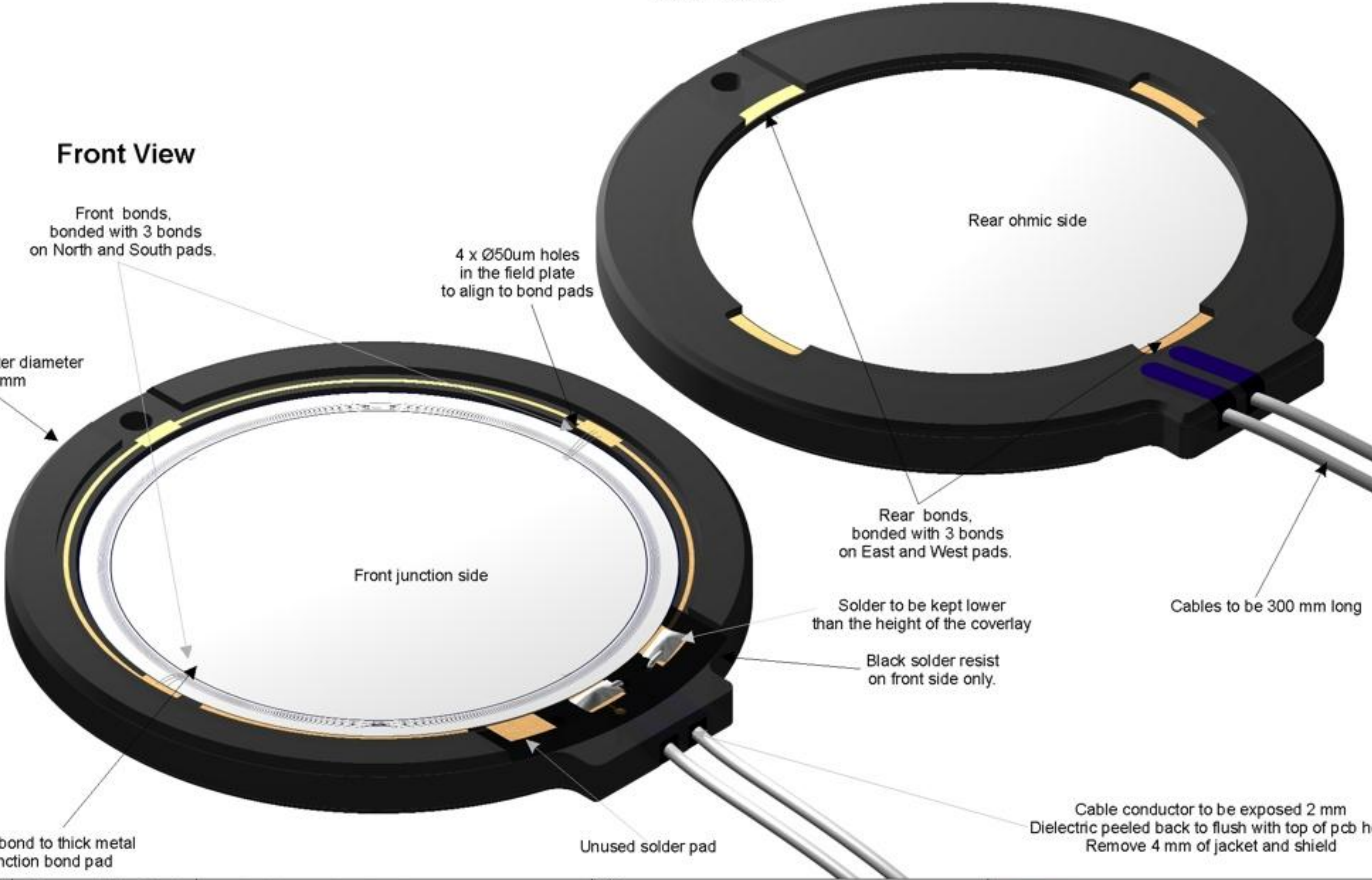
Title.

Ellipse-50
Co-Axial Version PCB.
A-3691 (machined from A-3554)
3D Assembly.
Front and Rear View

MICRON SEMICONDUCTO

graphics@micronsemiconducto

3717



Rear View

Front View

Front bonds,
bonded with 3 bonds
on North and South pads.

4 x Ø50um holes
in the field plate
to align to bond pads

sembly outer diameter
44.70mm

Rear ohmic side

Rear bonds,
bonded with 3 bonds
on East and West pads.

Front junction side

Solder to be kept lower
than the height of the coverlay

Black solder resist
on front side only.

Cables to be 300 mm long

Cable conductor to be exposed 2 mm
Dielectric peeled back to flush with top of pcb h
Remove 4 mm of jacket and shield

Wire bond to thick metal
junction bond pad

Unused solder pad

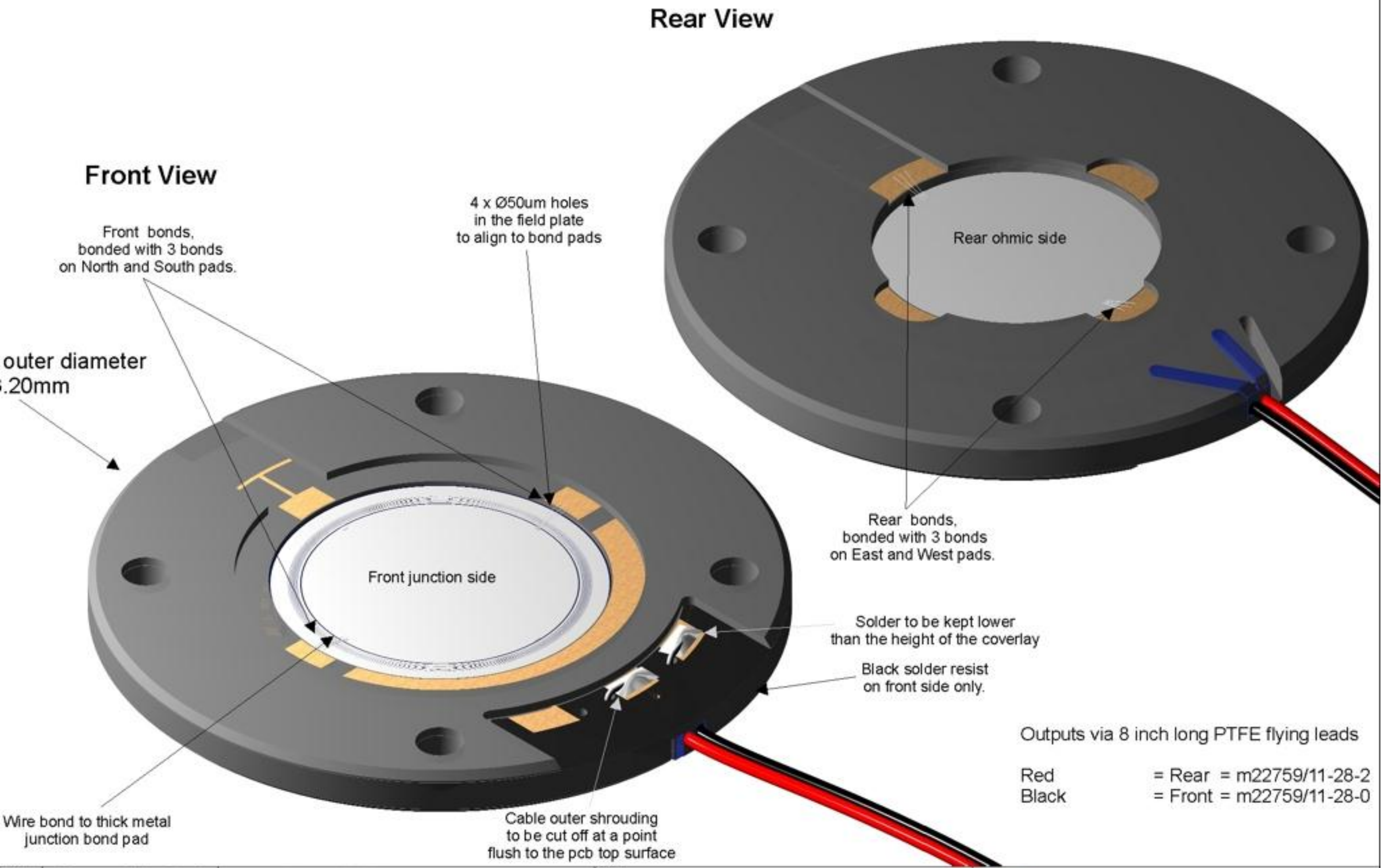
hecked	Date	Tolerances Unless Stated	Outputs Via: 300 mm long Co-axial cables	Title.
S.W	29/10/2009	Package O/D ± 0.1mm	Mating Connector: N/A	MSD032-1500 Co-axial Version PCB. A-3699 (Machined from A-3295) 3D Assembly. Front and Rear View.
		Package Hole ± 0.05mm	Potted Wire Bonds: No	
		Package Hole Pos'n ± 0.1mm	Substrate Number: A-3699	
		Detector O/D ± 20.0µm	Substrate Material: 3.6mm Thick black FR4 PCB Material	
		Total thickness tolerance ± 0.2mm	Connector Orientation: N/A	

MICRON SEMICONDUCTOR LIM

THIS DOCUMENT IS THE PROPERTY OF
MICRON SEMICONDUCTOR LTD AND IS
COMMERCIAL IN CONFIDENCE

graphics@micronsemiconductor.co.uk

Scale N/A	Dims In. mm	Drg No A-37



4 x Ø50um holes
in the field plate
to align to bond pads

Front bonds,
bonded with 3 bonds
on North and South pads.

outer diameter
.20mm

Rear bonds,
bonded with 3 bonds
on East and West pads.

Solder to be kept lower
than the height of the coverlay

Black solder resist
on front side only.

Outputs via 8 inch long PTFE flying leads

Red = Rear = m22759/11-28-2
Black = Front = m22759/11-28-0

Wire bond to thick metal
junction bond pad

Cable outer shrouding
to be cut off at a point
flush to the pcb top surface

Date	Tolerances Unless Stated	Outputs Via: 8 inch long PTFE flying leads.
26/10/200	Package O/D ± 0.1mm	Mating Connector: N/A
	Package Hole ± 0.05mm	Potted Wire Bonds: No
	Package Hole Pos'n ± 0.1mm	Substrate Number: A-3294
	Detector O/D ± 20.0µm	Substrate Material: 3.2mm Thick black FR4 PCB Material
		Connector Orientation: N/A

Title.

MSD017-1000.
3D Assembly With
White PTFE Cable Removed.
Front and Rear View.

MICRON SEMICONDUCTOR LIMITED

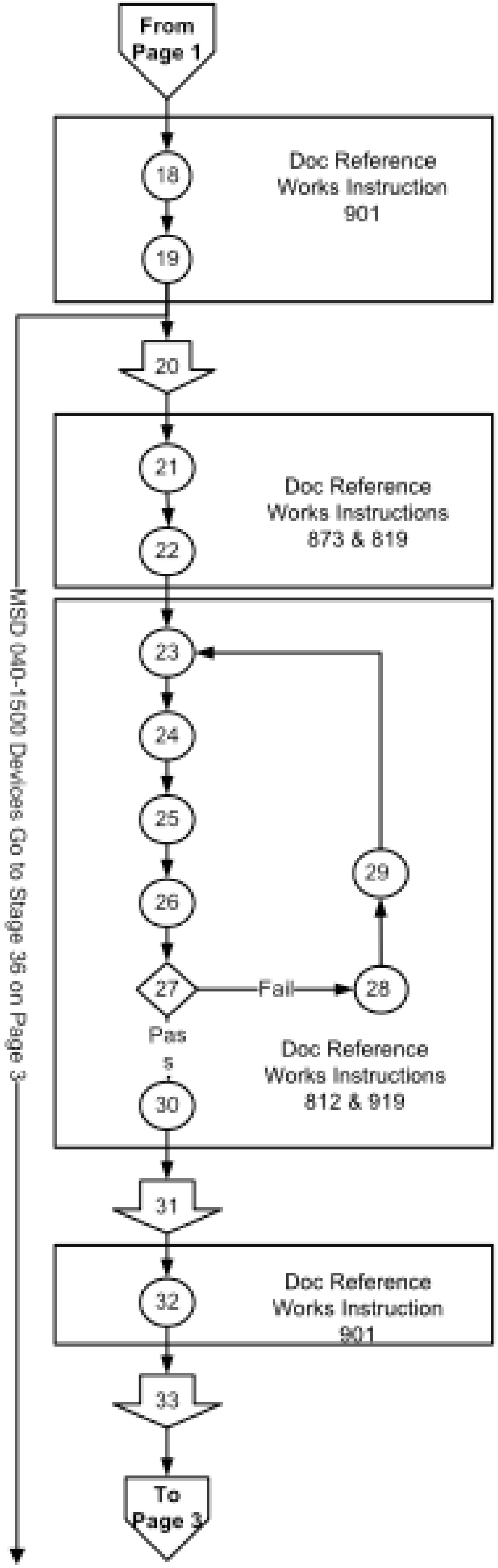
THIS DOCUMENT IS THE PROPERTY OF
MICRON SEMICONDUCTOR LTD AND IS
COMMERCIAL IN CONFIDENCE

graphics@micronsemiconductor.co.uk

Scale N/A	Dims In mm	Drg No A-3715

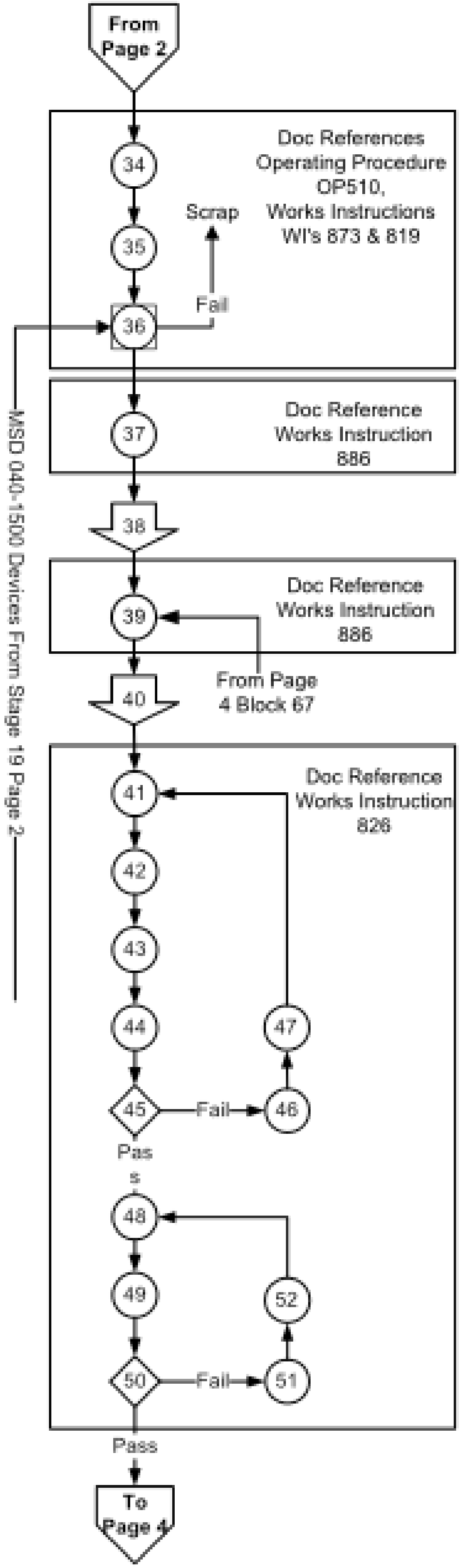
Operation Key

18. 1st Junction implant
19. Ohmic implant
20. Transport to Photo Lithographic facility
21. Clean wafers
22. High temp Anneal
23. Application of UV sensitive film
24. Soft bake of photo resist
25. 2nd stage lithographic imaging
26. Developing of photo resist
27. Visual Inspection of image
28. Strip photo resist
29. Clean wafers
30. Clean wafers
31. Transport to Metal Deposition facility
32. Stage 2 low energy junction implant
33. Transport to photo lithographic facility



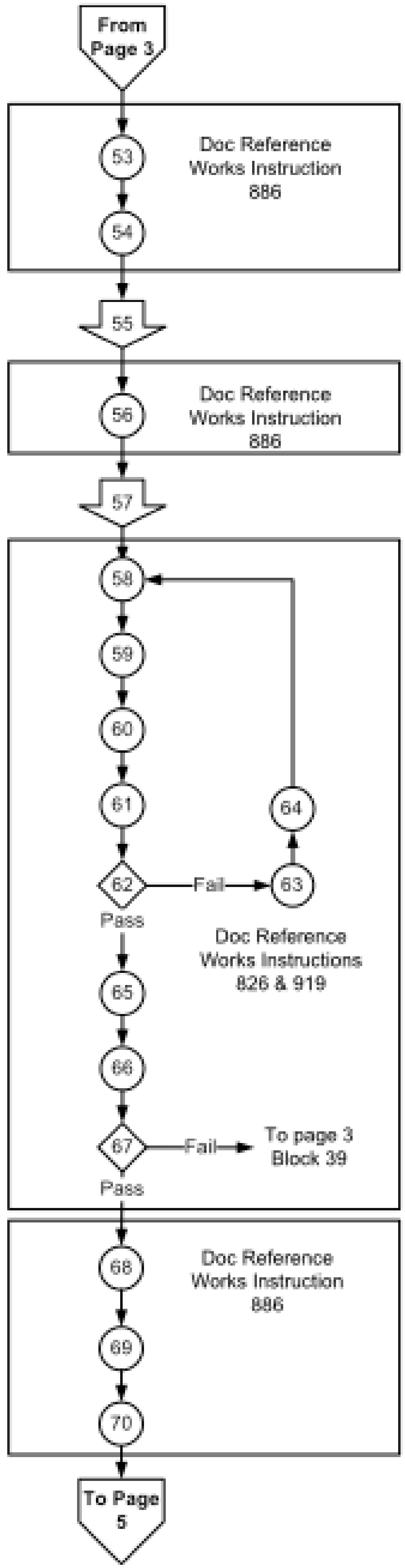
Operation Key

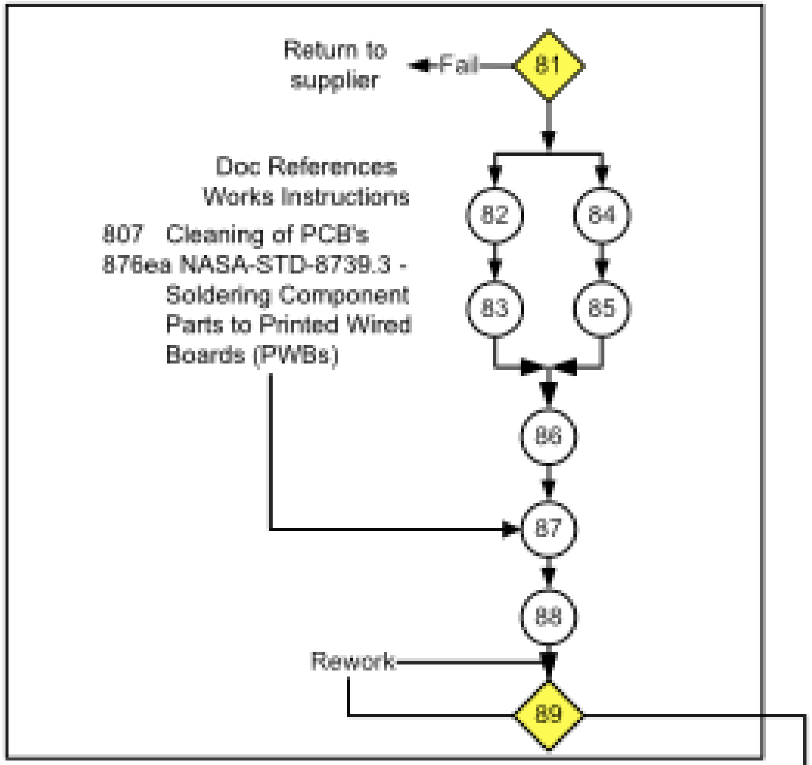
34. Clean wafers
35. 2nd Stage Anneal low temp.
36. 1st stage electrical test - Tested for IV characteristics
37. Clean wafers
38. Transport to Metal Deposition facility
39. 1st stage metal deposition to customer spec
40. Transport to Photo Lithographic Facility
41. Application of UV sensitive film
42. Soft bake of photo resist
43. 1st metal lithographic imaging
44. Developing of photo resist
45. Visual Inspection of image
46. Strip photo resist
47. Clean wafers
48. Hard bake
49. 1st Metal Etch
50. Visual Inspection of Image
51. Strip Image
52. Clean

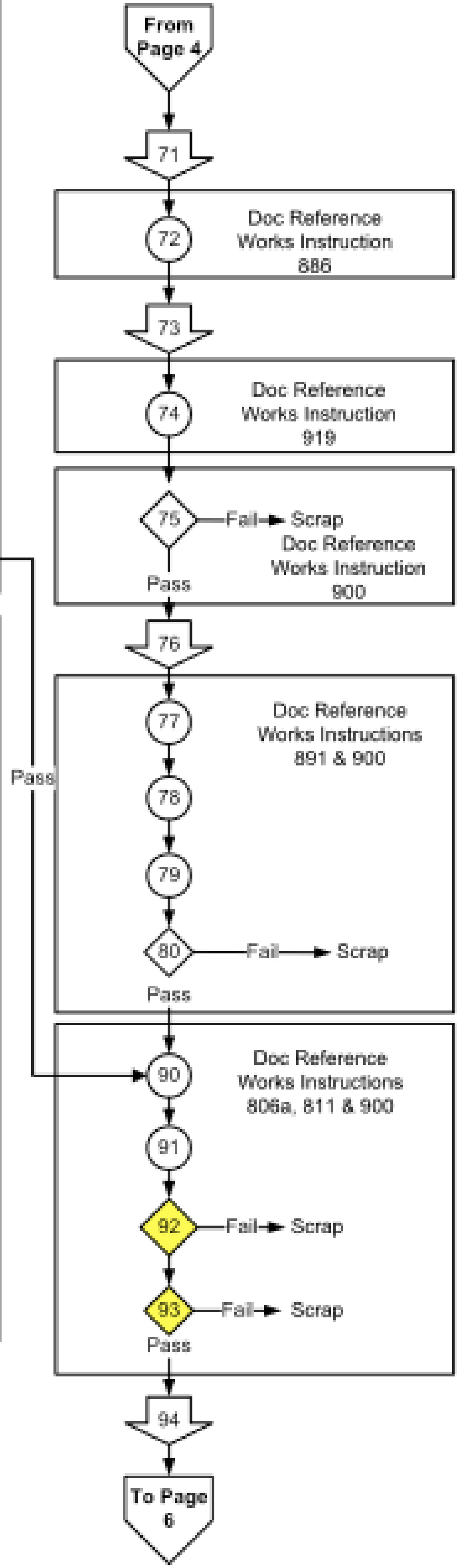


Operation Key

53. P-Etch wafers
54. Clean wafers
55. Transport to Metal Deposition Facility
56. 2nd front metallisation to customer spec
57. Transport to Photo Lithographic Facility
58. Application of UV sensitive film
59. Soft bake of photo resist
60. 2nd metal lithographic imaging
61. Developing of photo resist
62. Visual inspection of image
63. Strip photo resist
64. Clean wafers
65. Hard bake
66. 2nd metal etch
67. Visual inspection of image
68. Strip resist and Clean wafers
69. P Etch
70. Clean wafers





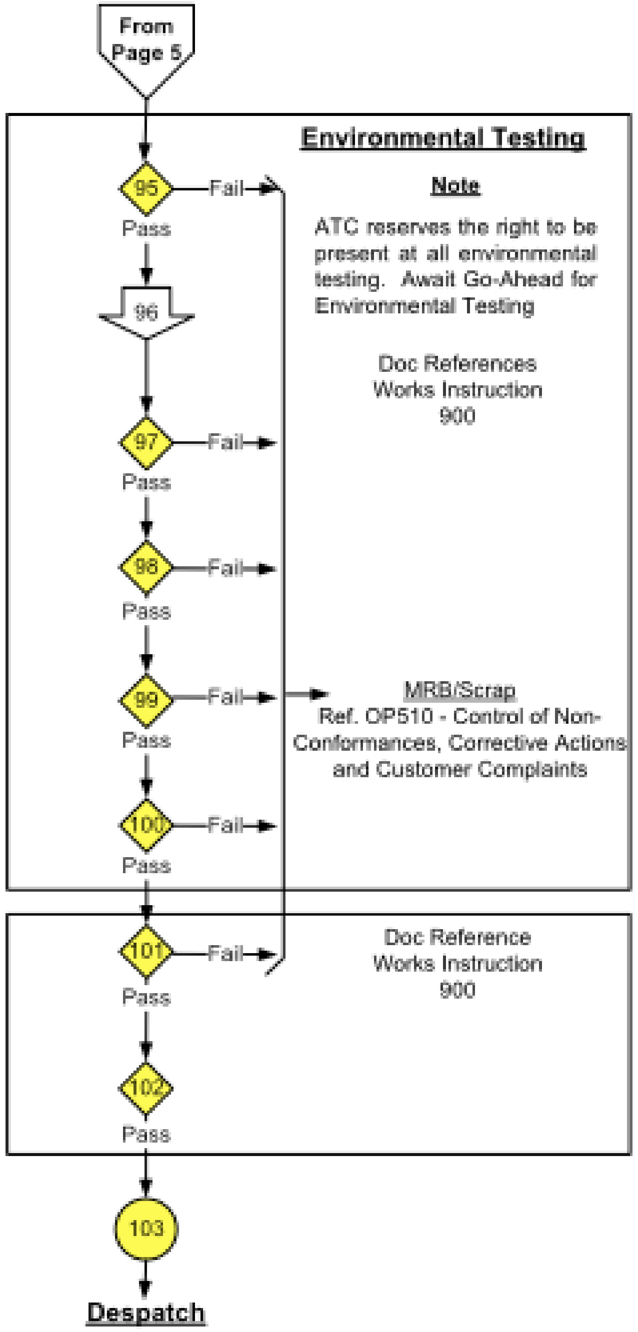


Operation Key

71. Transport to Metal Deposition Facility
72 Ohmic junction metalization to customer spec
73. Transport to Photo Lithographic Facility
74. 16 hr Hard bake
75. Junction leakage dark current test
76. Transport to Assembly Facility
77. Laser cut or diamond saw (Sawn greater than 500 Microns)
78. Chip debris cleaned
79. Hard bake for 16 hrs
80. Junction leakage dark current test
81. Goods inwards inspection (3 coupon samples of PCB to be sent to ATC for approval).
82. Strip and cut wires to length
83. Tin Leads
84. Clean and bake PCB's
85. Remove gold from solder pads
86. Solder wires to PCB.
87. Clean and bake PCB assemblies
88. Leads potted with able stick for strain relief
89. Inspect soldering and epoxy
90. Assemble wafer into PCB assembly with Shin-etsu resin
91. Wire bond wafer to PCB assembly
92. NDT 1 wire bond test
93. Junction leakage dark current test
94. Transport to Off Site Environmental Test Facility

Operation Key

95. Random Vibration Tests (Customer specification)
96. Transport to Micron Test Facility
97. Unbiased Temperature Cycle
98. Biased Temperature Cycle
99. Reliability Burn In (Customer specification)
100. Transport to Final QA inspection and Test
101. Final QA and Test
102. Pack & Ship
103. ATC Pre-Ship Review



Environmental Testing

Note

ATC reserves the right to be present at all environmental testing. Await Go-Ahead for Environmental Testing

Doc References
Works Instruction
900

MRB/Scrap
Ref. OP510 - Control of Non-Conformances, Corrective Actions and Customer Complaints

Doc Reference
Works Instruction
900

Green Text – Document & Process Reviewed

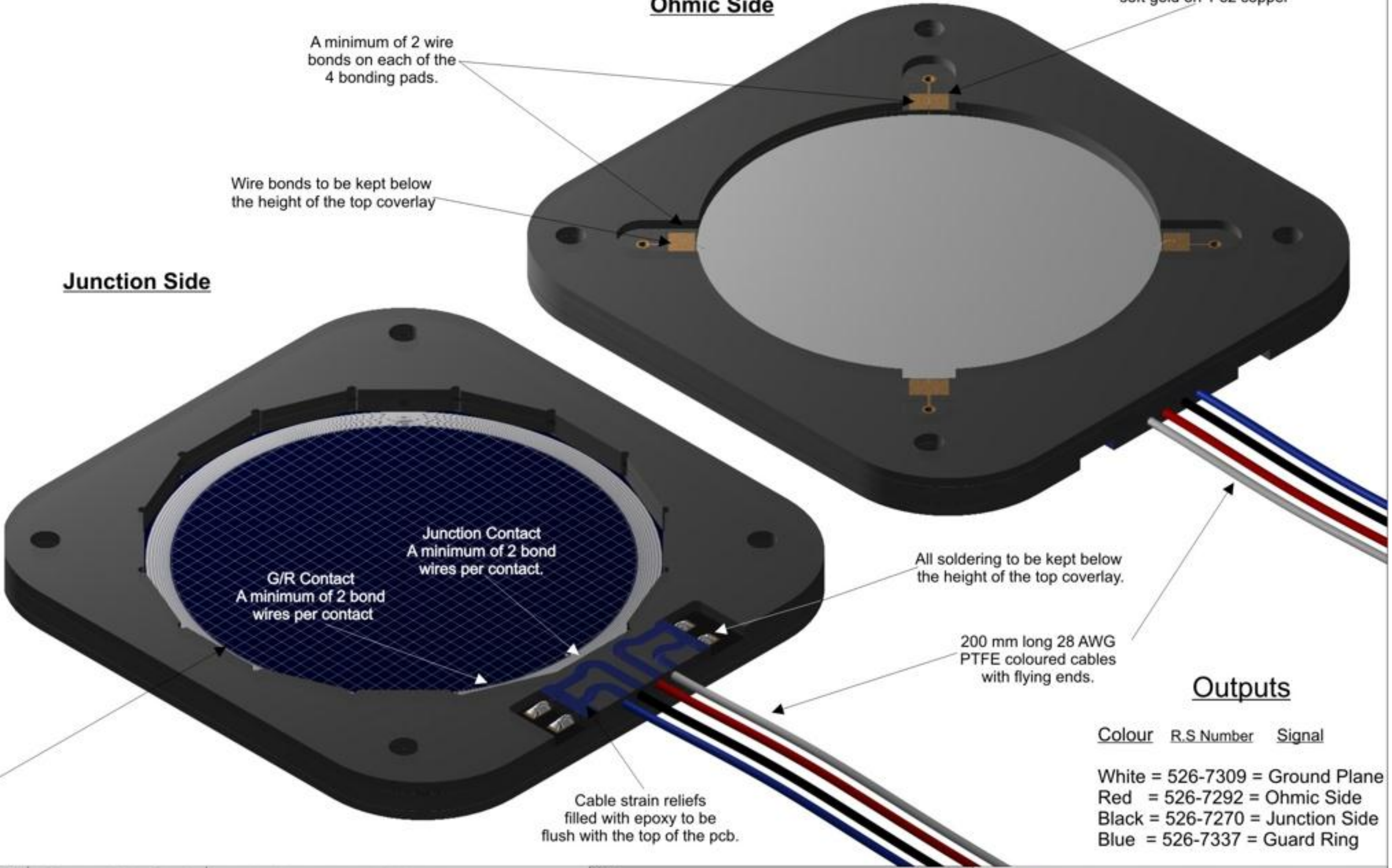
Red Text – Document & Process not completed

Black Text – Document & Process not reviewed

Issue C
29th April 2009

CRaTER

- Lunar Reconnaissance Orbiter (LRO) & the Vision for Space Exploration
- The CRaTER project
- LRO mission status
- CRaTER results
- Summary



Plating to be soft gold on 1 oz copper

A minimum of 2 wire bonds on each of the 4 bonding pads.

Wire bonds to be kept below the height of the top coverlay

Junction Contact
A minimum of 2 bond wires per contact.

G/R Contact
A minimum of 2 bond wires per contact

All soldering to be kept below the height of the top coverlay.

200 mm long 28 AWG PTFE coloured cables with flying ends.

Cable strain reliefs filled with epoxy to be flush with the top of the pcb.

Outputs

Colour R.S Number Signal

White = 526-7309 = Ground Plane
Red = 526-7292 = Ohmic Side
Black = 526-7270 = Junction Side
Blue = 526-7337 = Guard Ring

ate
11/05/2007

Tolerances Unless Stated	Outputs Via: 200mm long coloured PTFE cables
Package O/D ± 0.1mm	Mating connector: N/A
Package Hole ± 0.05mm	Potted Wire Bonds: No
Package Hole Pos'n ± 0.1mm	Substrate Number: A-3228, and A-3229
Detector O/D ± 20.0μm	Substrate Material: Black FR4 PCB Material approx 3.5mm total thickness
	Connector Orientation: N/A

Title.

Crater Flight .
3D Assembly.
Front and Rear View.

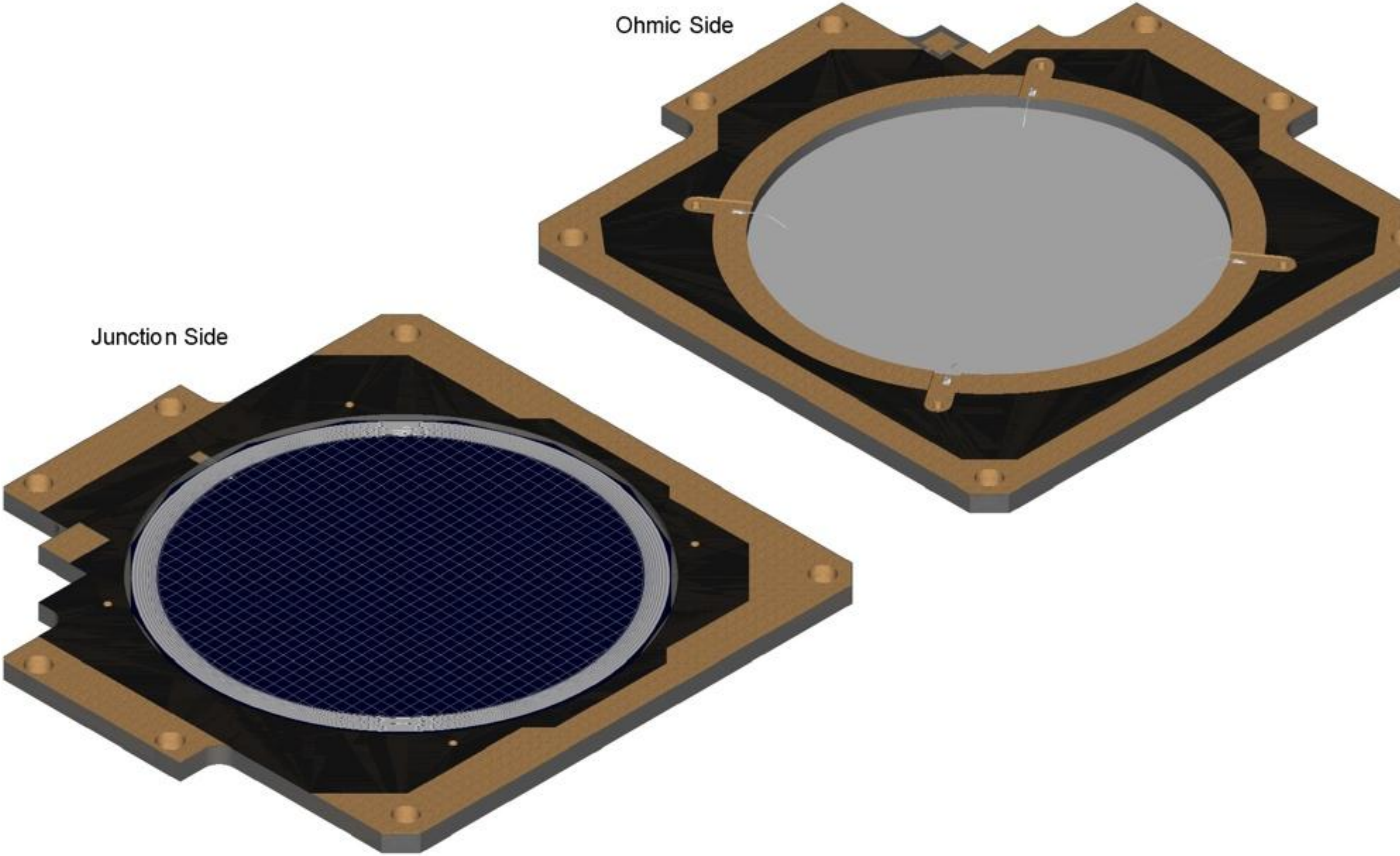
MICRON SEMICONDUCTOR LIMITED

THIS DOCUMENT IS THE PROPERTY OF
MICRON SEMICONDUCTOR LTD AND IS
COMMERCIAL IN CONFIDENCE

graphics@micronsemiconductor.co.uk

Scale N/A	Dims In. mm	Drg No A-3285

rg.
o A-2768



ssue	Date	Tolerances Unless Stated
1	16/04/04	PCB O/D ± 0.1mm
		PCB Hole Dia ± 0.05mm
		PCB Hole Pos'n ± 0.1mm
		Detector O/D ± 20.0µm

Details.
To be made from 1.6mm thick FR4 Material after plating.
Plating to be soft Gold on 1oz Copper.
Black Solder resist on front and rear.

Title. Compass PCB 3D Assembly.

Cust Po Number
Job Number 031118

MICRON SEMICONDUCTOR LIMITED
1 R[illegible] Buildings, Marlborough Rd,
Sussex, BN15 8UN, UK.
E-Mail microngraphics@btconnect.com

Scale N/A
Dims In. mm
Drg No A-27

Closeup of detector position

- 146um COMPASS detector
- Laser spot focused near edge

- Stage moves x and y, we moved mostly in x (from edge toward center)

- Laser spot in picture is at our coordinate origin

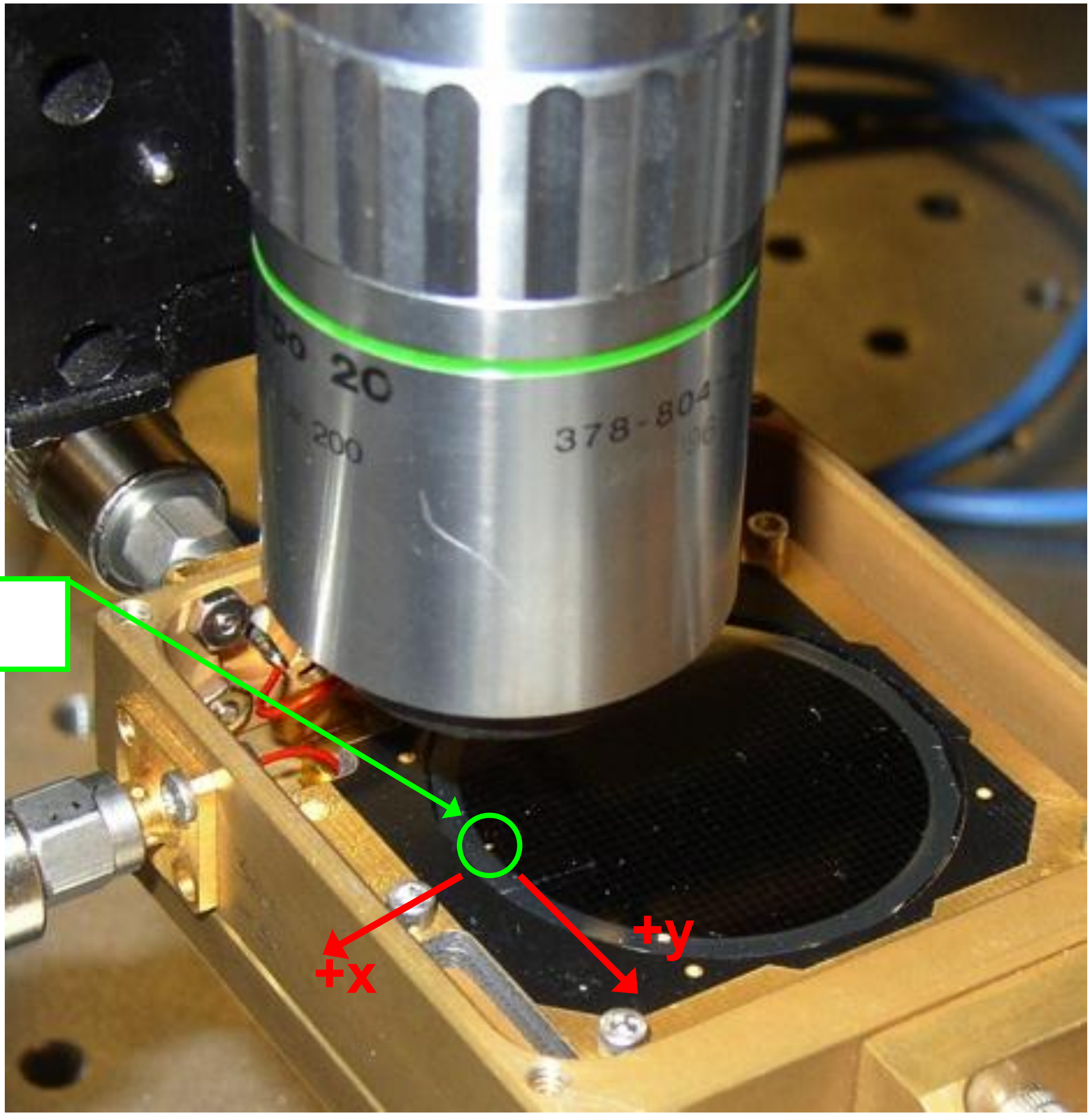
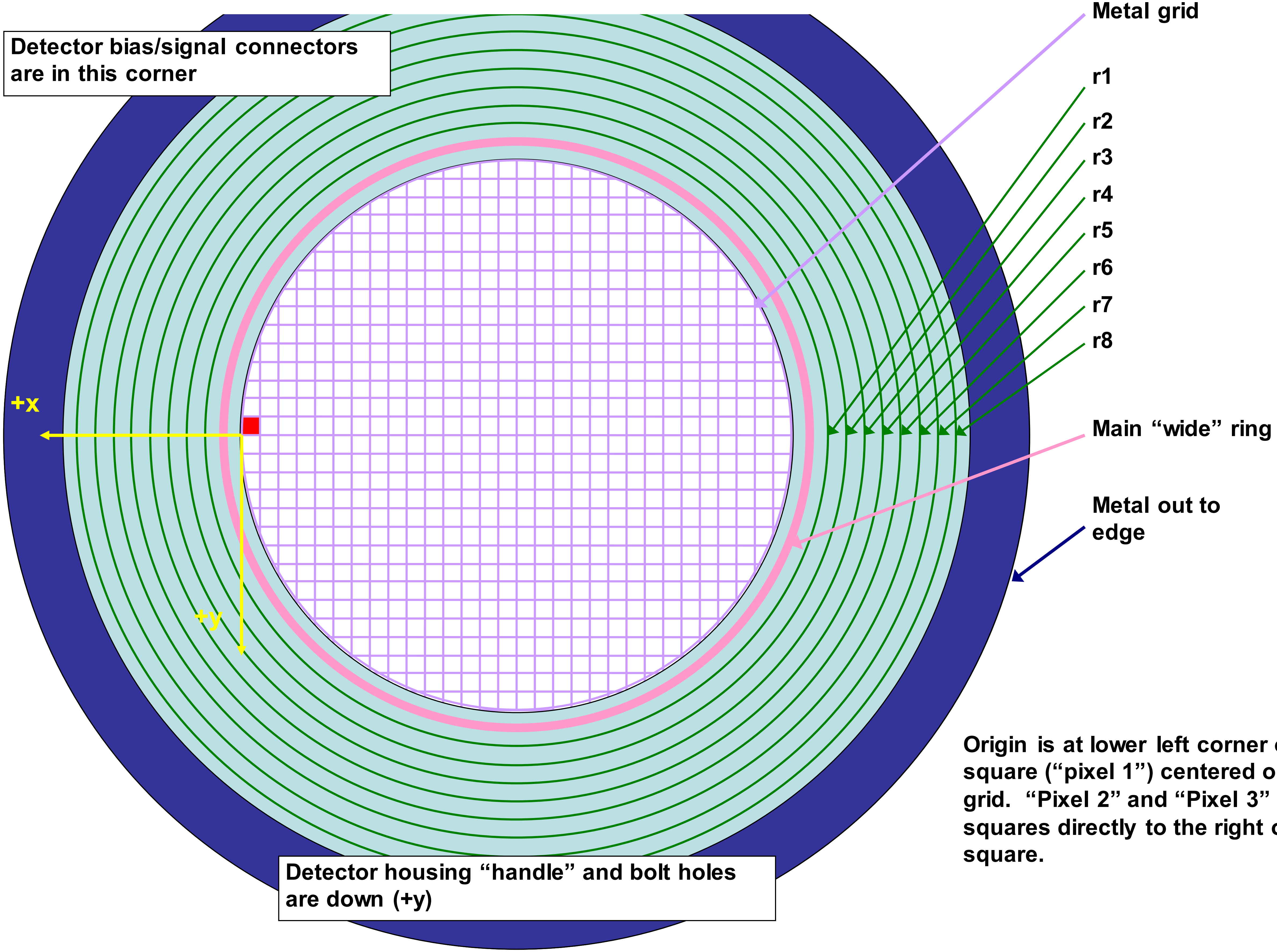

Laser Spot Location

Diagram of Detector Coordinates

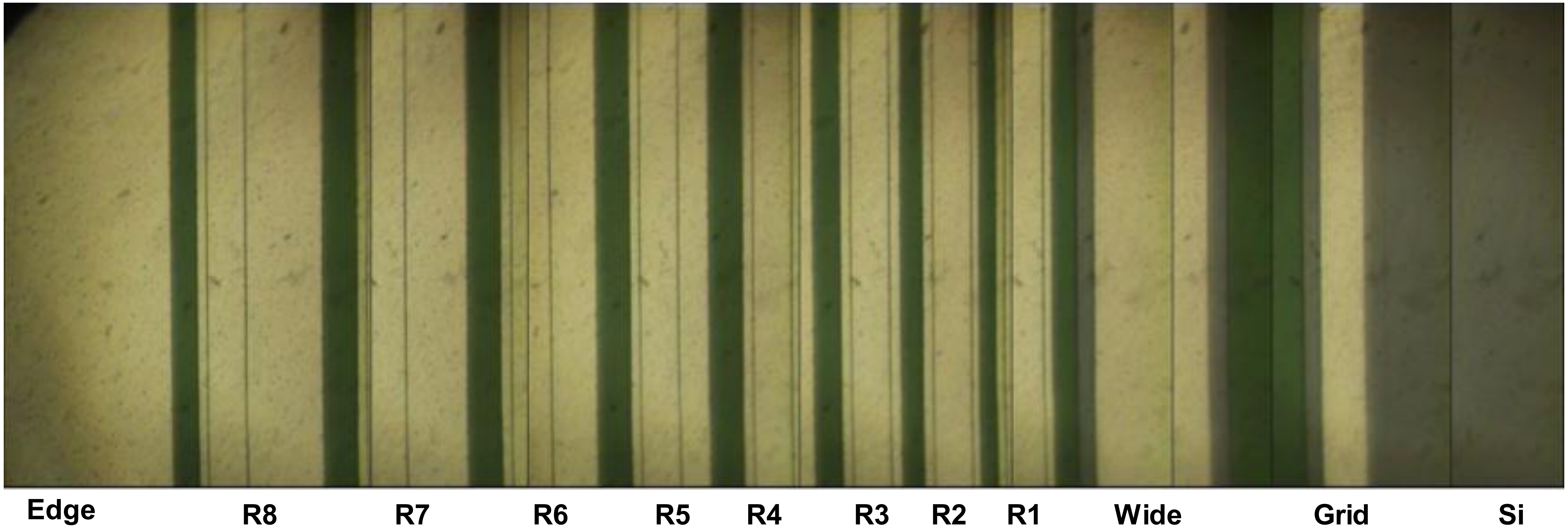


Detector bias/signal connectors are in this corner

Detector housing "handle" and bolt holes are down (+y)

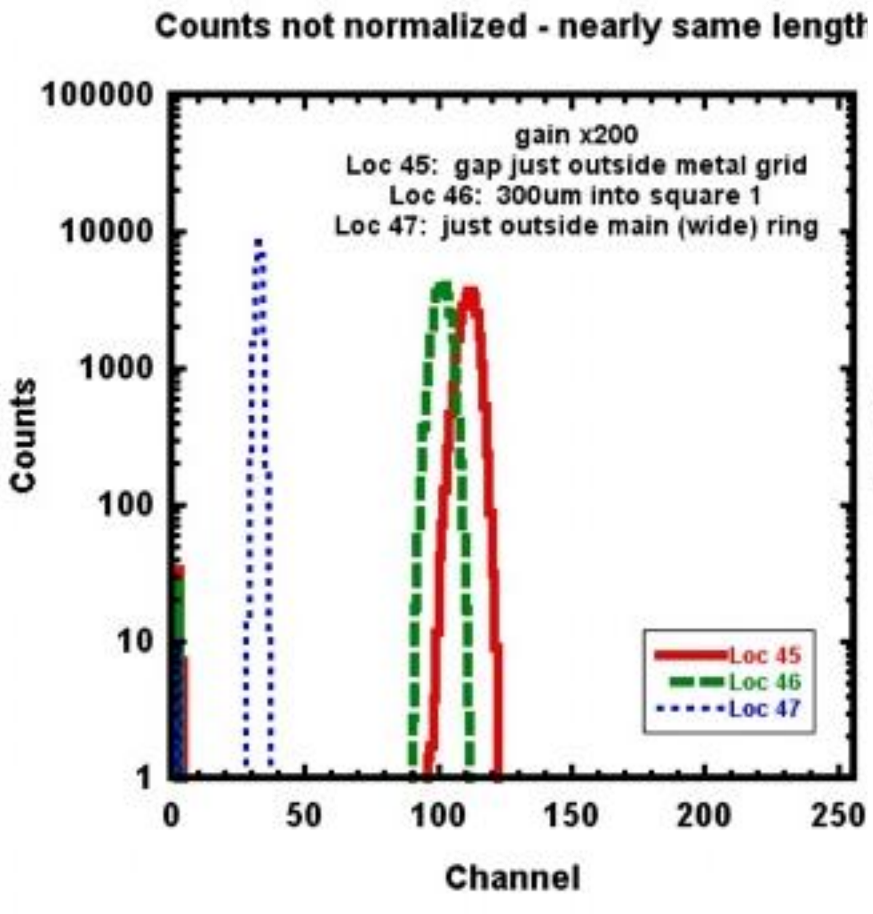
Origin is at lower left corner of red square ("pixel 1") centered on the metal grid. "Pixel 2" and "Pixel 3" are the next squares directly to the right of the red square.

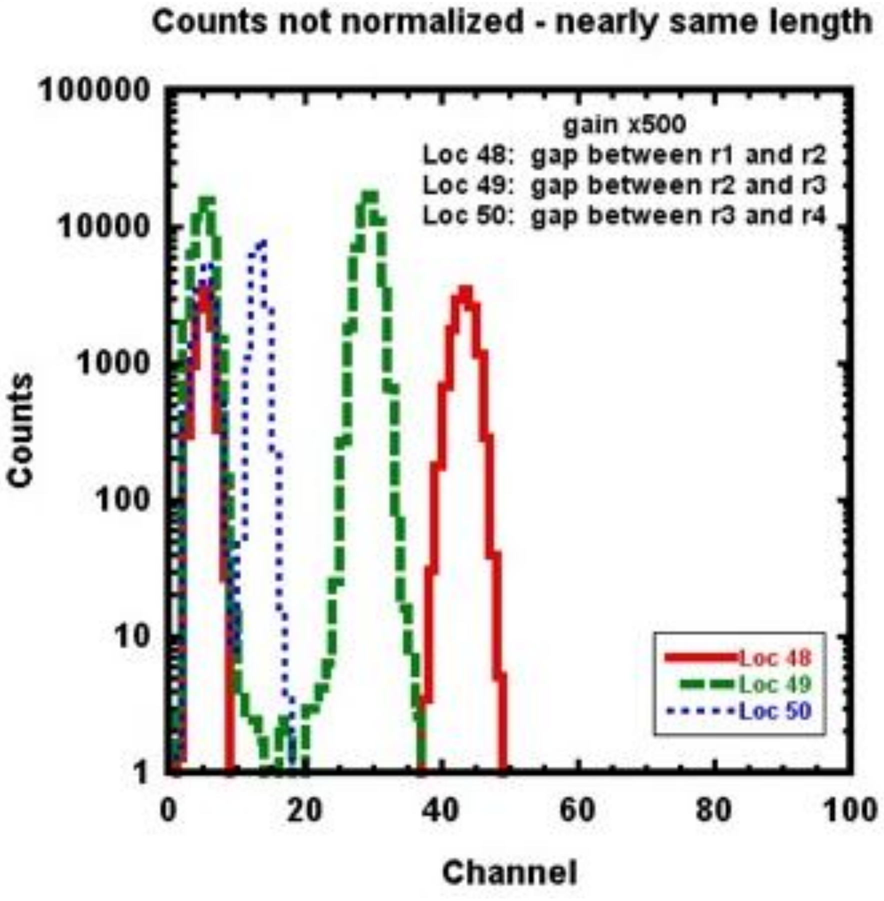
Composite View of Guard Structure

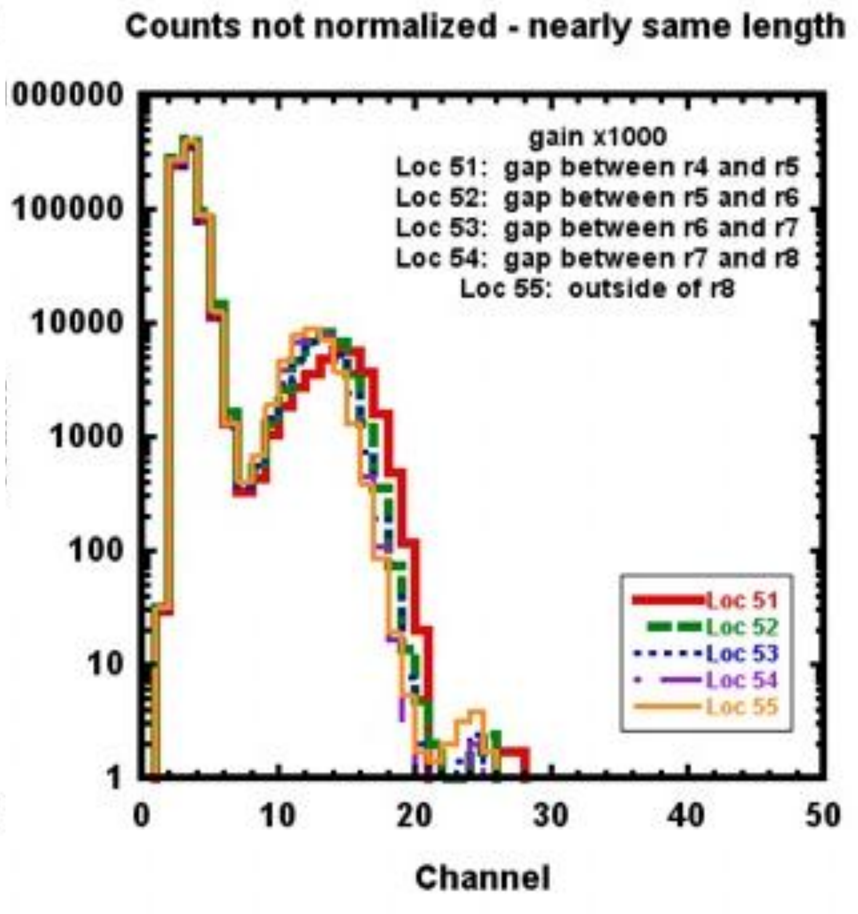


- Composite of many saved camera images
  - –Most rings have 2 vertical lines, others are artifacts of composition
- Grey area to right is active silicon area
- Yellow metal at left extends to edge of detector

Detector Signals

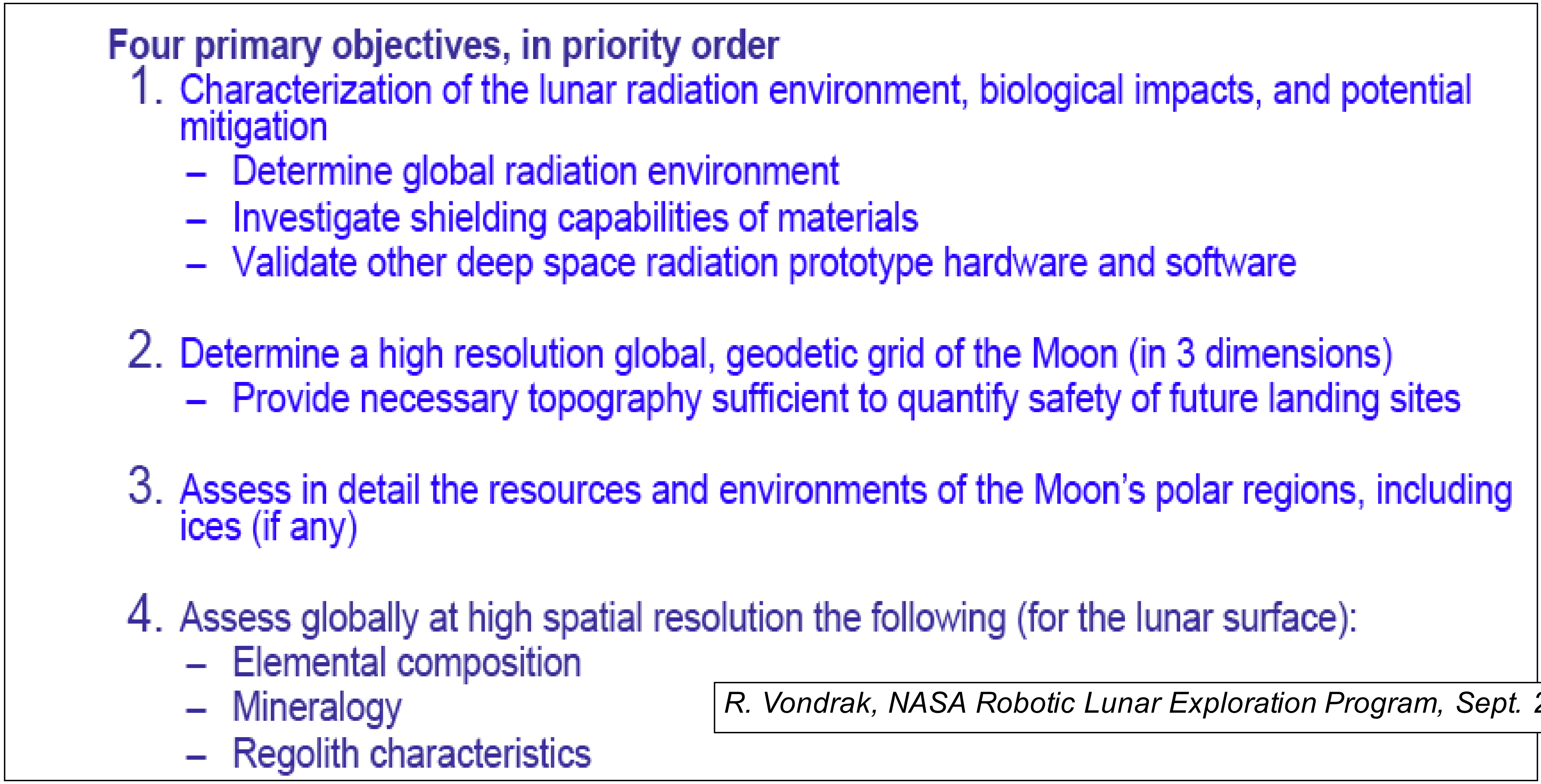






- As we move out from edge of grid the pulse height dropped steadily
- Exception: The spot just outside grid gave higher pulse than well into the square (“pixel

Lunar Reconnaissance Orbiter Objectives



Four primary objectives, in priority order

1. Characterization of the lunar radiation environment, biological impacts, and potential mitigation
   - Determine global radiation environment
   - Investigate shielding capabilities of materials
   - Validate other deep space radiation prototype hardware and software

2. Determine a high resolution global, geodetic grid of the Moon (in 3 dimensions)
   - Provide necessary topography sufficient to quantify safety of future landing sites

3. Assess in detail the resources and environments of the Moon's polar regions, including ices (if any)

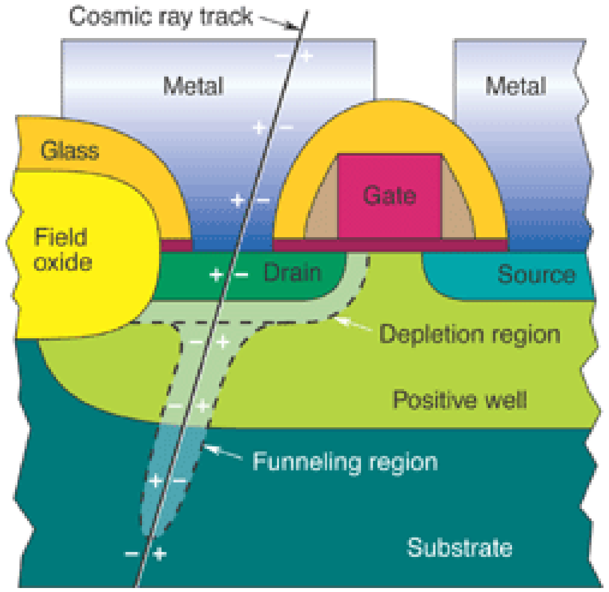
4. Assess globally at high spatial resolution the following (for the lunar surface):
   - Elemental composition
   - Mineralogy
   - Regolith characteristics

R. Vondrak, NASA Robotic Lunar Exploration Program, Sept. 2004

Wide-ranging Interest in the Effects of Ionizing Radiation

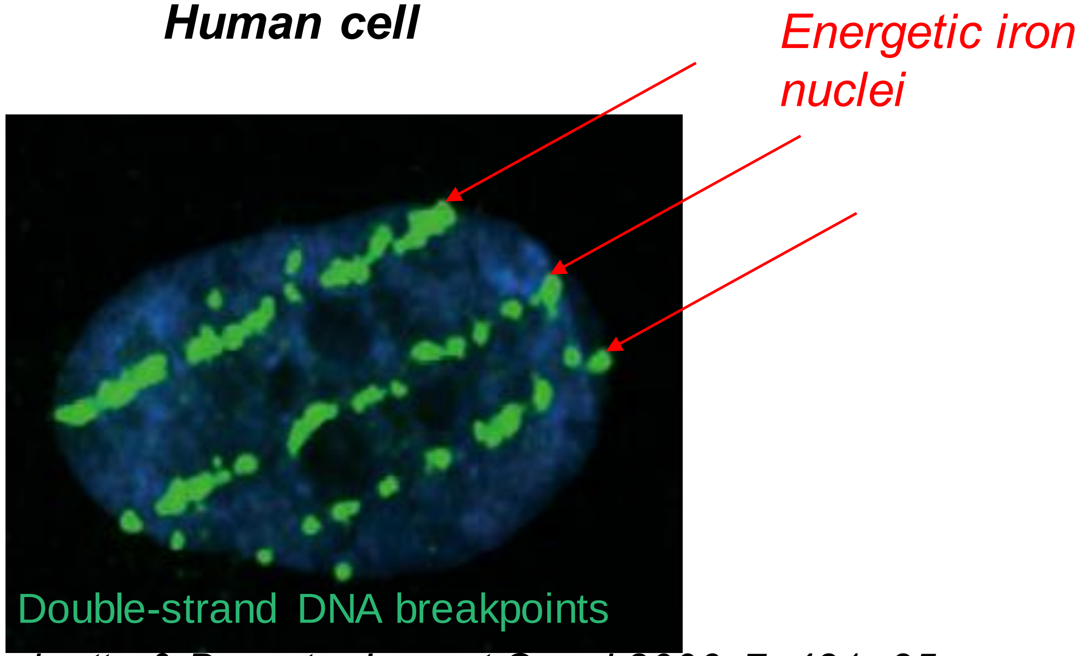
- The CRaTER investigation includes an instrument with its measurement requirements and a plan to use the data to augment existing models of how highly-ionizing ions propagate through matter
- These sophisticated propagation codes are important for predicting effects of highly-ionizing particles but they have **not** been verified with on-orbit data
- The same effects of interest to human spaceflight (total radiation dose & effects of highly-ionizing particles) are relevant to electronics used for space missions

NMOS transistor



Scarpulla & Yarbrough, Crosslink, 2003

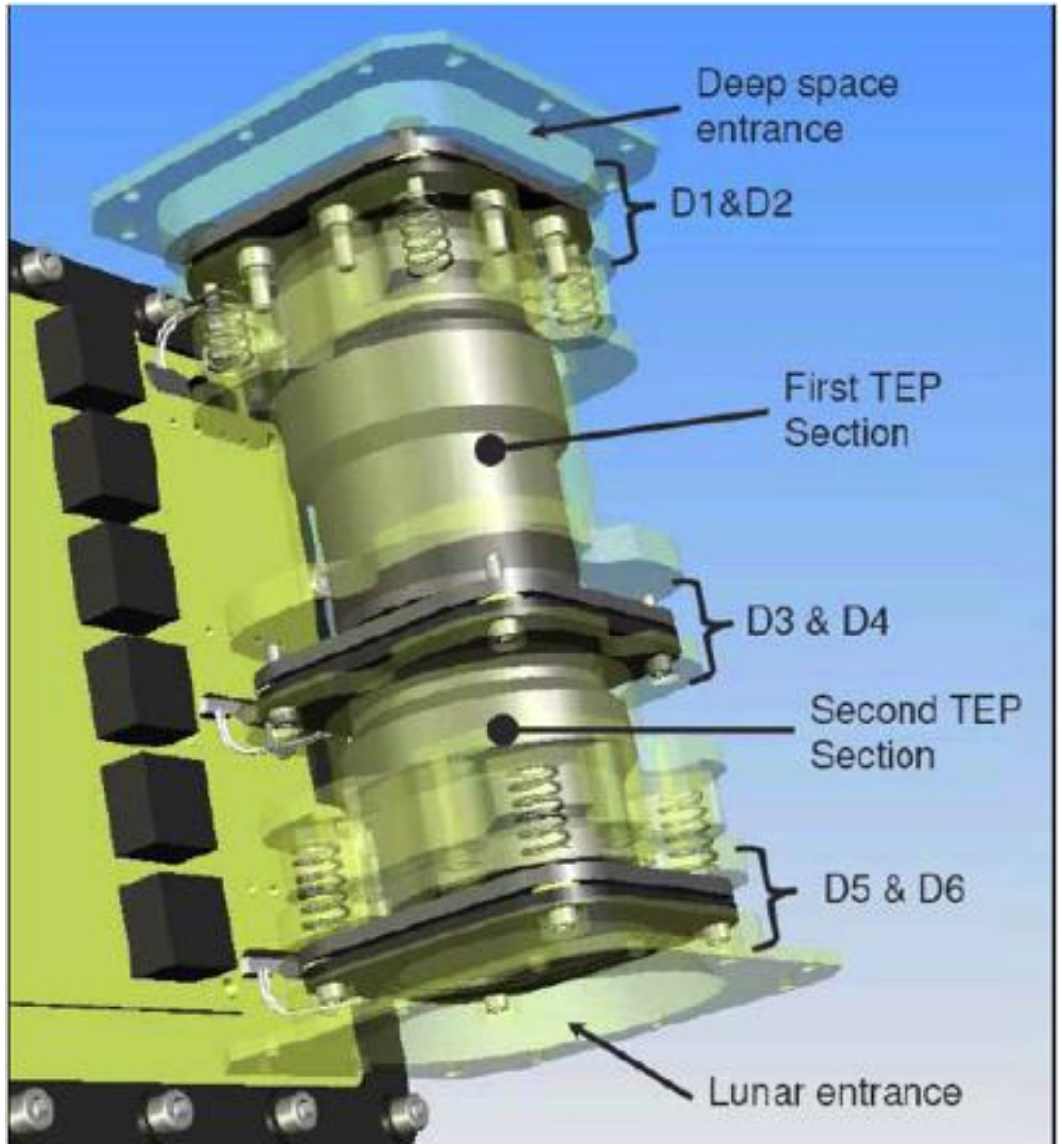
Human cell

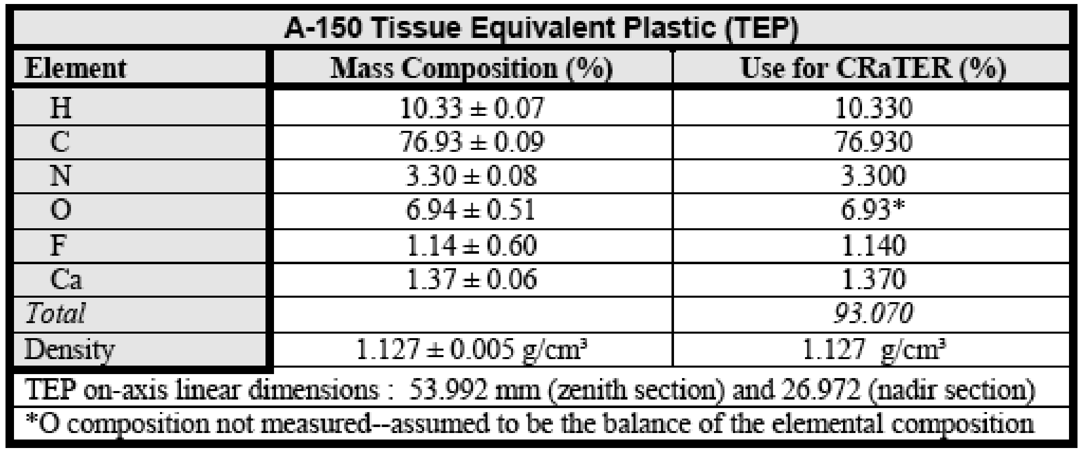


Cucinotta & Durante, Lancet Oncol 2006; 7: 431–35

The CRaTER Concept

- Two-way telescope responds to primary cosmic rays coming from zenith and from secondary cosmic rays coming from nadir produced by spallation off of the lunar surface
- The biological assessment of radiation requires the linear energy transfer (LET) spectra behind tissue-equivalent material, augmented with incident cosmic ray energy spectrum (obtained from other on-orbit science missions including ACE)
- Two pieces of tissue-equivalent plastic (TEP) are sandwiched between three sets of paired thick/thin detectors, optimized for low/high LET detection





A-150 Tissue Equivalent Plastic (TEP)

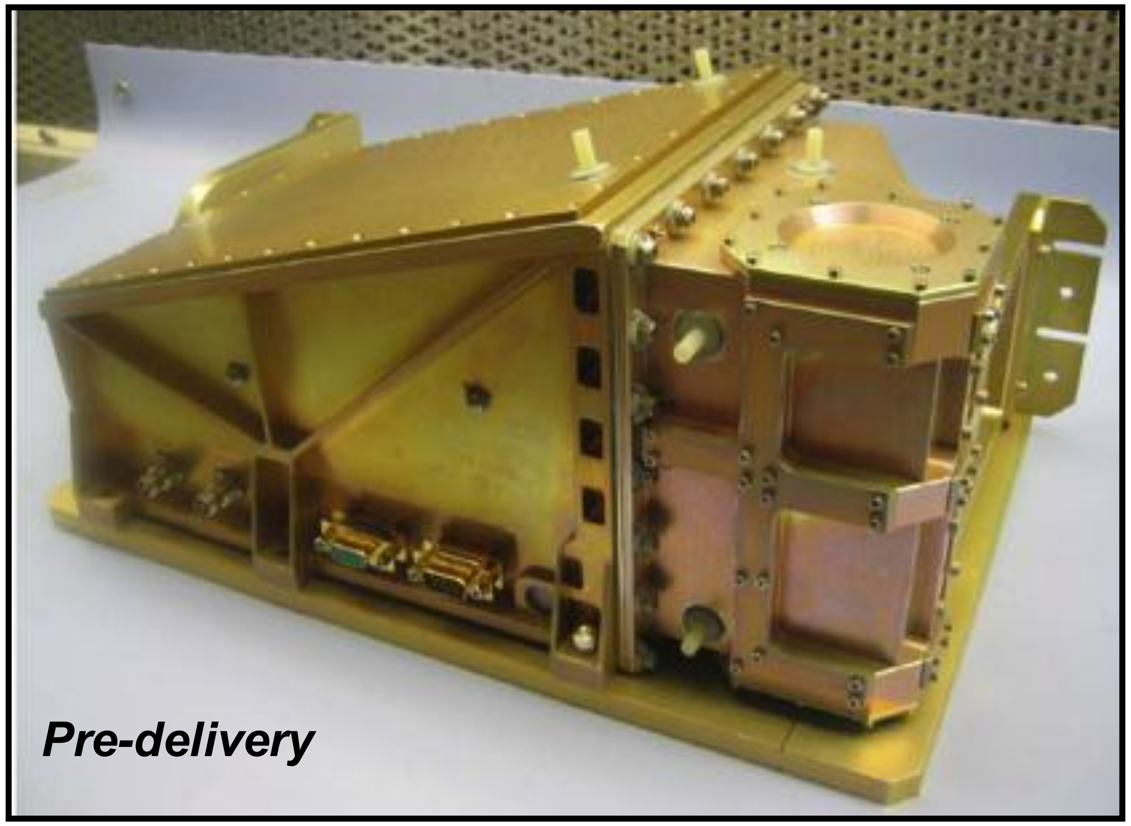
Element	Mass Composition (%)	Use for CRaTER (%)
H	10.33 ± 0.07	10.330
C	76.93 ± 0.09	76.930
N	3.30 ± 0.08	3.300
O	6.94 ± 0.51	6.93*
F	1.14 ± 0.60	1.140
Ca	1.37 ± 0.06	1.370
Total		*93.070*
Density	1.127 ± 0.005 g/cm^3	1.127 g/cm^3
TEP on-axis linear dimensions : 53.992 mm (zenith section) and 26.972 (nadir section)		
*O composition not measured--assumed to be the balance of the elemental composition		

CRaTER Specifications

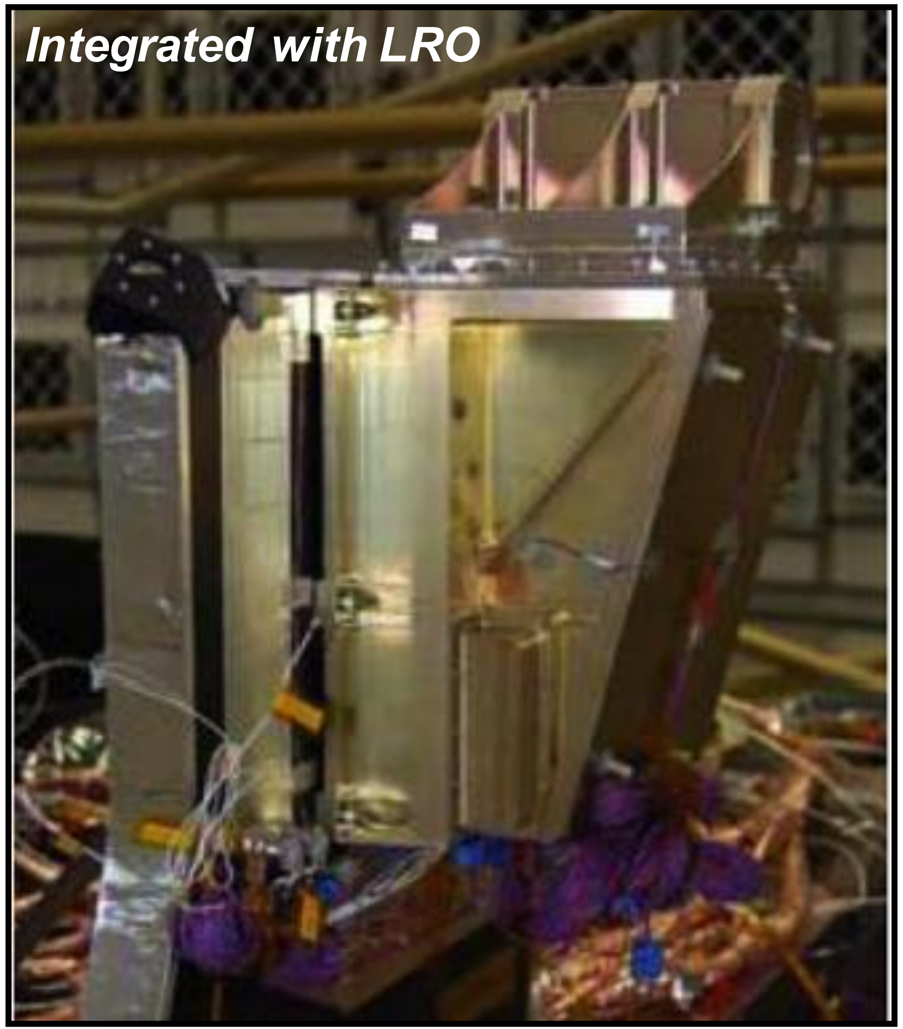
Property	Value	Comments
Mass	5.53 kg	6.36 kg allocation
Power	6.66 W	9.00 W allocation
Maximum Telemetry Rate	89.1 Kbps	Sized for largest historic solar proton event
Maximum Event Transmission Rate	1200 events/sec	Event defined as pulse height analysis on all 6 detectors for any valid detection
Minimum Determinable LET	0.09 keV /µm	Determined with thick detectors (D2, D4, D6)
Maximum Determinable LET	2.2 MeV /µm	Determined with thin detector (D1, D3, D5)
Energy Deposition Resolution	<0.3% of maximum energy	Net RSS value including detector and electronics noise, and gain uncertainty
Minimum Geometric Factor	0.57 $cm^2 sr$	Defined by D1-D6 geometry
Zenith Field of View	33°	Defined by D2-D5 geometry
Nadir Field of View	69°	Defined by D4-D5 geometry

Representative Coincidences	Field of view (full angle)	Geometric factor (cm^2-sr)	Proton threshold energy (MeV)
D1·D2	169.0	24.152	12.7 (z)
D1·D4	53.4	1.679	90.8 (z)
D1·D6	31.4	0.569	114.5 (z)
D6·D5	170.0	24.566	17.7 (n)
D6·D4	65.9	2.564	63.9 (n)

H. Spence et al. Space Sci. Rev., 2010



Pre-delivery



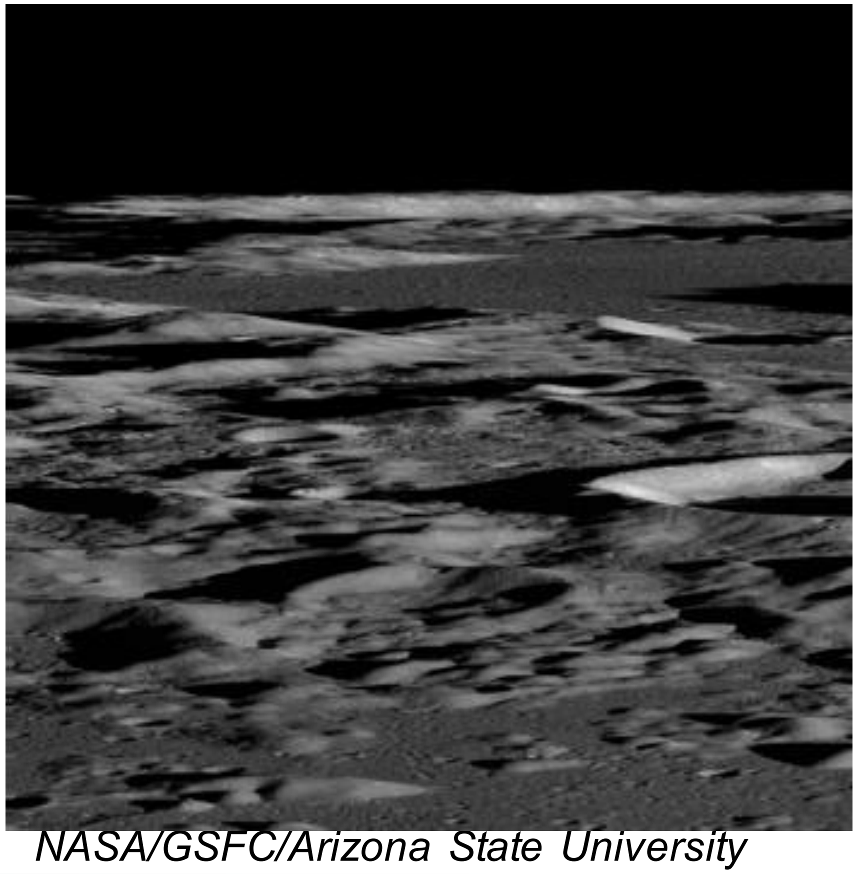
Integrated with LRO

CRaTER Mission Status

- Launch on 6/18/09
- Successful lunar orbit insertion on 6/22/09
- Commissioning Review completed 9/9/09
- Entered mission orbit (average 50km circular & polar) on 9/15/09

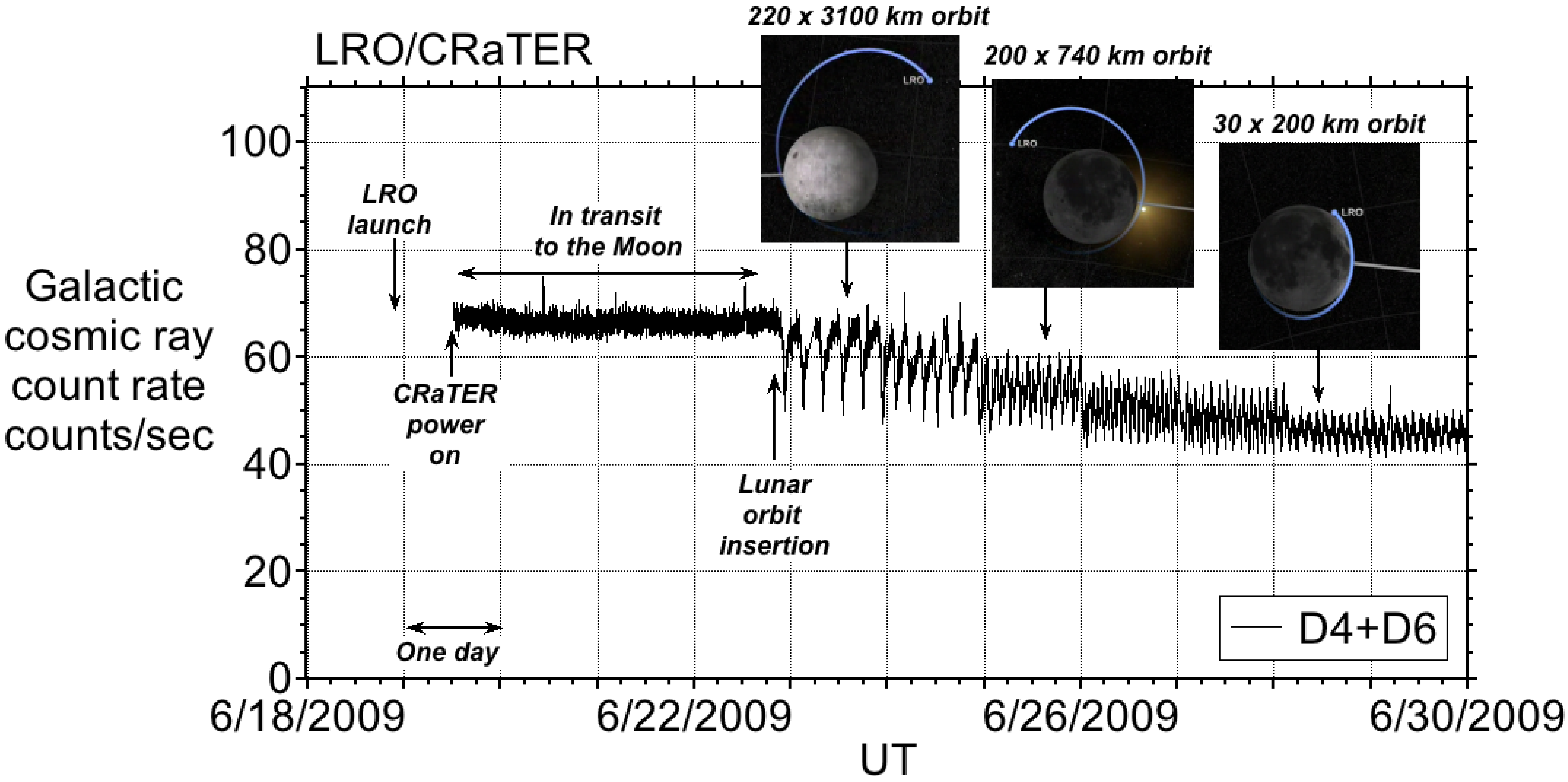
NASA LRO CCR Package , 9 Sept 09

- Operations ran for 1 year as an ESMD mission
- Transitioned on 9/16/10 into a 2 year SMD project
- 36% more fuel remaining than predicted (262 kg v 192 kg prior to mission orbit insertion)



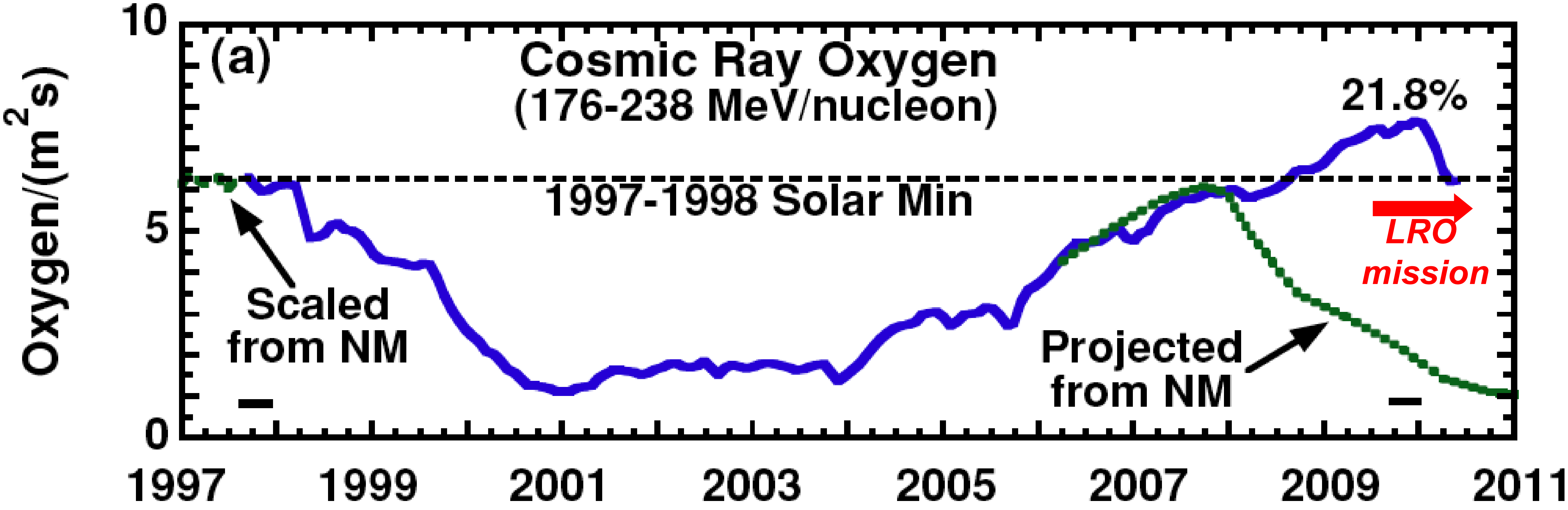
NASA/GSFC/Arizona State University

Cruise and Early Orbit as Seen With CRaTER



- Altitude-dependent GCR rate due to the presence of a massive body without its own trapped radiation (*e.g. Lin, JGR 73, 1968*)
- Approximately 3 days of cruise data as a reference for unobstructed GCR

Solar Cycle Context of CRaTER Mission

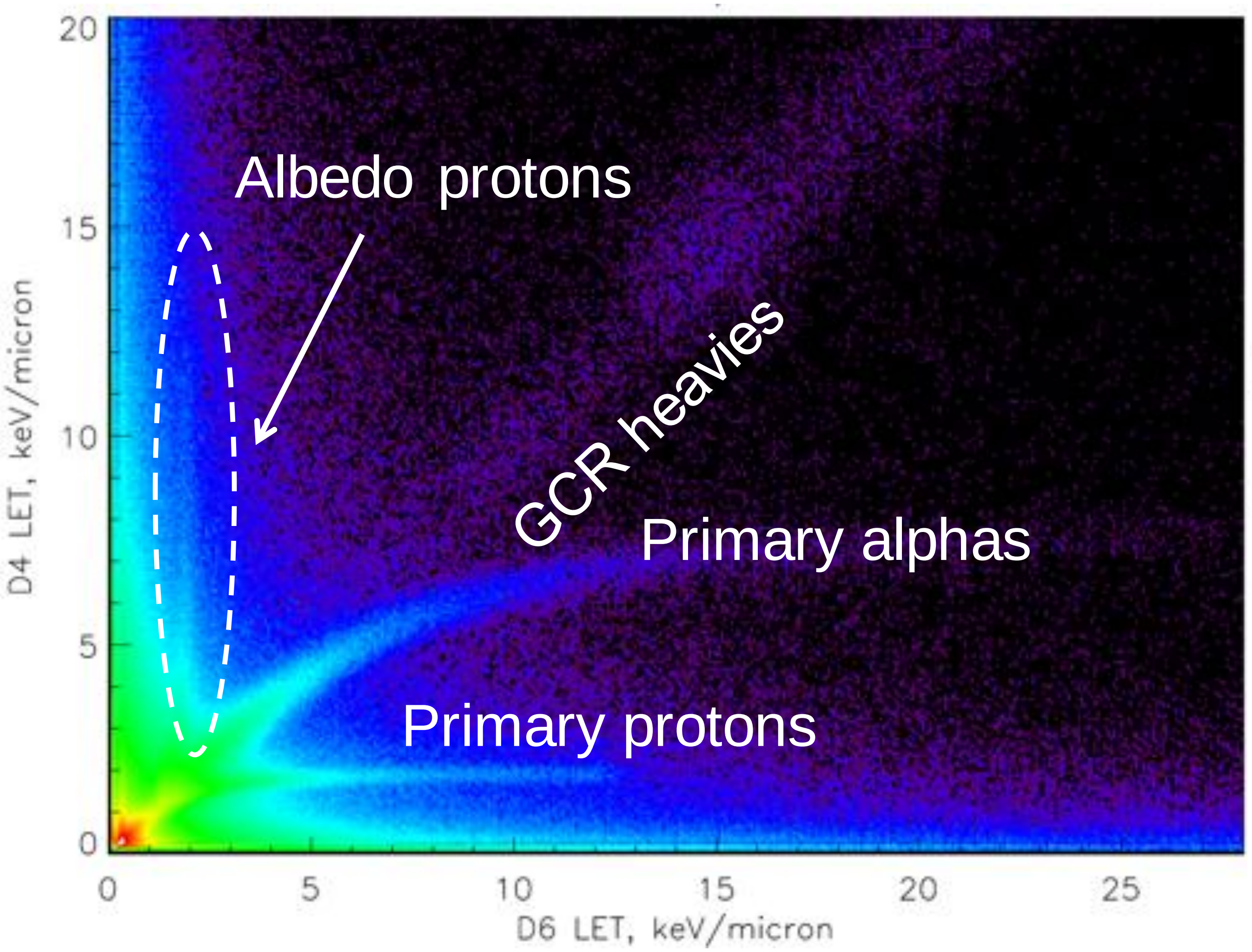


After R. A. Mewaldt et al. ApJ. Lett. 723, 2010

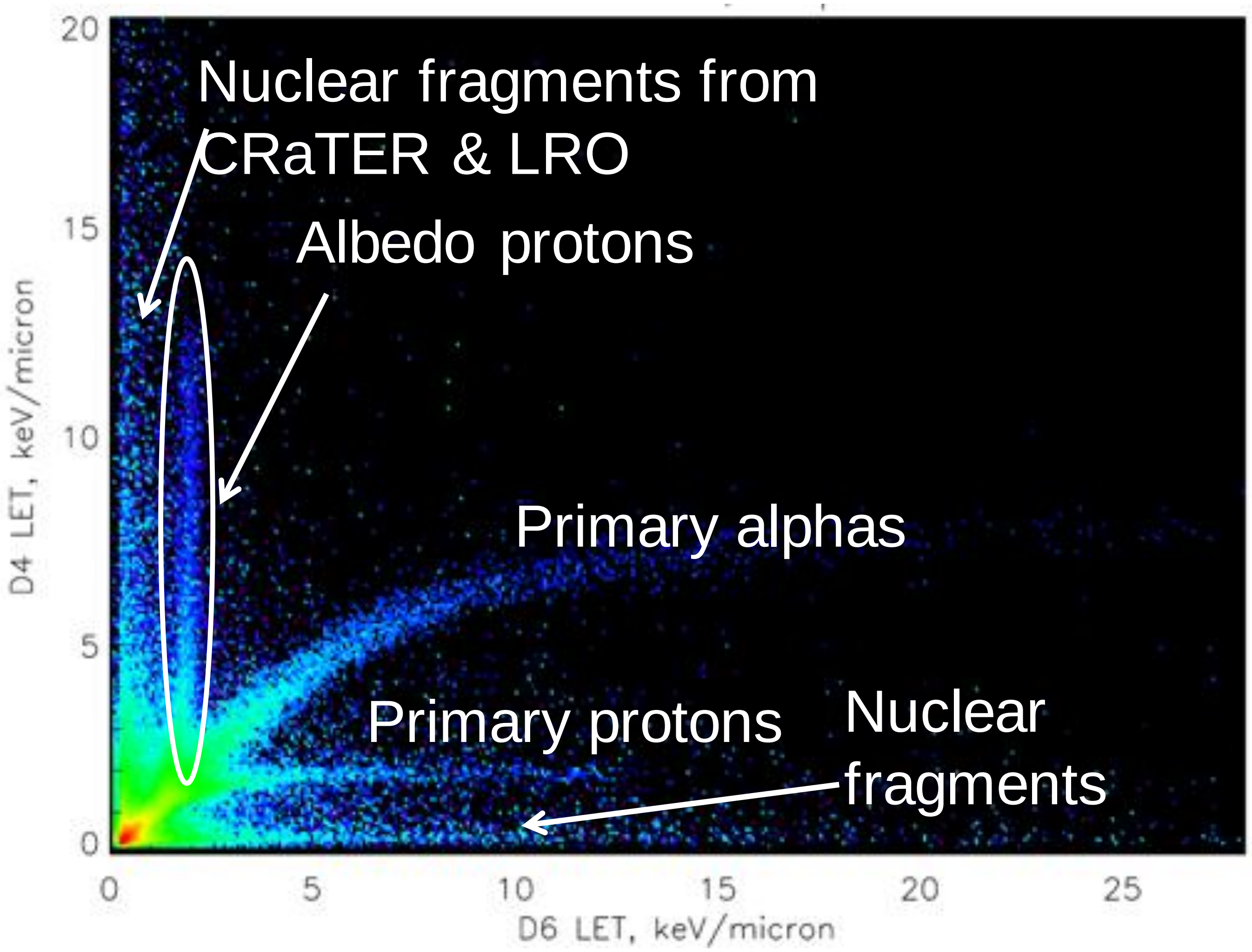
- The CRaTER mission fortuitously captured the recent GCR maximum intensity
- As a consequence of the prolonged solar minimum, we have been able to collect decent statistics of the LET spectrum from GCR as well as their secondaries

Example of CRaTER Level-1 Data

Observations ($\overline{\text{D2}}$D4D6 Jun-Nov 2009)

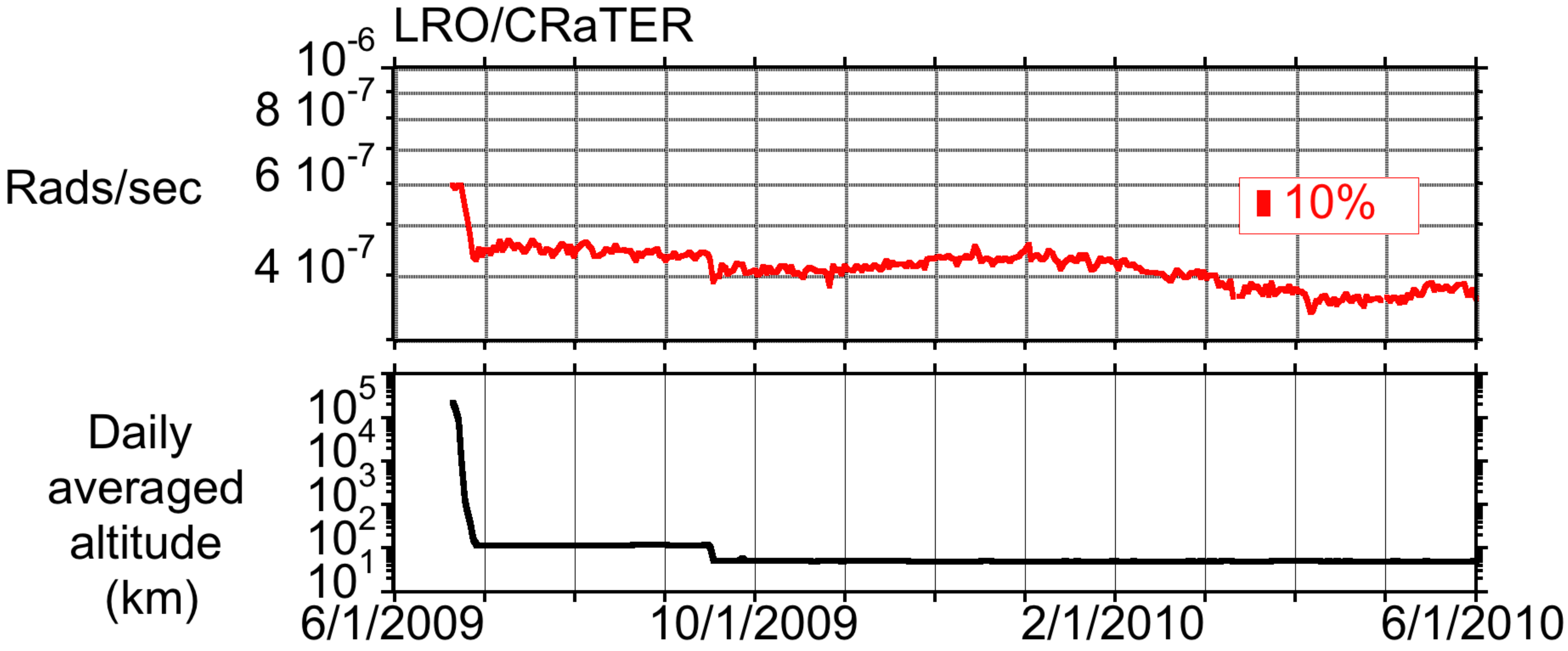


Modeled Response to GCR H & He



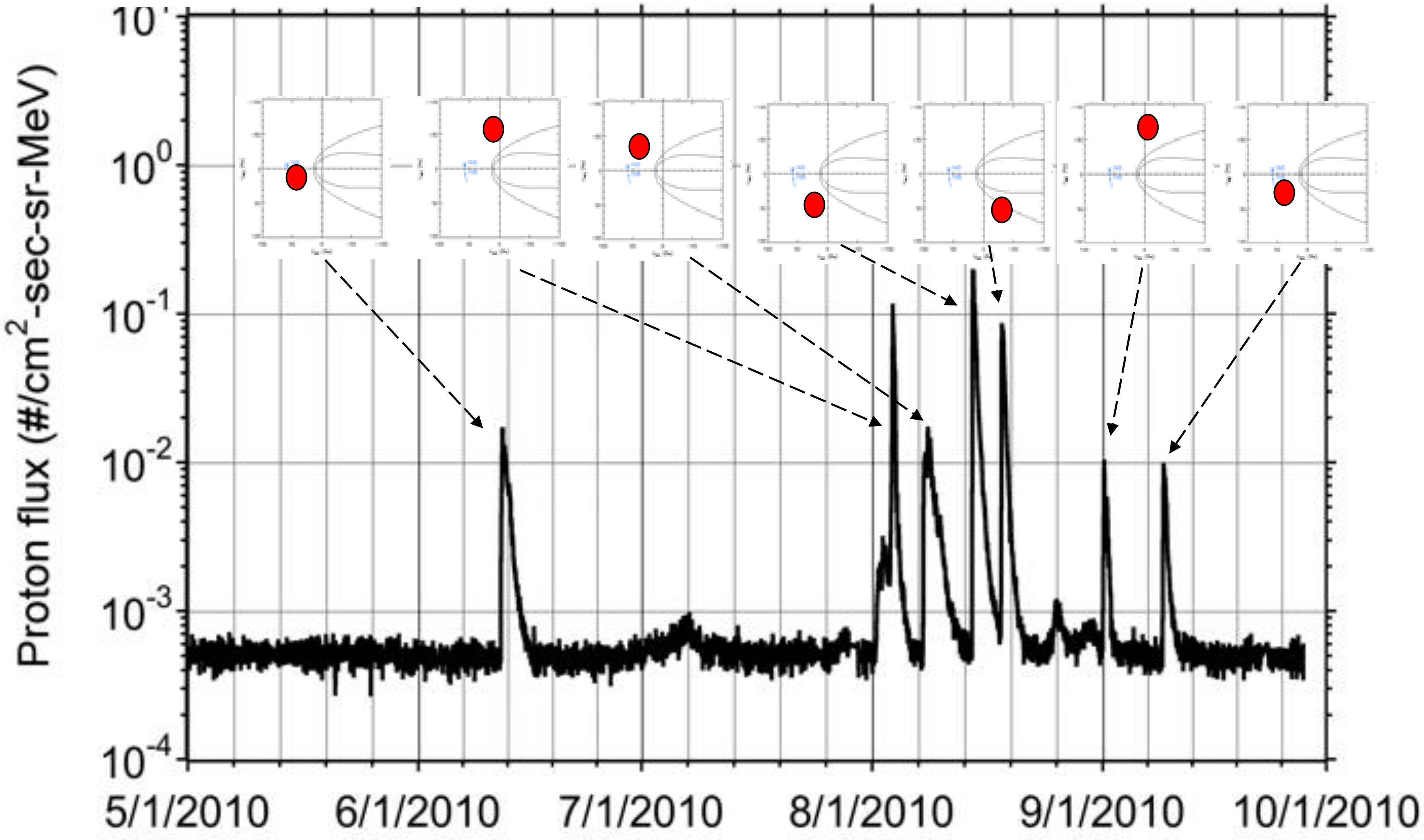
- Upward-moving lunar albedo protons created from primary GCR impacts with the Moon
- Nuclear fragments generated from primary GCR interactions with CRaTER and LRO spacecraft
- Modeling effort is now focusing on the details of the local spacecraft mass distributions to better understand the fragment contributions

Solar Minimum Radiation Dose



- LRO also houses a micro dosimeter designed to measure total radiation dose in silicon behind ~130 mils aluminum
- Results to date show a trifling 12.2 Rads for the first year of the mission, a low value due to the lack of SEPs (LRO mission specification was 4.6 kRads for the first year)
- The current analysis includes data mining of Apollo dosimetry

Recent SEP Events



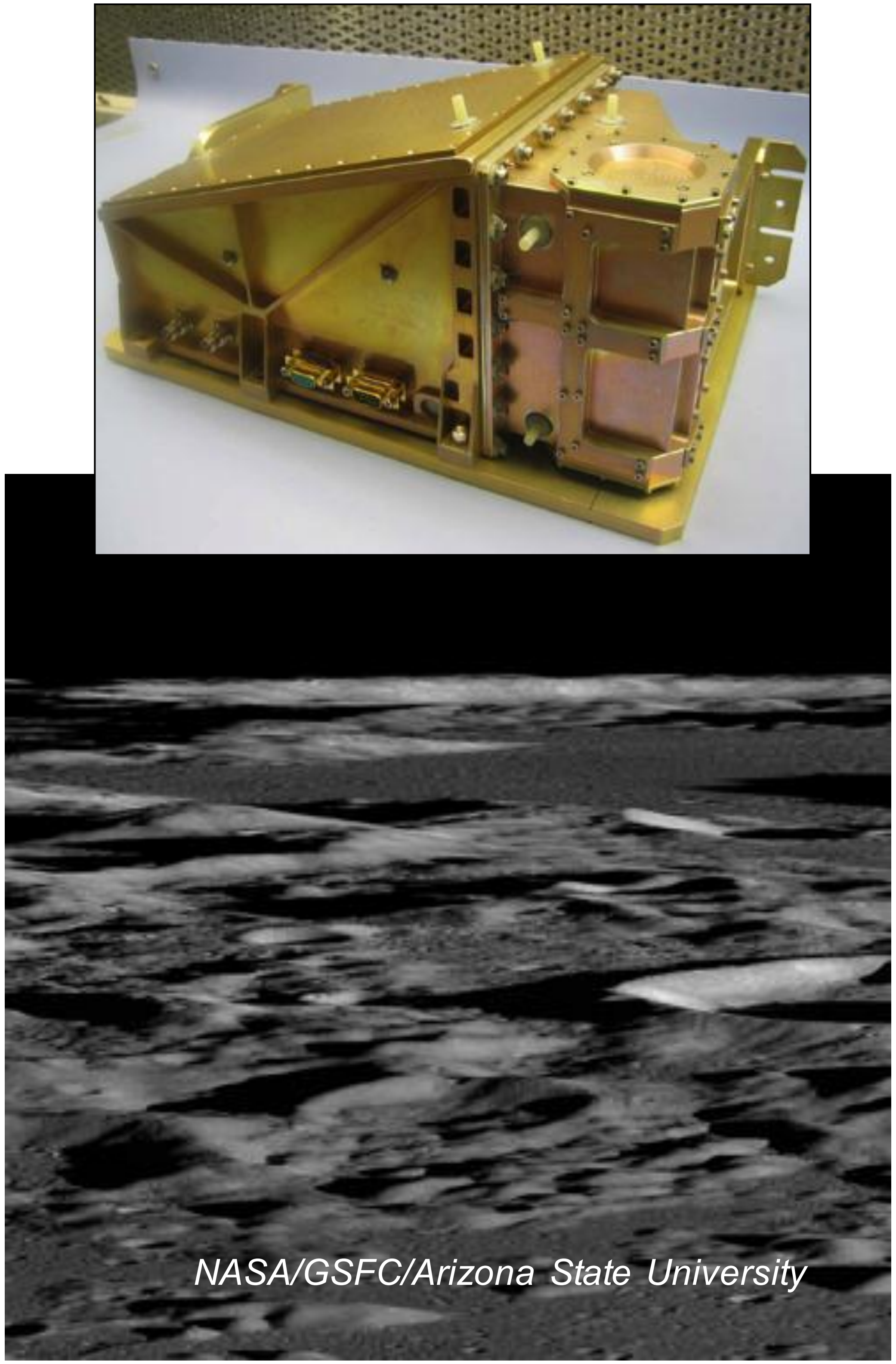
LRO/CRaTER

12.7-18.5 MeV protons

- All recent events have occurred while the Moon was outside the magnetosphere
- These relatively low-intensity events did not have a signature beyond D1-D2 and the 54 mm of tissue-equivalent plastic (as expected given the event intensity and 90 MeV threshold for D1D4 events)
- CRaTER attitude and LRO orbit might provide a different view of SEP anisotropy

CRaTER Summary

- CRaTER is in excellent health after one year at the Moon
- Measurements of LET spectra at Moon reveal known features (*e.g.,* peaks from most-abundant ions) as well as surprises (*e.g.,* high fluxes compared to pre-launch expectations; complex signatures of likely local nuclear interactions)
- GCR radiation environment remains a major concern for long missions well beyond LEO
- Lunar GCR flux (and radiation dose) reduced compared to deep space because of proximity to absorbing Moon, however, Earth's magnetotail provides no shelter from >15 MeV GCR (*i.e.,* at energies of biological relevance)
- First detection of proton albedo from lunar regolith
- LRO is a unique platform for SEP studies & will be a useful tool for SMD-phase science



NASA/GSFC/Arizona State University

Teledyne - Radiation Dosimeter

The Micro Dosimeter is a compact hybrid microcircuit which directly measures total ionizing dose (TID) absorbed by an internal silicon test mass. The test mass simulates silicon die of integrated circuits on-board a host spacecraft in critical mission payloads and subsystems.

By accurately measuring the energy absorbed from electrons, protons, and gamma rays, an estimate of the dose absorbed by other electronic devices on the same vehicle can be made. The Micro Dosimeter can operate from a wide range of input voltages.

The accumulated dose is presented to three DC linear outputs and one pseudo-logarithmic output giving a dose resolution of 14 uRads and a measurement range up to 40 kRads. These outputs are intended to be directly connected to most analog-to-digital converters (ADCs) or spacecraft housekeeping analog inputs (0-5V range), which makes minimal demands on the host vehicle.

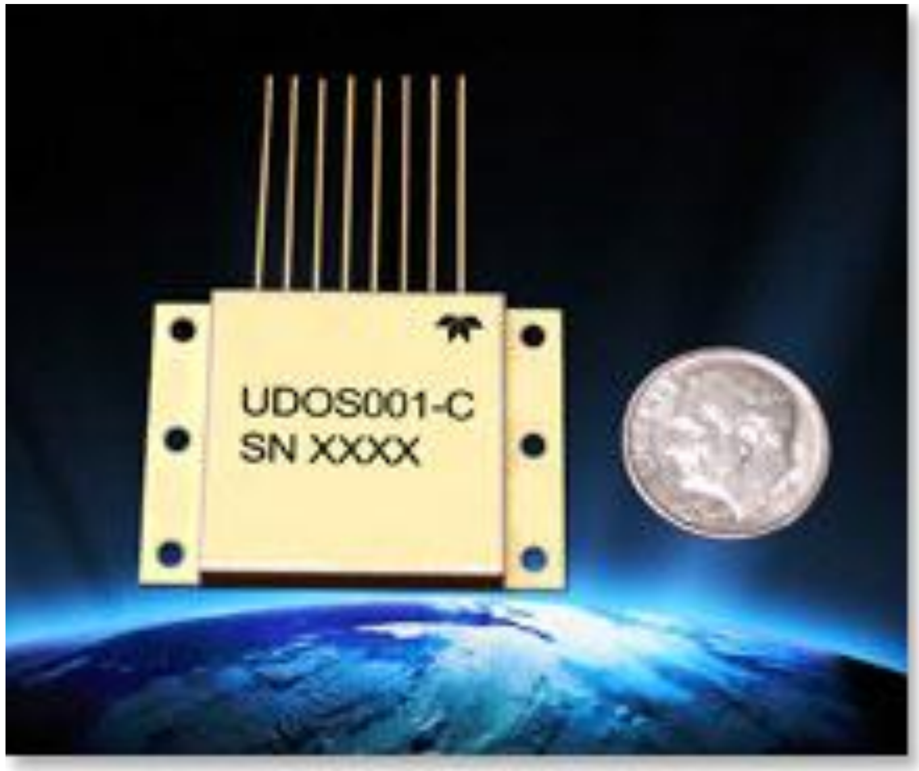
The Micro Dosimeter incorporates a test function to allow electrical testing of the hybrid without the need for a radiation source.

Teledyne - Radiation Dosimeter

Challenge: Electronics degrade with accumulation of radiation dose

Issues: Current radiation dose instruments are large, heavy, expensive and difficult to integrate

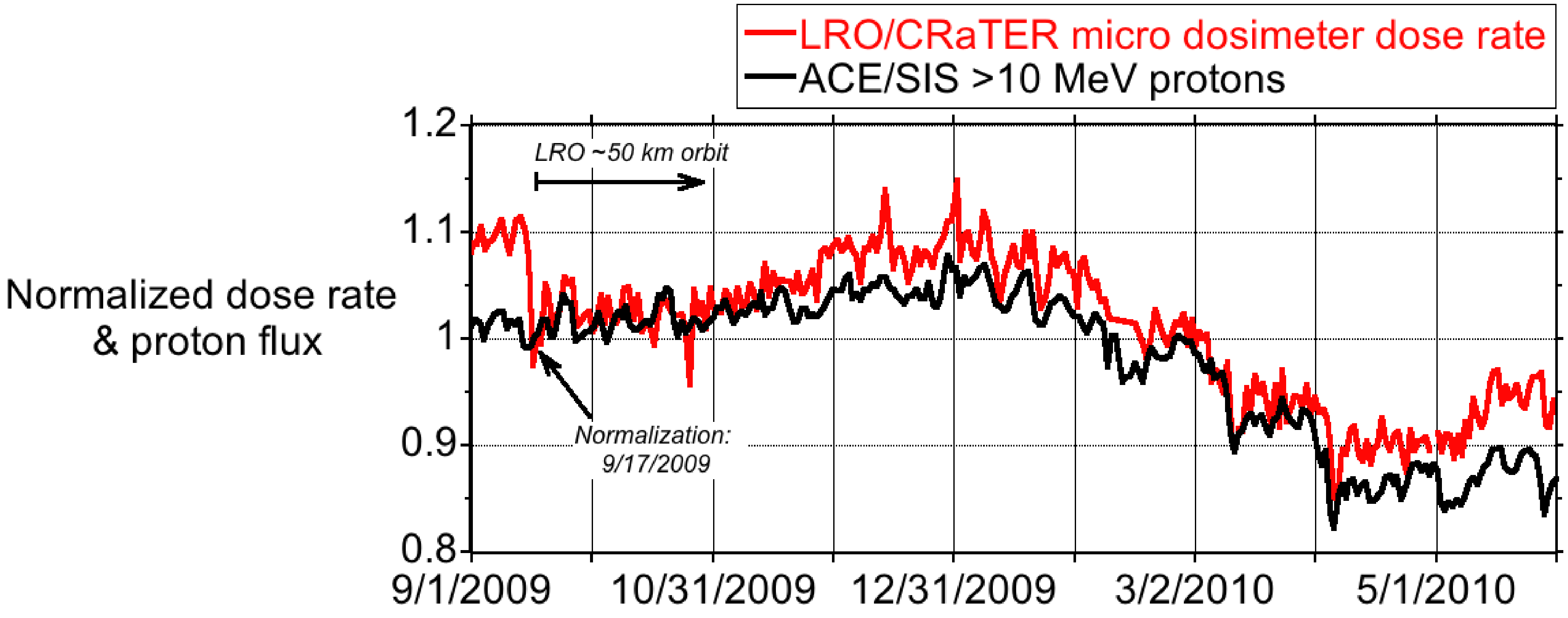
Solution: World’s Smallest Radiation Dosimeter



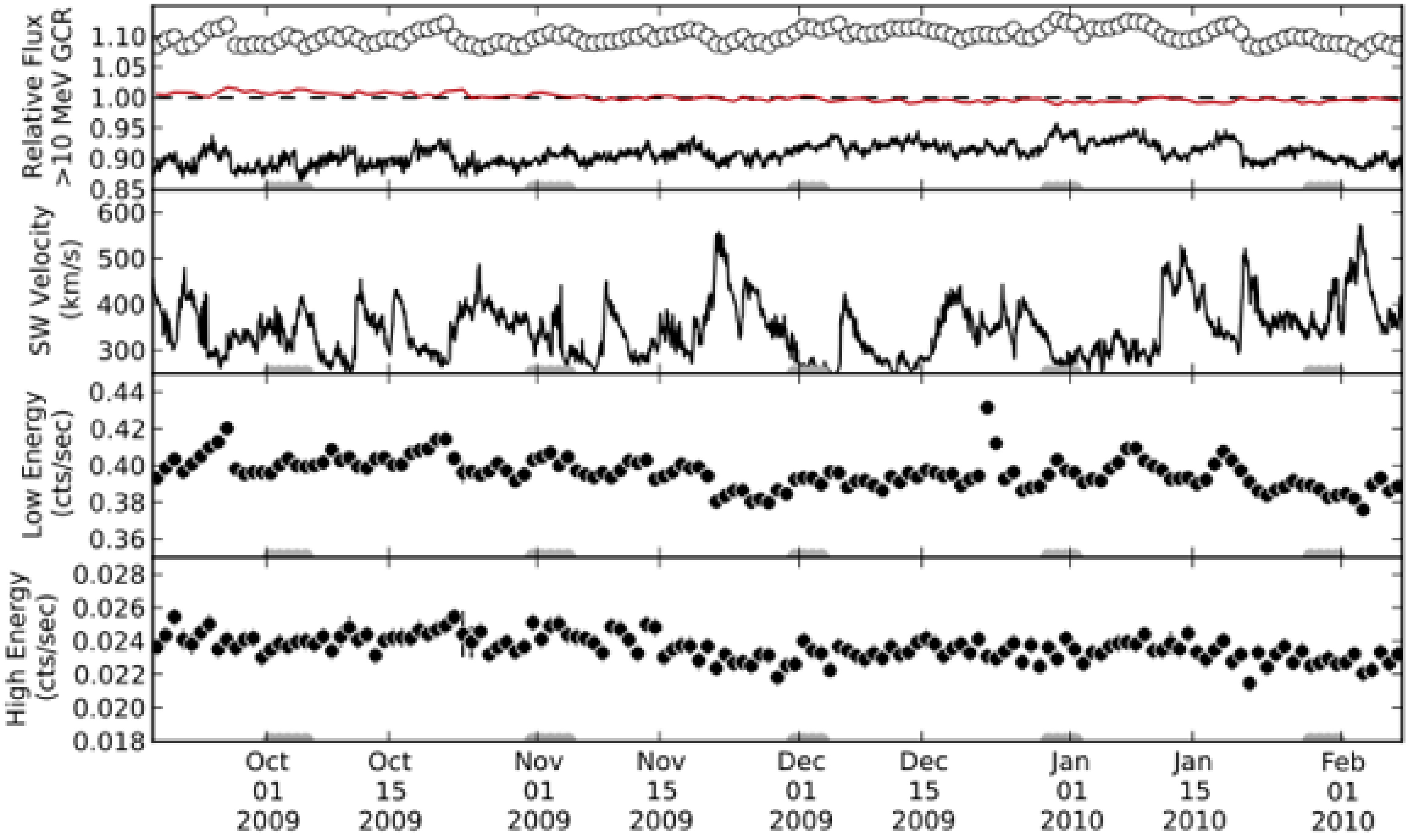
Space, Defense, Nuclear and Medical Radiation Measurement

- Total ionizing dose measurement
- Alert for hazardous conditions or hostile action
- Diagnose anomalies
- Improve system design and life estimates
- Improve future radiation models
- Plug & play connectivity

Correlations Using ACE



J. Mazur et al. to be submitted, 2010

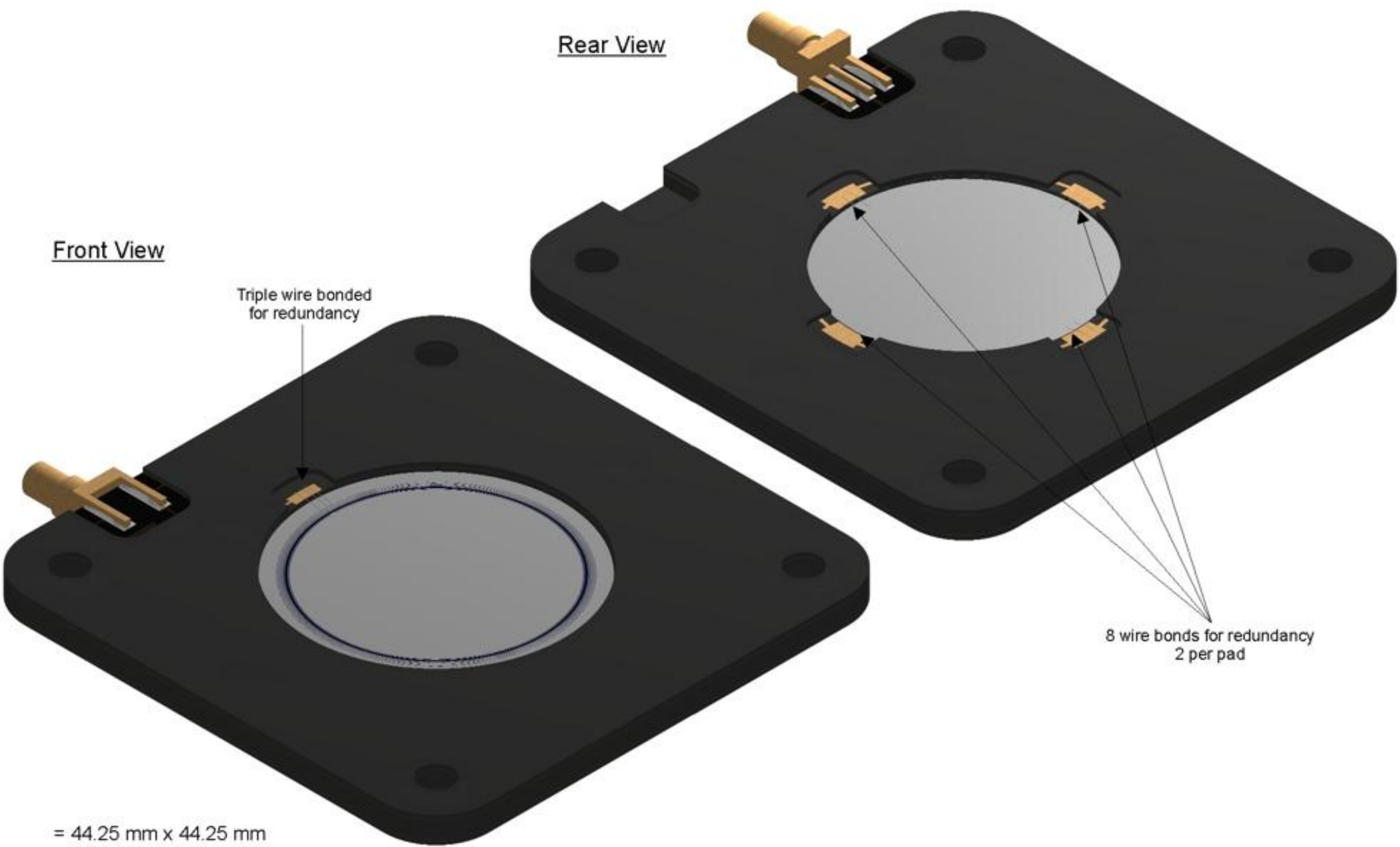


T. Case et al. GRL in press, 2010

RPS

- Ion beam tests of H1 detectors for RPS have shown low pulse heights when the beam hits the outer edge of the detector or guards.
- Wanted to probe a similar technology detector with a laser to try to identify which areas cause the low pulse heights
- If there is an edge effect, how far inside the edge of the active area do we need to collimate to get good peaks?

- Jeff George, Steve LaLumondiere
  - Bern Blake, Steve Moss both provided help part of the time



ns = 44.25 mm x 44.25 mm
ns = Ø24.00 mm
= Ø20.00 mm

ate 03/08/200	Tolerances Unless Stated	Outputs Via: AEP connector Part number SK-1413-1 Modified for 1.6mm thick PCB
	Package O/D ± 0.1 mm	Mating connector: N/A
	Package Hole ± 0.05 mm	Potted Wire Bonds: No
	Package Hole Pos'n ± 0.1 mm	Substrate Number: A- 3529
	Detector O/D ± 20.0 μm	Substrate Material: 1.6 mm thick Black FR4 PCB material with 2 x 0.4 mm thick unplated spacers

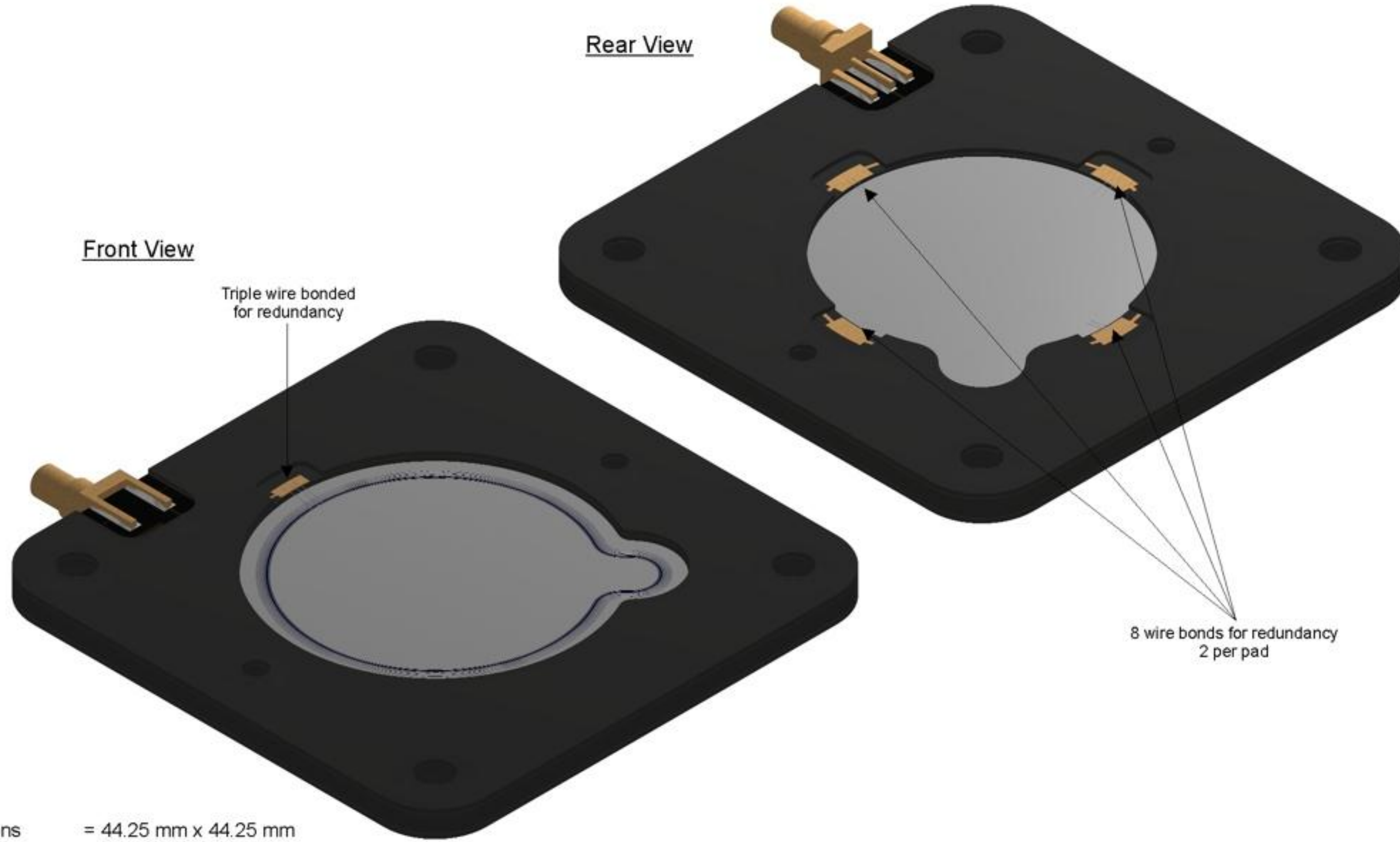
Title.

RPS Flight MSD020.
3D Assembly.
Front and Rear View.

MICRON SEMICONDUCTOR LIMITED

graphics@micronsemiconductor.co.uk

3672



mensions = 44.25 mm x 44.25 mm
mensions = Ø27.00 - 35.00 mm
rea = Ø23.00 - 31.00mm

ecked
.W

Date
03/08/200

Tolerances Unless Stated	Outputs Via: AEP connector Part number SK-1413-1 Modified for 1.6mm thick PCB
Package O/D ± 0.1 mm	Mating connector: N/A
Package Hole ± 0.05 mm	Potted Wire Bonds: No
Package Hole Pos'n ± 0.1 mm	Substrate Number: A- 3527
Detector O/D ± 20.0 µm	Substrate Material: 1.6 mm thick Black FR4 PCB material with 2 x 0.4 mm thick unplated spacers

Title.

RPS Flight MSD023.
3D Assembly.
Front and Rear View.

MICRON SEMICONDUCTOR LIMI

graphics@micronsemiconductor.co.uk

RBSP (*Radiation Belt Storms Probes Mission)*

Radiation Belts

The radiation belts are two donut-shaped regions of high-energy particles, mainly protons and electrons, trapped by the magnetic field of the Earth. These belts are often referred to as "The Van Allen Belts" because they were discovered by James Van Allen and his team at the University of Iowa.

The first American satellite, Explorer 1, was launched into Earth's orbit on a Jupiter C missile from Cape Canaveral, Florida, on January 31, 1958.

Aboard Explorer 1 were a micrometeorite detector and a cosmic ray experiment designed by Dr. Van Allen and his graduate students.

RBSP (*Radiation Belt Storms Probes Mission)*

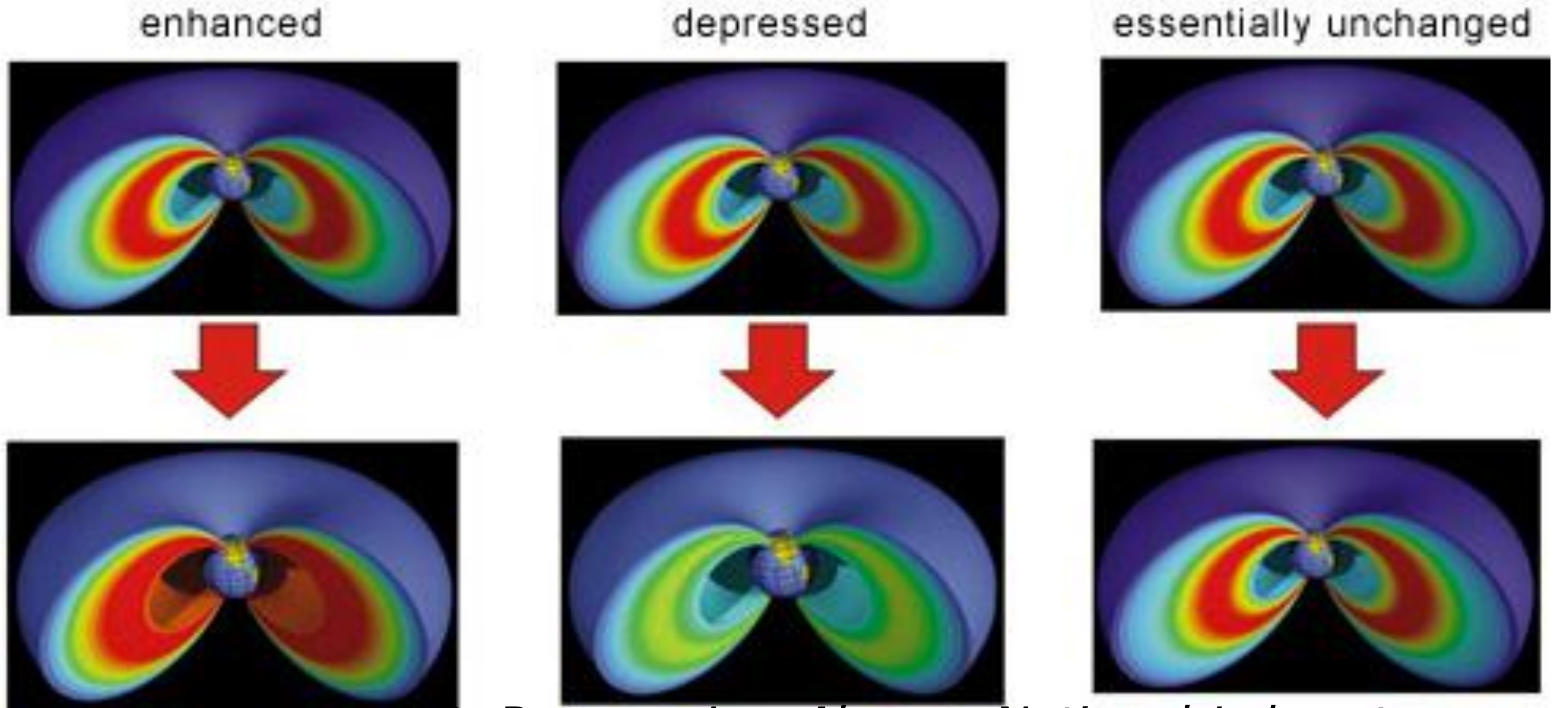
Provide unprecedented insight into the physical dynamics of the radiation belts and give scientists the data they need to make predictions of changes in this critical region of space.

The two spacecraft will measure the particles, magnetic and electric fields, and waves that fill geospace. Only with two spacecraft taking identical measurements and following the same path, can scientists begin to understand how the belts change in both space and time.

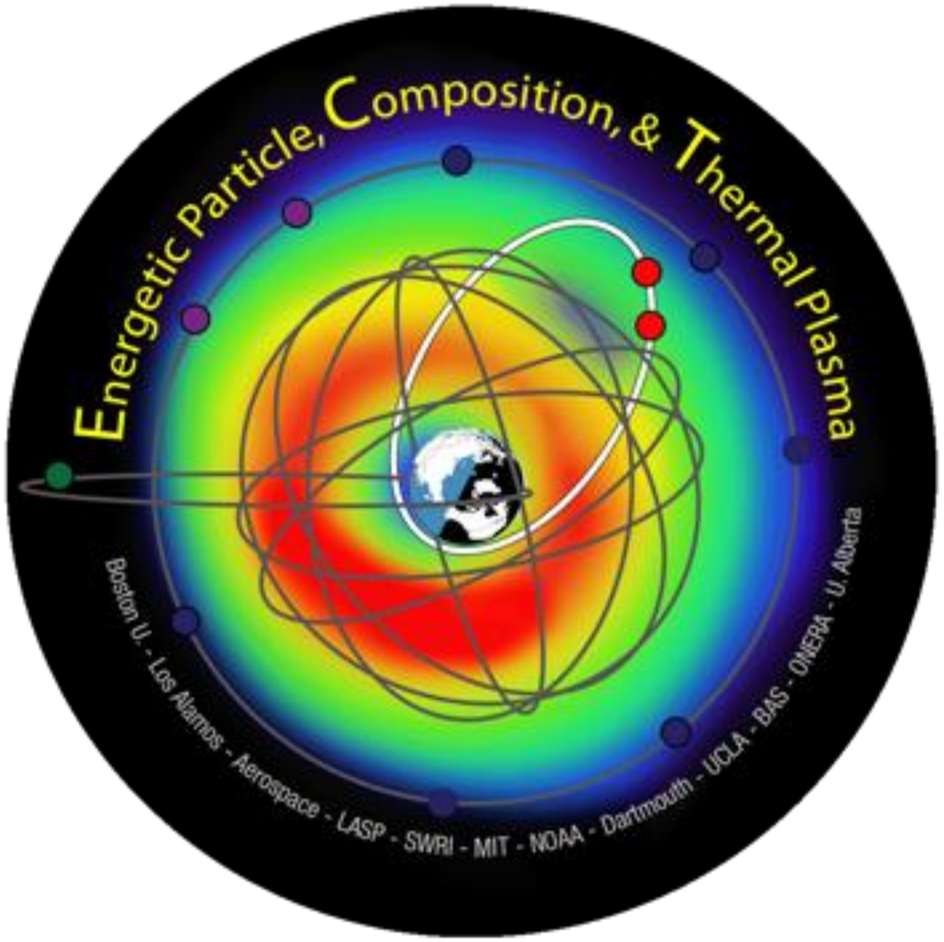
RBSP (*Radiation Belt Storms Probes Mission)*

Radiation Belts

It is this constant variability of the radiation belts which is of most interest to scientists. There are known phenomena which give rise to these changes but the radiation belts do not always respond in the same way to the drivers. For example, there is a close, but by no means simple, relationship between storms at Earth and changes in the radiation belts. Each of these storms was preceded by similar solar conditions. Due to complex processes that can occur simultaneously during the storm period, the radiation belts can be enhanced (left), depressed (middle), or essentially unchanged (right) compared with conditions before the storm.

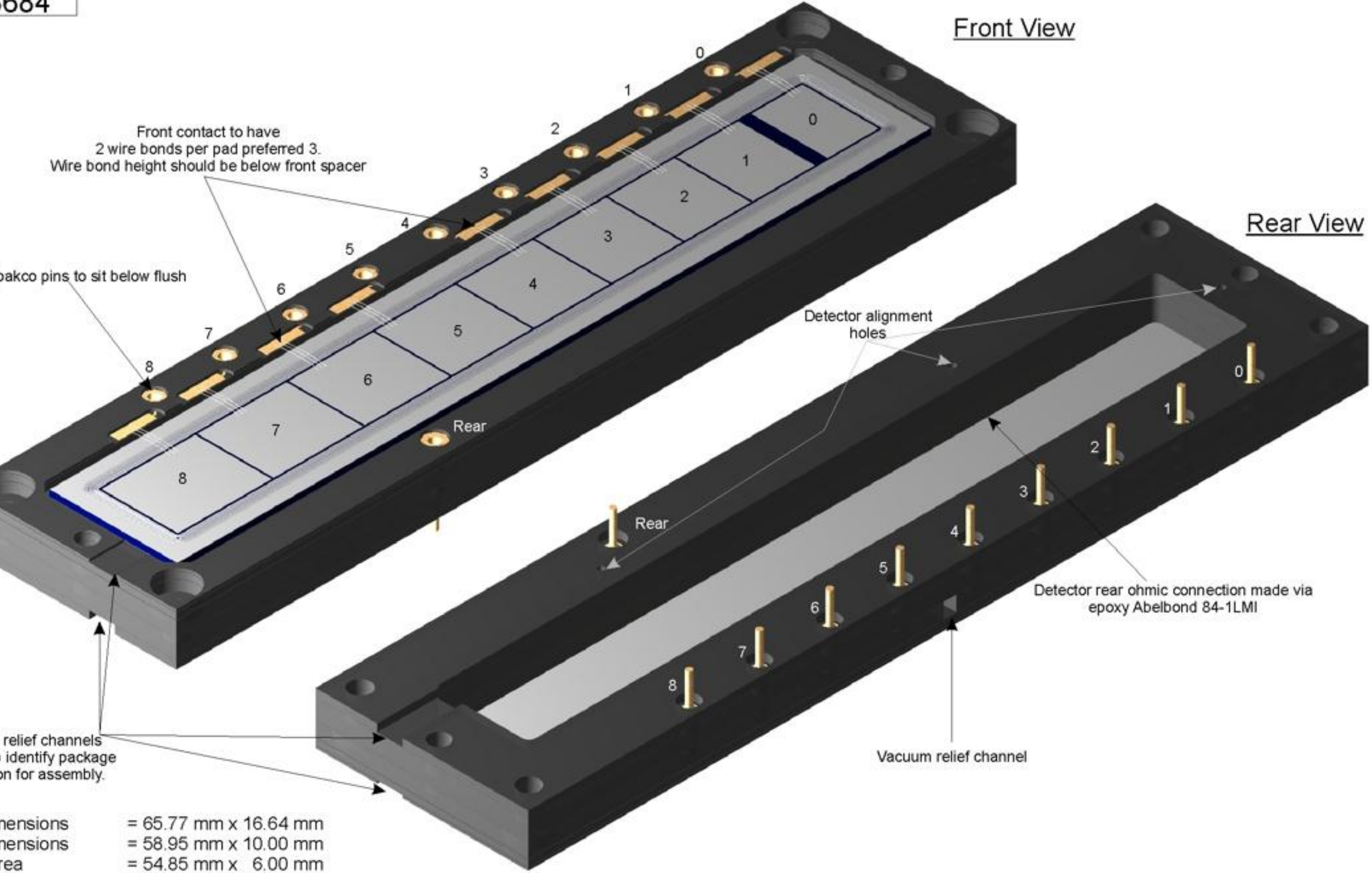


Images courtesy of G. Reeves, Los Alamos National Laboratory



MagEIS Systems Engineering

684



nensions = 65.77 mm x 16.64 mm
nensions = 58.95 mm x 10.00 mm
rea = 54.85 mm x 6.00 mm

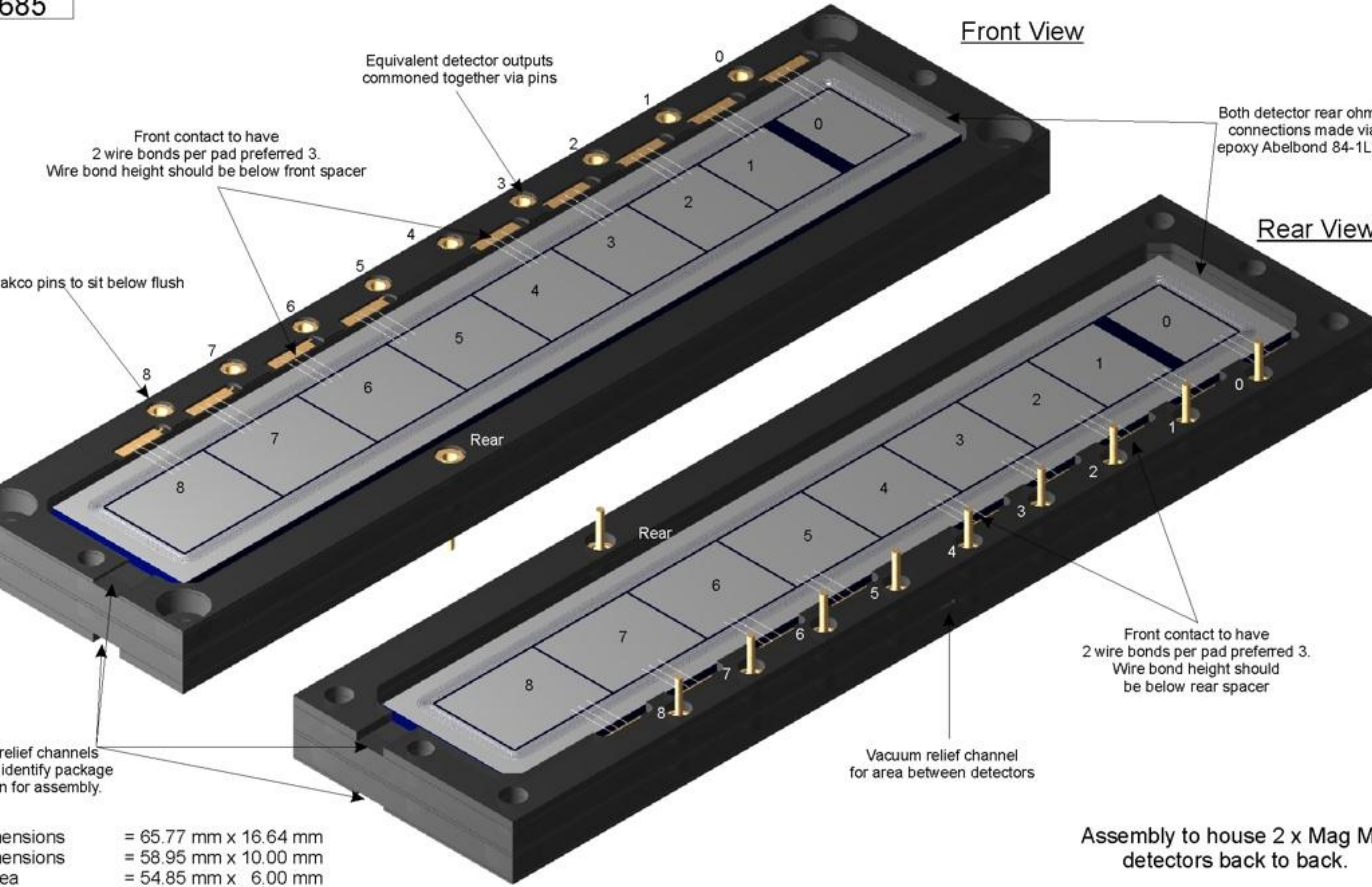
ecked	Date	Tolerances Unless Stated	Outputs Via: Elpakco Part Number 4010-04-32-14	Title.
W	18/08/2009	Package O/D ± 0.1 mm	Mating connector: Elpakco Part Number 4026-04-32-14	Mag LE. 3D Assembly. Front and Rear View.
		Package Hole ± 0.05 mm	Potted Wire Bonds: No	
		Package Hole Pos'n ± 0.1 mm	Substrate Number: A-3607	
		Detector O/D ± 20.0 μm	Substrate Material: Black FR4 PCB Material	
			Connector Orientation: Pins to exit rear side of PCB.	

MICRON SEMICONDUCTOR LIMITED

graphics@micronsemiconductor.co.uk

Scale N/A	Dims In. mm	Drg No A-3684

685



Equivalent detector outputs commoned together via pins

Front contact to have
2 wire bonds per pad preferred 3.
Wire bond height should be below front spacer

akco pins to sit below flush

Both detector rear ohm
connections made via
epoxy Abelbond 84-1L

Front contact to have
2 wire bonds per pad preferred 3.
Wire bond height should
be below rear spacer

Vacuum relief channel
for area between detectors

relief channels
identify package
n for assembly.

ensions = 65.77 mm x 16.64 mm
ensions = 58.95 mm x 10.00 mm
ea = 54.85 mm x 6.00 mm

Assembly to house 2 x Mag M
detectors back to back.

cked	Date	Tolerances Unless Stated	Outputs Via: Elpakco Part Number 4010-04-32-14
W	18/08/20	Package O/D ± 0.1 mm	Mating connector: Elpakco Part Number 4026-04-32-14
		Package Hole ± 0.05 mm	Potted Wire Bonds: No
		Package Hole Pos'n ± 0.1 mm	Substrate Number: A-3609
		Detector O/D ± 20.0 µm	Substrate Material: Black FR4 PCB Material

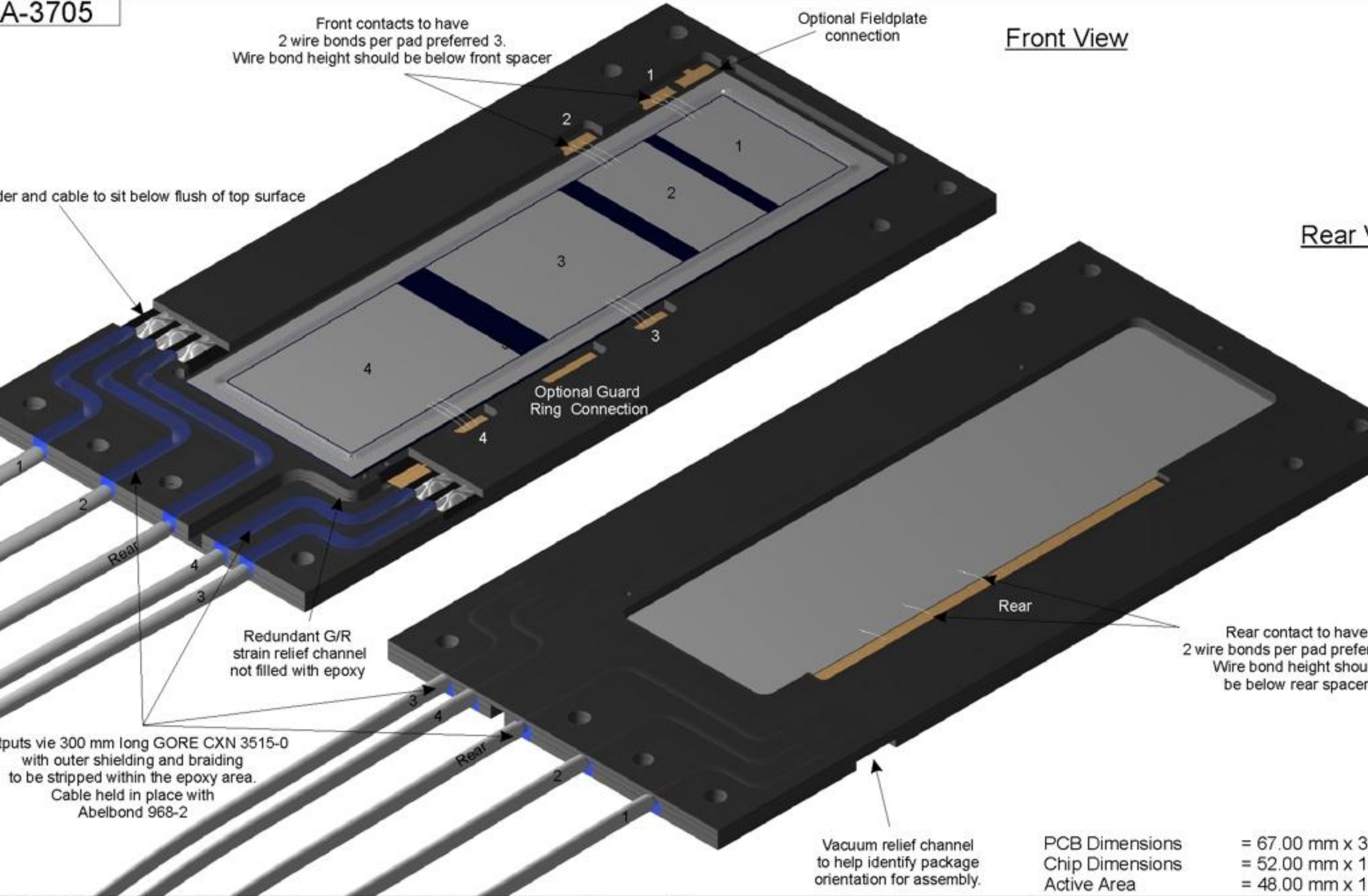
Title.

Mag ME.
3D Assembly.
Front and Rear View.

MICRON SEMICONDUCTOR LIMIT

graphics@micronsemiconductor.co.uk

A-3705



Front View

Front contacts to have
2 wire bonds per pad preferred 3.
Wire bond height should be below front spacer

Optional Fieldplate
connection

der and cable to sit below flush of top surface

Optional Guard
Ring Connection

Rear V

Redundant G/R
strain relief channel
not filled with epoxy

Rear contact to have
2 wire bonds per pad prefer
Wire bond height shou
be below rear spacer

tputs vie 300 mm long GORE CXN 3515-0
with outer shielding and braiding
to be stripped within the epoxy area.
Cable held in place with
Abelbond 968-2

Vacuum relief channel
to help identify package
orientation for assembly.

PCB Dimensions = 67.00 mm x 3
Chip Dimensions = 52.00 mm x 1
Active Area = 48.00 mm x 1

wn	Checked	Date	Tolerances Unless Stated	Outputs Via: 300 mm long GORE cable part number CXN 3515-0
W	S.W	06/08/2009	Package O/D ± 0.1 mm	Mating connector: N/A
s. d.			Package Hole ± 0.05 mm	Potted Wire Bonds: No
mer			Package Hole Pos'n ± 0.1 mm	Substrate Number: A-3635
			Detector O/D ± 20.0 µm	Substrate Material: Black FR4 PCB Material
				Connector Orientation: N/A.

Title.

Mag HEf.
3D Assembly.
Front and Rear View.

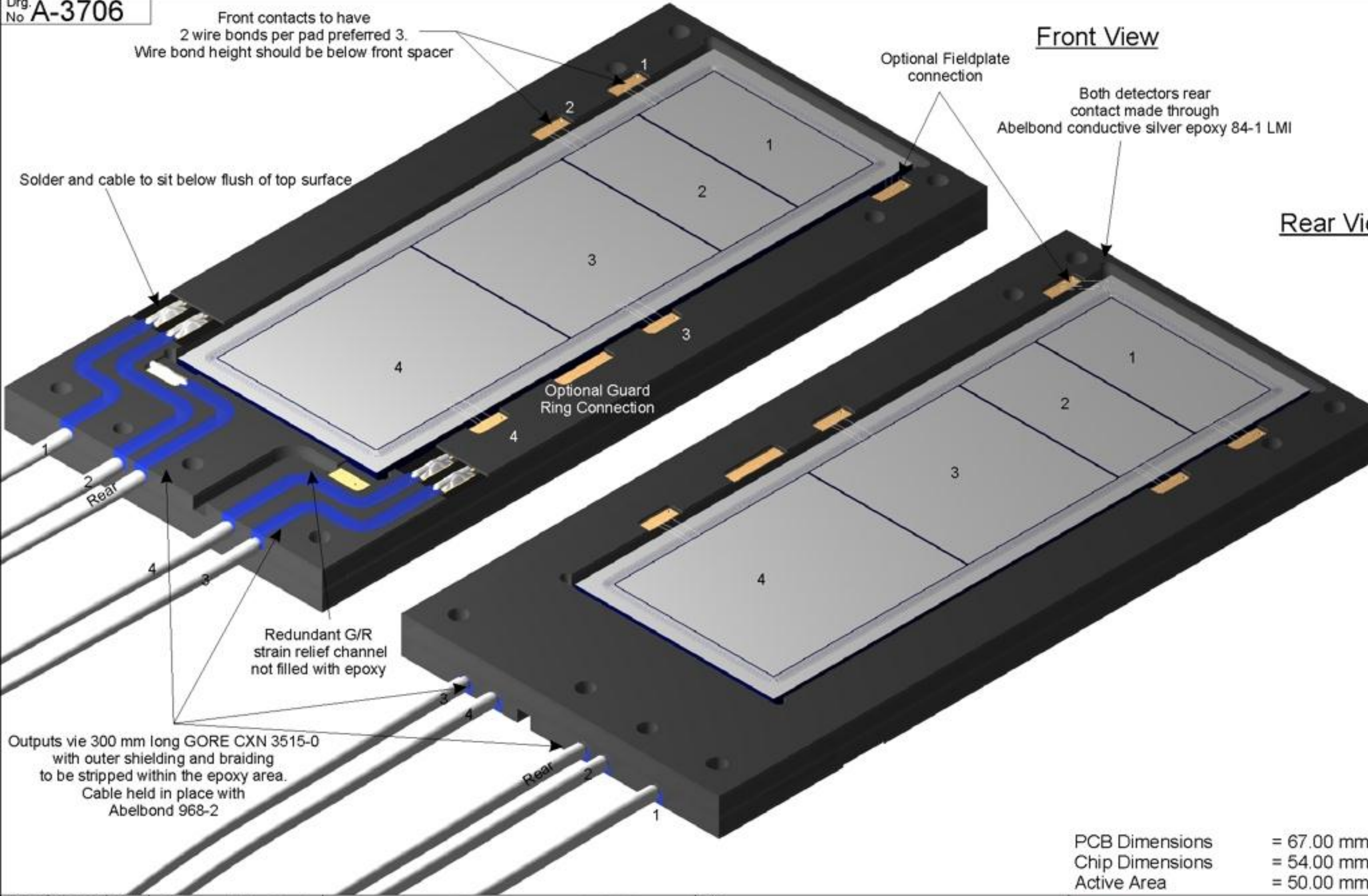
MICRON SEMICONDUCTOR

THIS DOCUMENT IS THE PROPERTY OF
MICRON SEMICONDUCTOR LTD AND IS
COMMERCIAL IN CONFIDENCE

graphics@micronsemiconductor.c

Scale N/A	Dims In. mm	Drg No A

Drg. No A-3706



Front contacts to have
2 wire bonds per pad preferred 3.
Wire bond height should be below front spacer

Optional Fieldplate
connection

Both detectors rear
contact made through
Abelbond conductive silver epoxy 84-1 LMI

Solder and cable to sit below flush of top surface

Optional Guard
Ring Connection

Redundant G/R
strain relief channel
not filled with epoxy

Outputs vie 300 mm long GORE CXN 3515-0
with outer shielding and braiding
to be stripped within the epoxy area.
Cable held in place with
Abelbond 968-2

PCB Dimensions = 67.00 mm
Chip Dimensions = 54.00 mm
Active Area = 50.00 mm

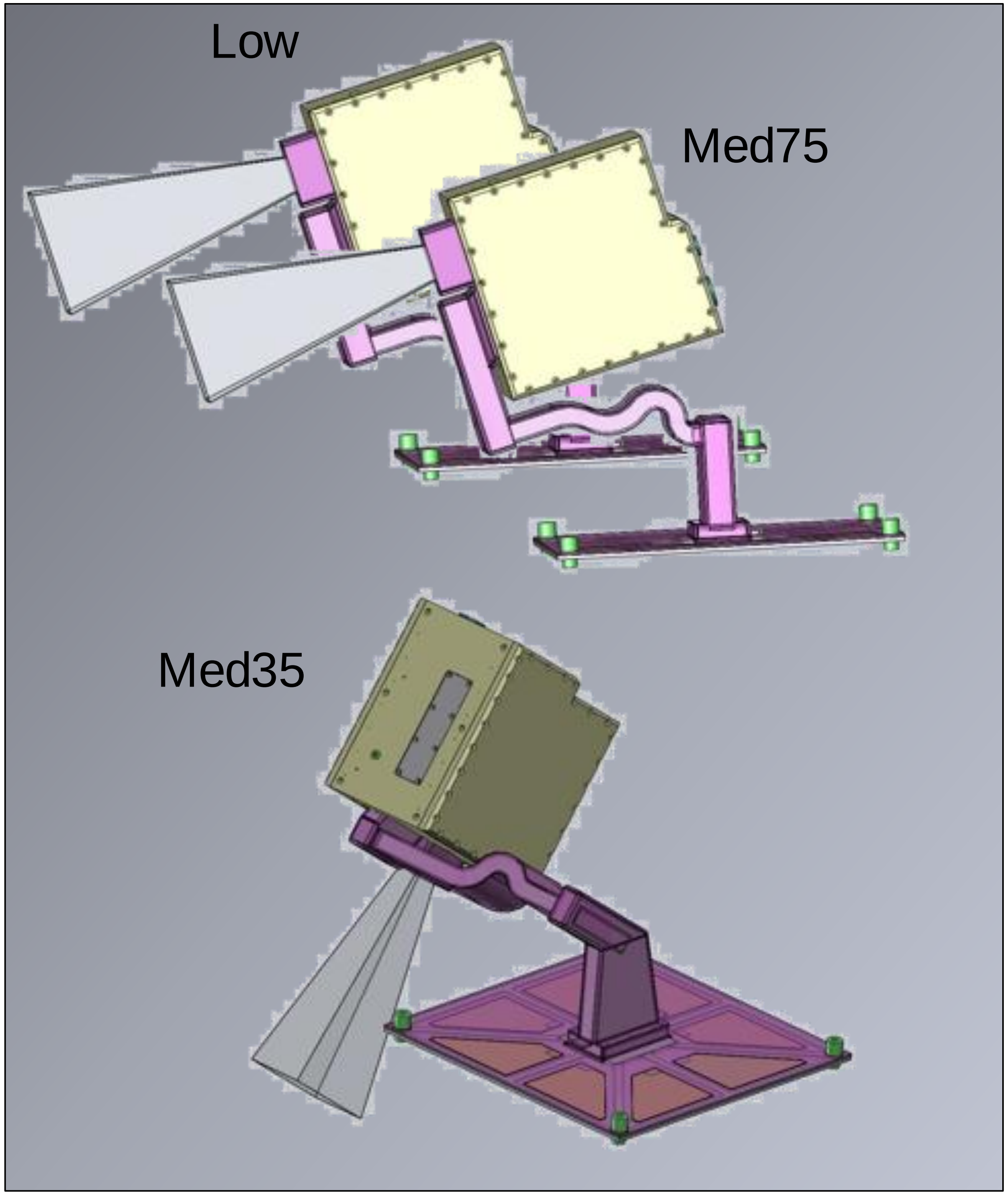
Drawn	Checked	Date	Tolerances Unless Stated	Outputs Via: 300 mm long GORE cable part number CXN 3515-0	Title.
N.W	S.W	16/10/2009	Package O/D ± 0.1 mm	Mating connector: N/A	Mag HEb. 3D Assembly. Front and Rear View.
Des. Appd.			Package Hole ± 0.05 mm	Potted Wire Bonds: No	
customer			Package Hole Pos'n ± 0.1 mm	Substrate Number: A-3636	
			Detector O/D ± 20.0 µm	Substrate Material: Black FR4 PCB Material	
				Connector Orientation: N/A.	

MICRON SEMICONDUCT

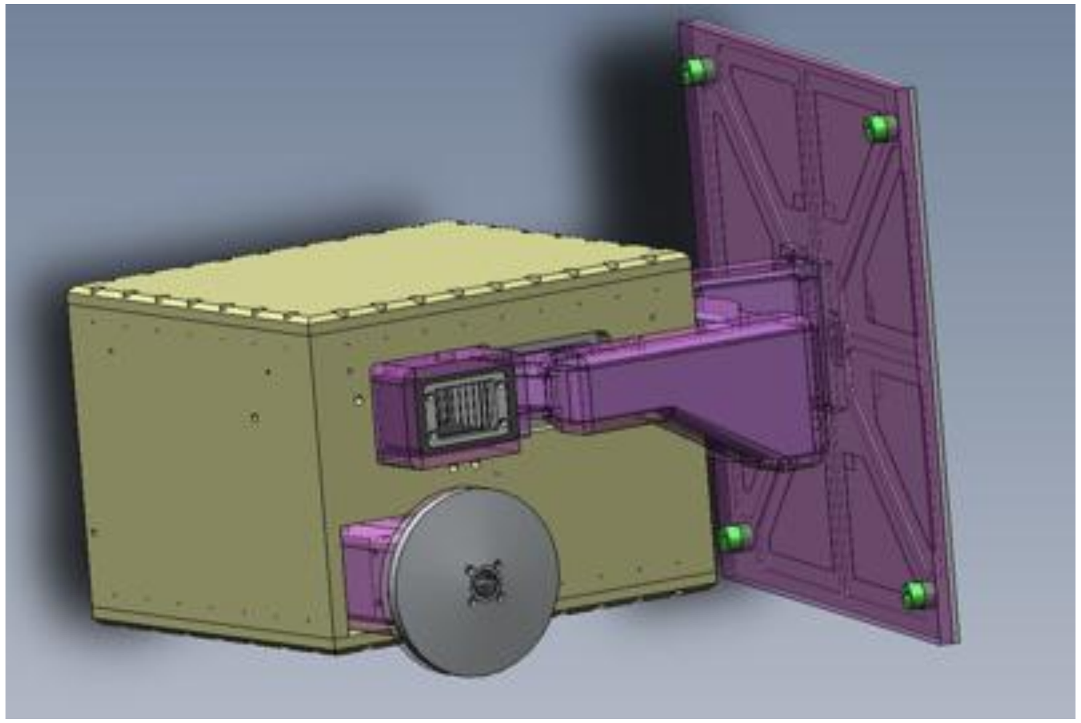
THIS DOCUMENT IS THE PROPERTY
MICRON SEMICONDUCTOR LTD AND
COMMERCIAL IN CONFIDENCE

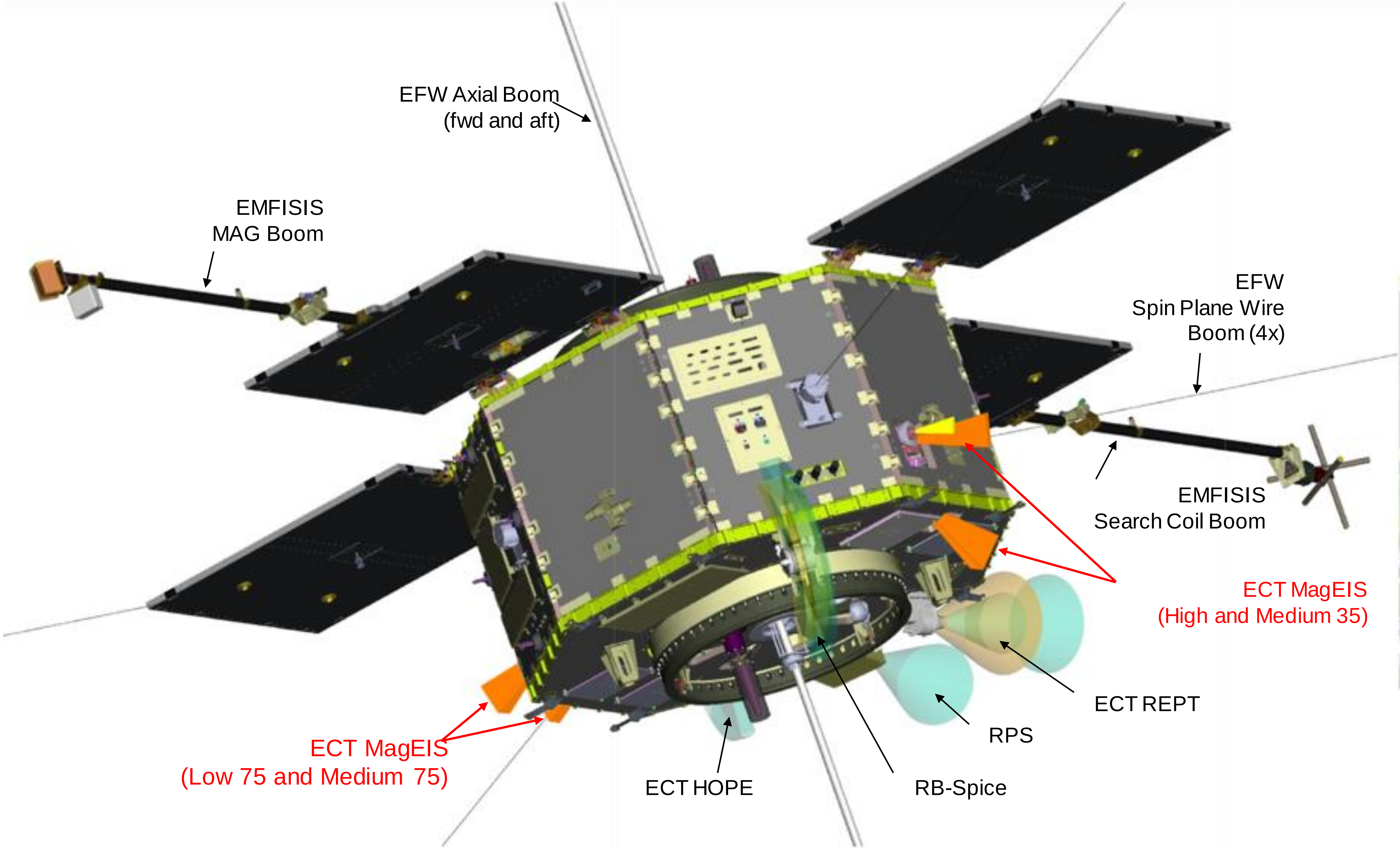
graphics@micronsemiconduc

Scale N/A	Dims In. mm	Drg N



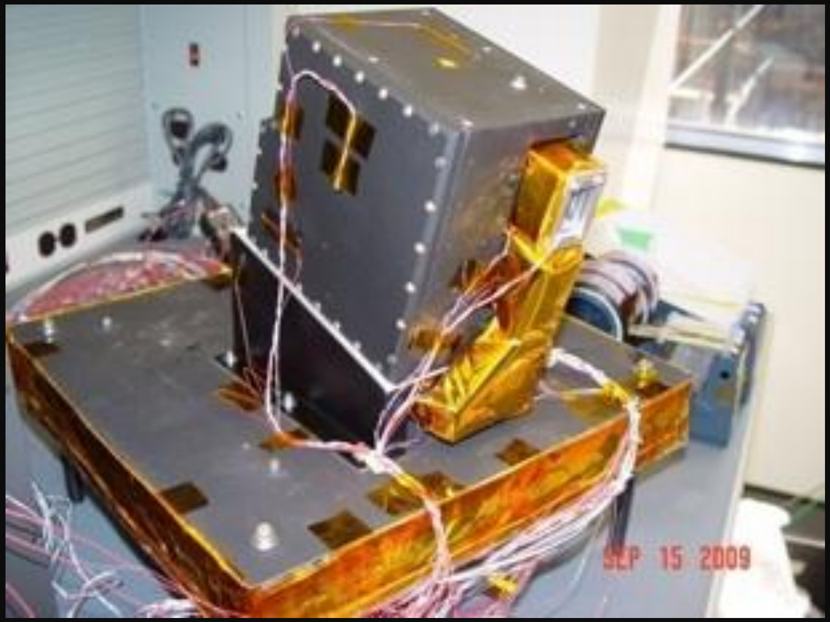
High Instrument



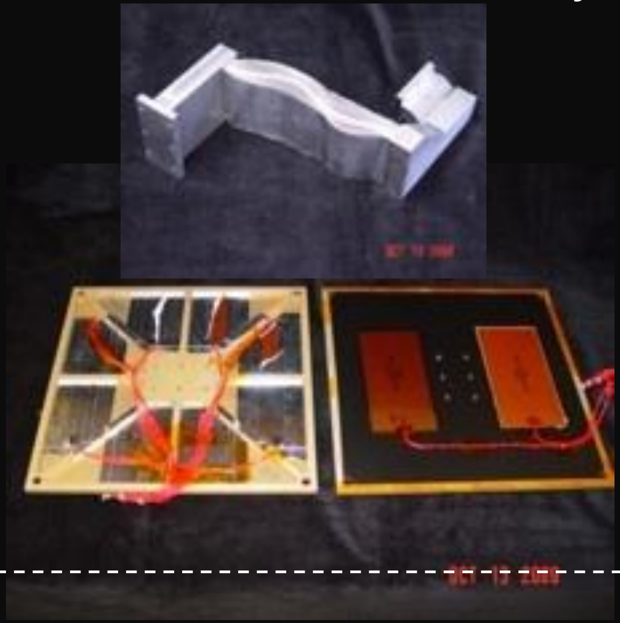

EFW Axial Boom
(fwd and aft)
EMFISIS
MAG Boom
EFW
Spin Plane Wire
Boom (4x)
EMFISIS
Search Coil Boom
ECT MagEIS
(High and Medium 35)
ECT REPT
RPS
RB-Spice
ECT HOPE
ECT MagEIS
(Low 75 and Medium 75)

MagEIS EM Assemblies

Low/Medium Instrument in Thermal Balance Test



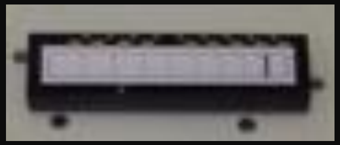
Thermal Control Assembly



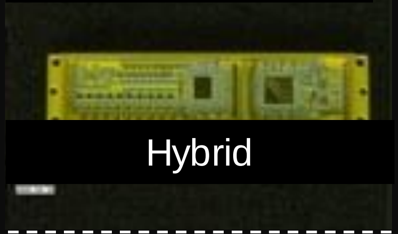
High Instrument

Electron Analyzer

Magnetic Optics

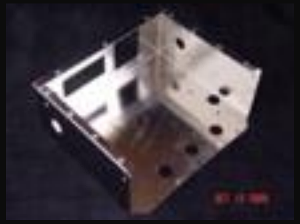


SS Detector



Hybrid

Housing



Mu-metal shield

DPU

LVPS/B

STARD	Requirement	CDR	IRD Sec 5	Flowdown Specs	Subsystems
IPLD-65	**Measure Medium and High Energy Electrons**				
	- Energy range <=45 keV to >= 4 MeV	Comply	Energy Range	Low: 45 keV to 200 keV Med: 200 keV to 1 MeV High: 1 MeV to 4 MeV	Magnetic Optics, SSDs, Hybrid
			Noise	Low: < 15 keV FWHM Med: < 60 keV FWHM High: < 100 keV FWHM	SSDs, Hybrid, LVPS/B
	- Med-e Energy resolution <= 30% at 300 keV	Comply	Electron Resolution	Low: 8 electron rates min Med: 8 electron rates min	Hybrid, DPU, FSW, Thermal
			Electron Histogram	All: 64 histogram rates	Hybrid, DPU, FSW, Thermal
	- High-e Energy resolution <= 30% at 3 MeV	Comply	Electron Resolution	High: 4 electron rates min	Hybrid, DPU, FSW, Thermal
			Electron Histogram	High: 64 histogram rates	Hybrid, DPU, FSW, Thermal
	- Cadence: 1 minute, but integral # spins	Exceed	Time Resolution	All: Inherited	DPU, FSW
	- Angular resolution: at least 18 sectors/spin	Comply	Angular Resolution	All: Inherited	Magnetic Optics, DPU, FSW

STARD	Requirement	CDR	IRD Sec 5	Flowdown Specs	Subsystems
IPLD-81	**Measure Medium Energy Protons**				
	- Energy Range 100 keV to 1 MeV	Comply	Energy Range	High: <100 keV to > 1MeV	PT_SSDs, Hybrid
			Noise	High: < 30 keV FWHM	PT_SSDs, Hybrid
	- Energy Resolution 40% at 300 keV	Comply	Proton Resolution	High: 8 proton rates min	Hybrid, DPU, FSW, Thermal
			Proton Histogram	High: 64 histogram rates	Hybrid, DPU, FSW, Thermal
	- Cadence: 1 minute, but integral # spins	Exceed	Time Resolution	High: Inherited	DPU, FSW
	- Angular resolution: at least 18 sectors/spin	Comply	Angular Resolution	High: Inherited	Optics, DPU, FSW

Thermal Requirements

- MagEIS Responsibilities
  - Radiator, Thermal Strap, Instrument MLI, standoffs
- Conform to EDTRD requirements (7417-9019)
  - Margins on predictions
  - Other test requirements
- Maintain Magnetic Optics temperature stable within 10°C.
- Requirements flow to mechanical, thermal, and LVPS/B subsystems

Low / Medium Instrument Temperature Limits

Assembly	Design/Test		Survival	
Housing DPU LVPS/B	-35C	+55C	-40C	+60C
e-Analyzer Magnet Optics SSDs MAPPER	-30C	+0C	-40C	+60C

High Instrument Temperature Limits

Assembly	Design/Test		Survival	
Housing	-35C	+55C	-40C	+60C
e-Analyzer	-30C	+0C	-40C	+60C
p-Telescope	-30C	+30C	-40C	+60C

Radiation Requirements

- Total Ionizing Dose
  - 350 mils box thickness required
  - 34 krads per EDTRD
  - RDM=2
- Single Event Effects
  - No latchup or functional failure to LET=80
- Operation in significant proton and electron events
  - Specifications given in EDTRD
  - Results in high background environment
  - MagEIS histograms allow subtraction
- Detailed discussion provided in Section S

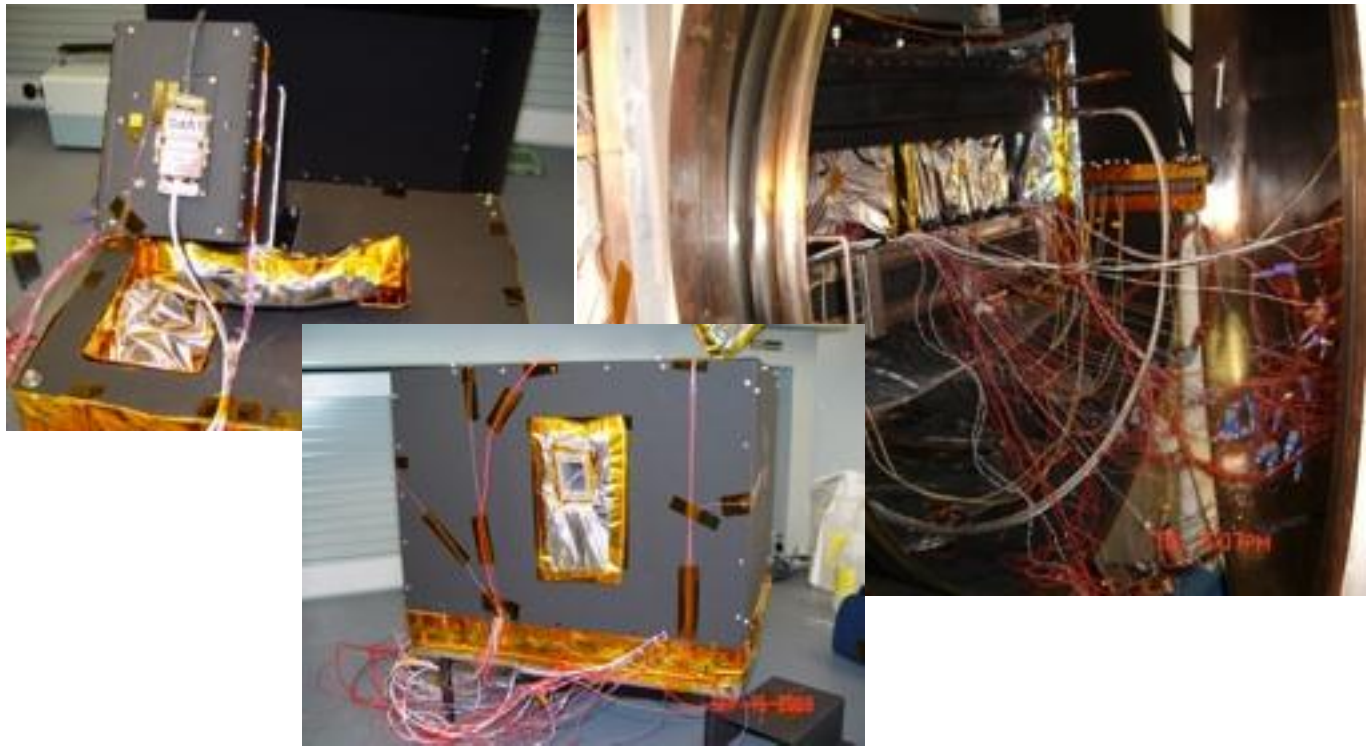
RBSP Ray Tracing Results

RDM=2

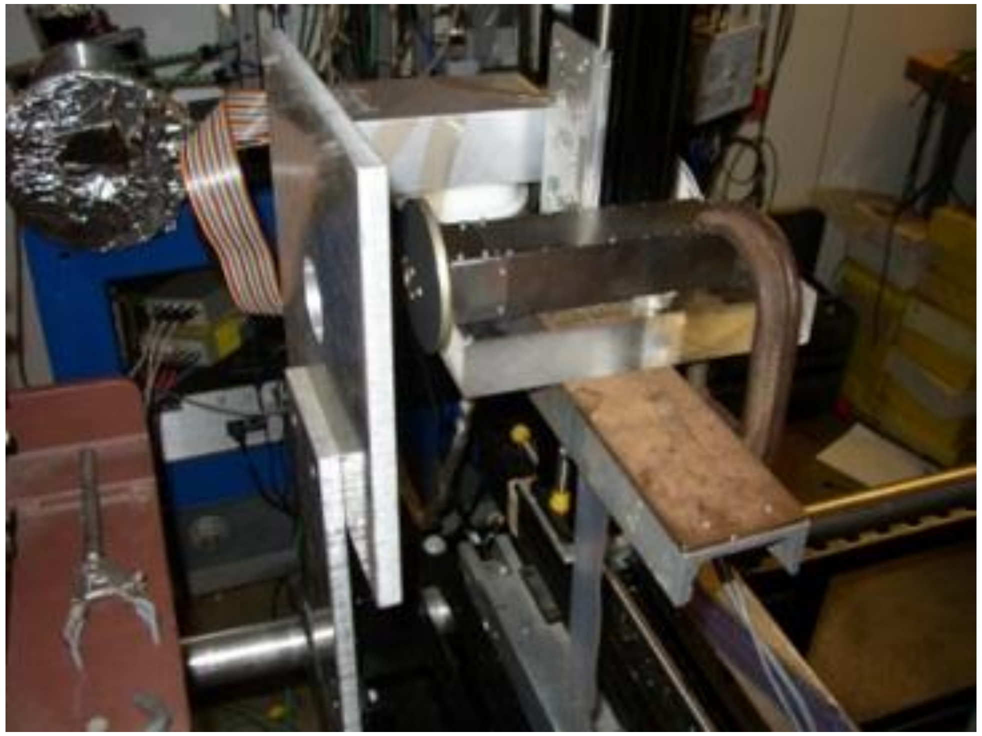
MagEIS Instrument	Max krads
Low Electronics	11.8
Medium Electronics (2)	12.4, 12.6
High Electronics	12.6

EM Test Highlights

Mechanical Assembly & Thermal Balance Test



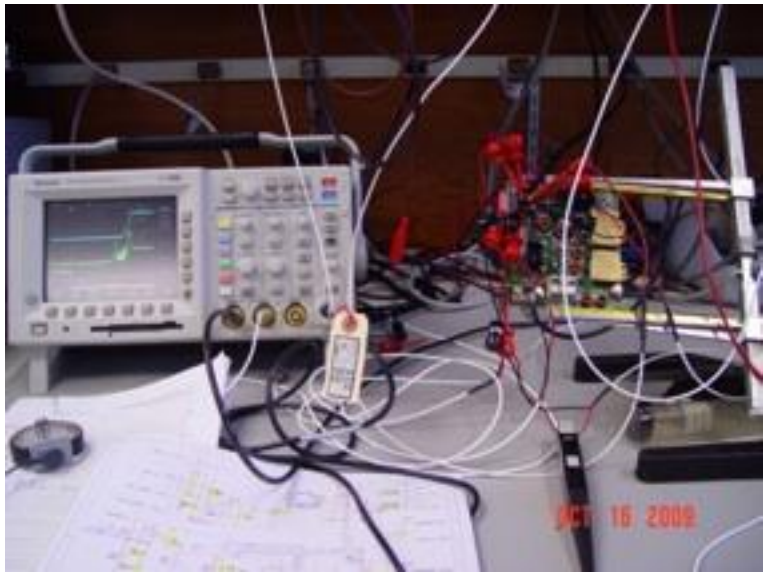
Proton Telescope at LBNL



DPU Science Code Burn-in

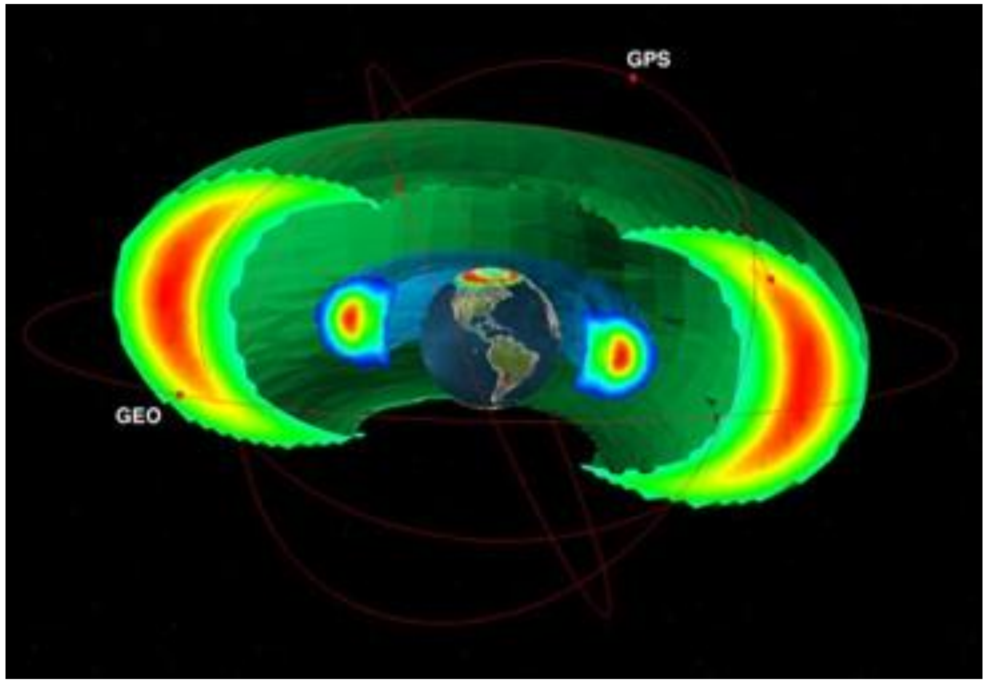
ASICs under Test

LVPS/B under Test



RBSP (*Radiation Belt Storms Probes Mission)*

Radiation Belts



Model-generated image showing the two main radiation belts, the outer belt and the inner belt. The model was developed at the Air Force Research Laboratory. Shown here are representative orbits for three GPS and one geosynchronous spacecraft.

PAbelt particles.

Understanding the radiation belt environment and its variability has extremely important practical applications in the areas of spacecraft operations, spacecraft and spacecraft system design, and mission planning and astronaut safety.

JAXA GOSAT

The Greenhouse Gases Observing Satellite "IBUKI" (GOSAT) is the world's first spacecraft to measure the concentrations of carbon dioxide and methane, the two major greenhouse gases, from space (Figure 1). The spacecraft was launched successfully on January 23, 2009, and has been operating properly since then.

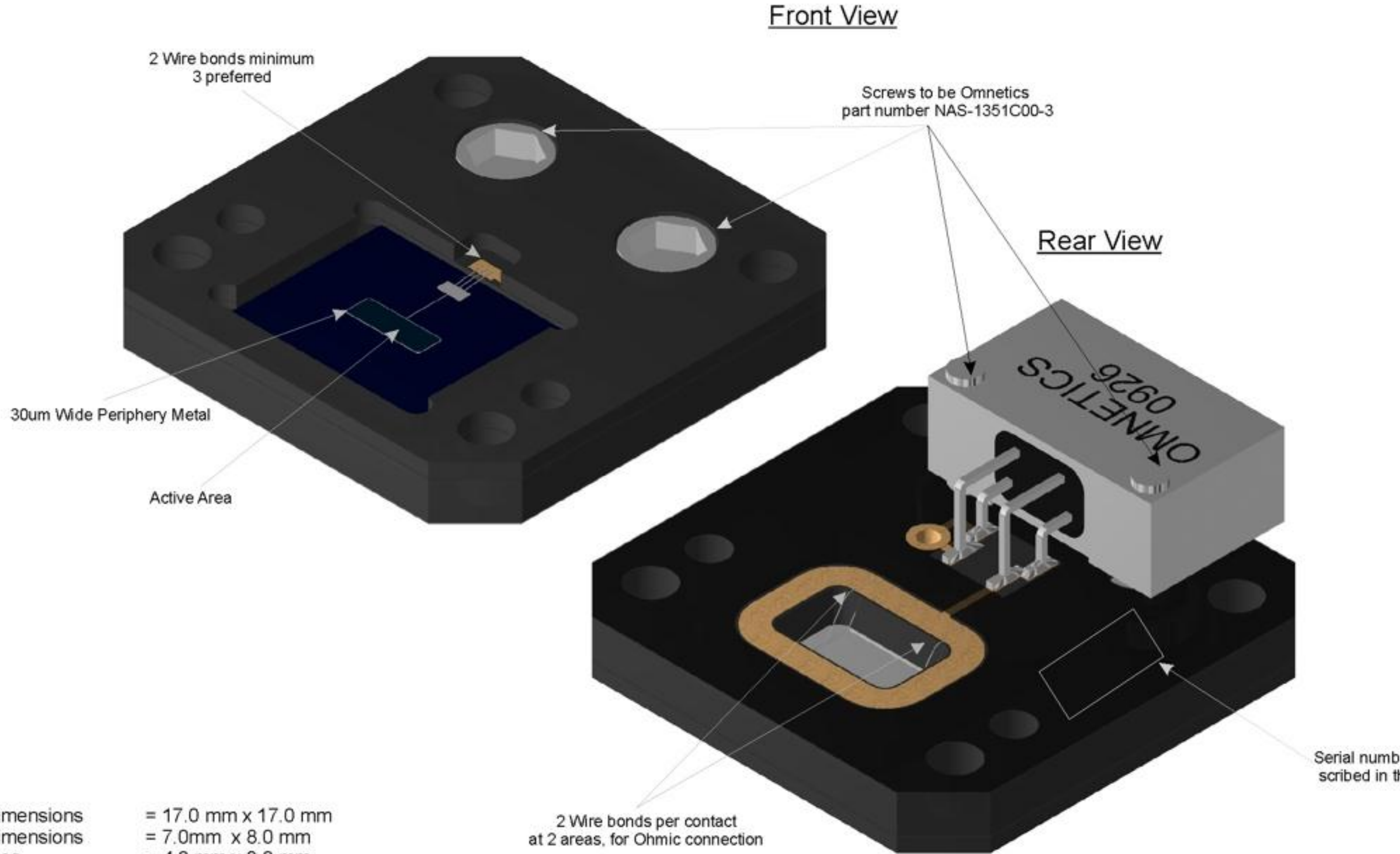
Through analyzing the GOSAT observational data, scientists will be able to ascertain the global distribution of carbon dioxide (CO_2) and methane (CH_4), and how the sources and sinks of these gases vary with seasons, years, and locations. These new findings will enhance scientific understanding on the causes of global warming. Also, they will serve as fundamental information for improving climate change prediction and establishing sound plans for mitigating global warming. The GOSAT Project is a joint effort of the Ministry of the Environment (MOE), the National Institute for Environmental Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA)

MMS/Feeps

Feeps Small

9 micron thick detector

A-3663



cB Dimensions = 17.0 mm x 17.0 mm
ip Dimensions = 7.0mm x 8.0 mm
ch Area = 4.0 mm x 3.0 mm
tive Area = 3.1mm x 1 mm

wn	Checked	Date	Tolerances Unless Stated	Outputs Via: Omnetics Part Number A40881-001
W	S.W	17/08/200	Package O/D ± 0.1 mm	Mating connector: Omnetics Part Number A40882-001
es. pd.			Package Hole ± 0.05 mm	Potted Wire Bonds: No
omer			Package Hole Pos'n ± 0.1 mm	Substrate Number: A-3621
			Detector O/D ± 20.0 μm	Substrate Material: Black FR4 PCB Material

Title.

FEEPS Small.
3D Assembly.
Front and Rear View.

MICRON SEMICONDUCTOR

THIS DOCUMENT IS THE PROPERTY OF
MICRON SEMICONDUCTOR LTD AND IS
COMMERCIAL IN CONFIDENCE

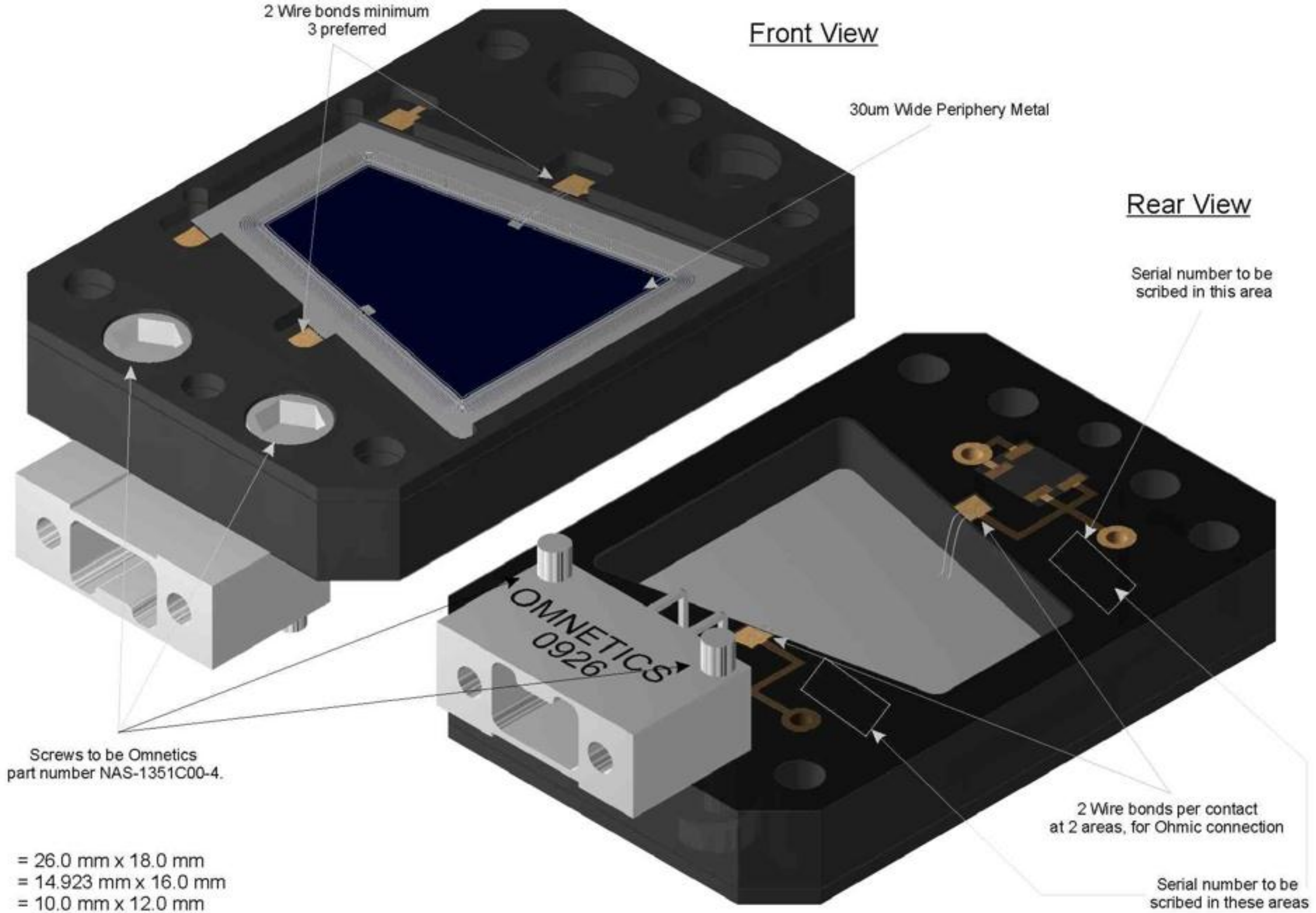
graphics@micronsemiconductor.c

MMS/Feeps

Feeps Large

1000 micron thick detector

664



Front View

2 Wire bonds minimum
3 preferred

30um Wide Periphery Metal

Screws to be Omnetics
part number NAS-1351C00-4.

Rear View

Serial number to be
scribed in this area

2 Wire bonds per contact
at 2 areas, for Ohmic connection

Serial number to be
scribed in these areas

nensions = 26.0 mm x 18.0 mm
nensions = 14.923 mm x 16.0 mm
rea = 10.0 mm x 12.0 mm

cked	Date	Tolerances Unless Stated	Outputs Via: Omnetics Part Number A40881-001
W	27/07/200	Package O/D ± 0.1 mm	Mating connector: Omnetics Part Number A40882-001
		Package Hole ± 0.05 mm	Potted Wire Bonds: No
		Package Hole Pos'n ± 0.1 mm	Substrate Number: A-3633 (machined to parts A-3740 & A-2741
		Detector O/D ± 20.0 µm	Substrate Material: Black FR4 PCB Material

Title.

FEEPS Trapezoid (Left).
3D Assembly.
Front and Rear View.

MICRON SEMICONDUCTOR LIMI

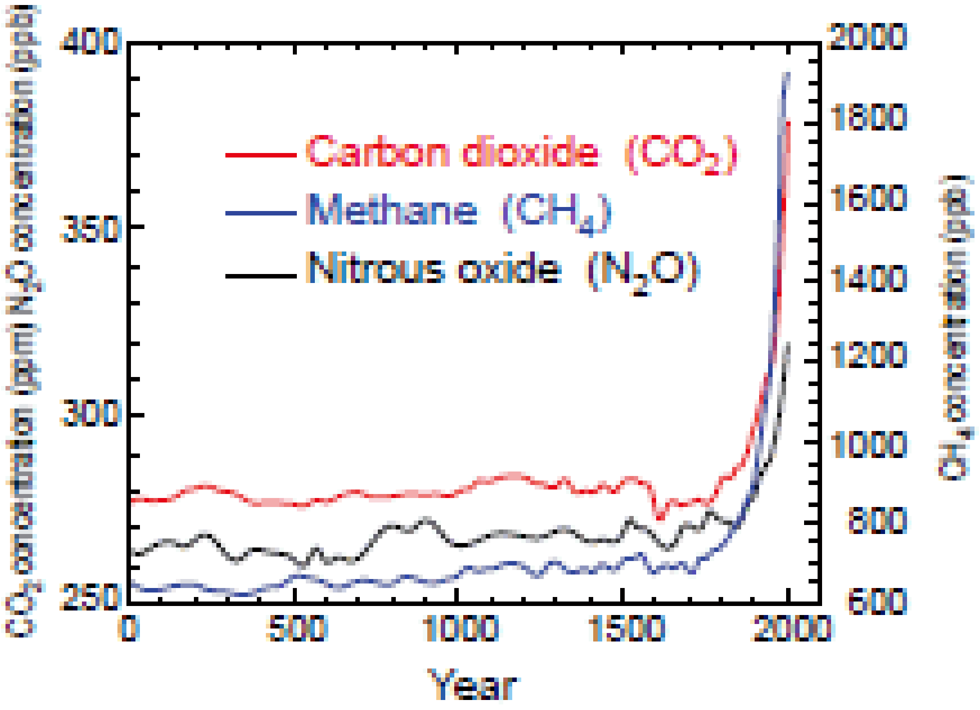
THIS DOCUMENT IS THE PROPERTY OF
MICRON SEMICONDUCTOR LTD AND IS
COMMERCIAL IN CONFIDENCE

graphics@micronsemiconductor.co.uk

JAXA GOSAT

Goals of the GOSAT Project

Due to mass consumption of fossil fuels in the expansion of industrial activities, worldwide emissions of CO_2 increased considerably during the past century. As shown in Figure 3, atmospheric CO_2 concentrations are rising very rapidly. CO_2 has a potential to warm the atmosphere and hence an increase in the concentrations leads to a rise in atmospheric temperatures. CO_2 and other chemical compounds, such as CH_4, nitrous oxide, and halocarbons, are designated as greenhouse gases that are subject to emission regulations under the Kyoto Protocol. CO_2 and CH_4 together account for over 80 percent of the total warming effect caused by these gases

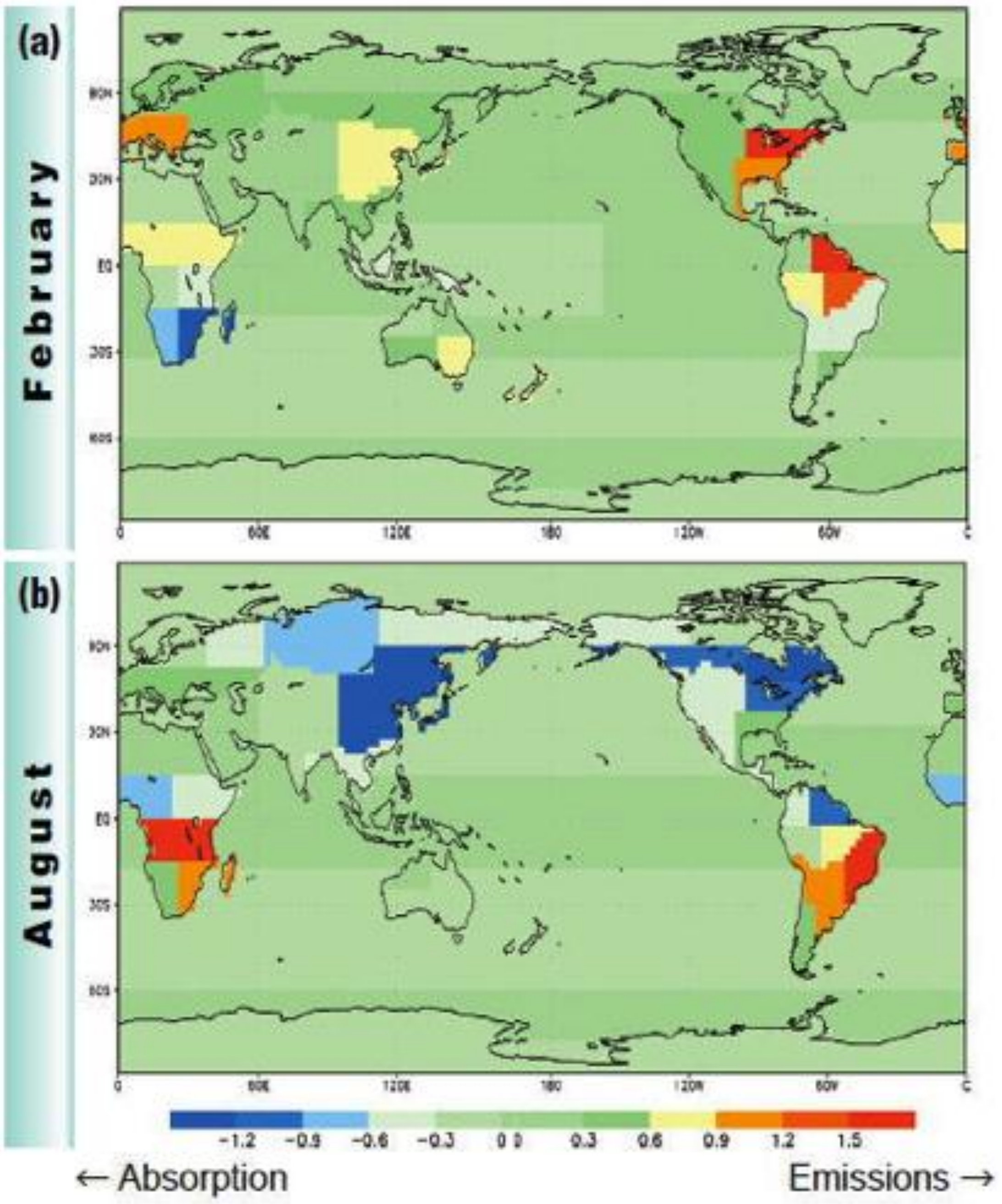


JAXA GOSAT

GOSAT Instruments and Observational Methods

The primary purpose of the GOSAT Project is to estimate emissions and absorptions of the greenhouse gases on a subcontinental scale (several thousand kilometers square; see Figure 5 for an example) more accurately and to assist environmental administration in evaluating the carbon balance of the land ecosystem and making assessments of regional emissions and absorptions.

Figure 5. Sample simulation of global CO_2 sources and sinks ($gC/m^2/day$). a) February; b) August

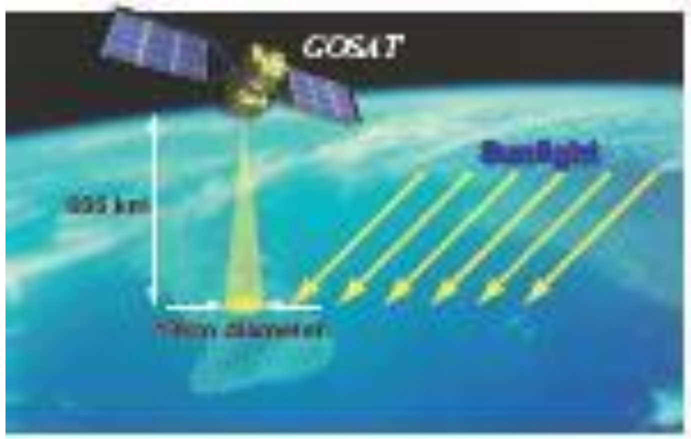


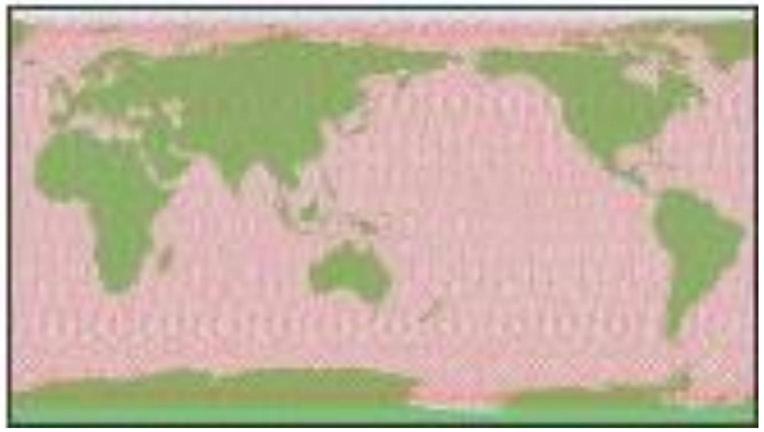
JAXA GOSAT

GOSAT Instruments and Observational Methods

GOSAT observes infrared light reflected and emitted from the earth's surface and the atmosphere. Column abundances of CO_2 and CH_4 are calculated from the observational data. The column abundance of a gas species is expressed as the number of the gas molecules in a column above a unit surface area.

GOSAT flies at an altitude of approximately 666 km and completes one revolution in about 100 minutes. The satellite returns to the same point in space in three days (Figure 6). The observation instrument onboard the satellite is the Thermal And Near-infrared Sensor for carbon Observation (TANSO). TANSO is composed of two subunits: the Fourier Transform Spectrometer (FTS) and the Cloud and Aerosol Imager (CAI).



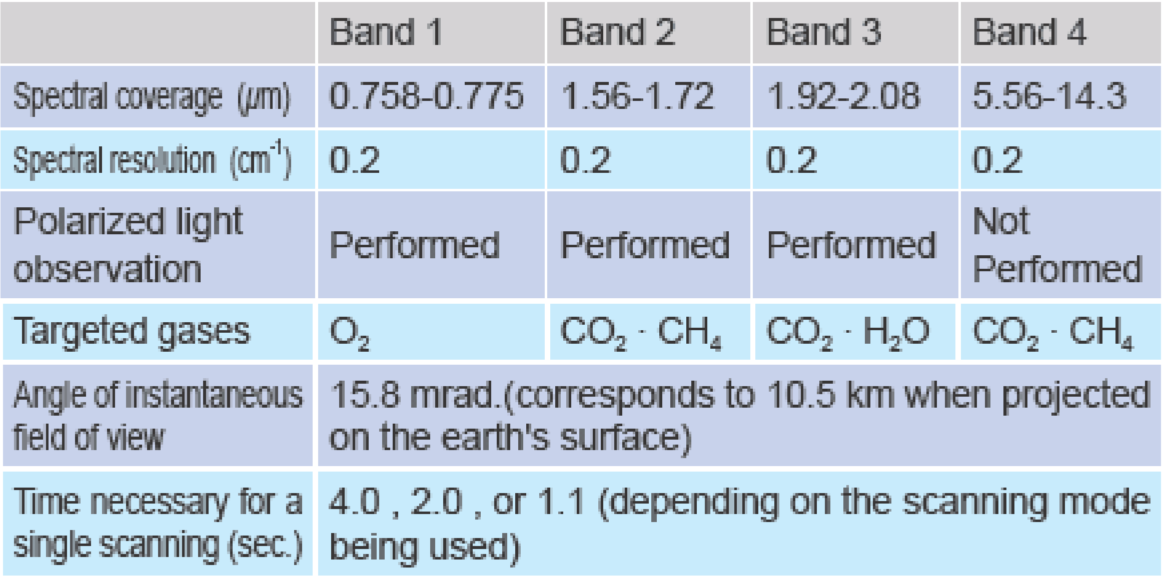


JAXA GOSAT

Specfication

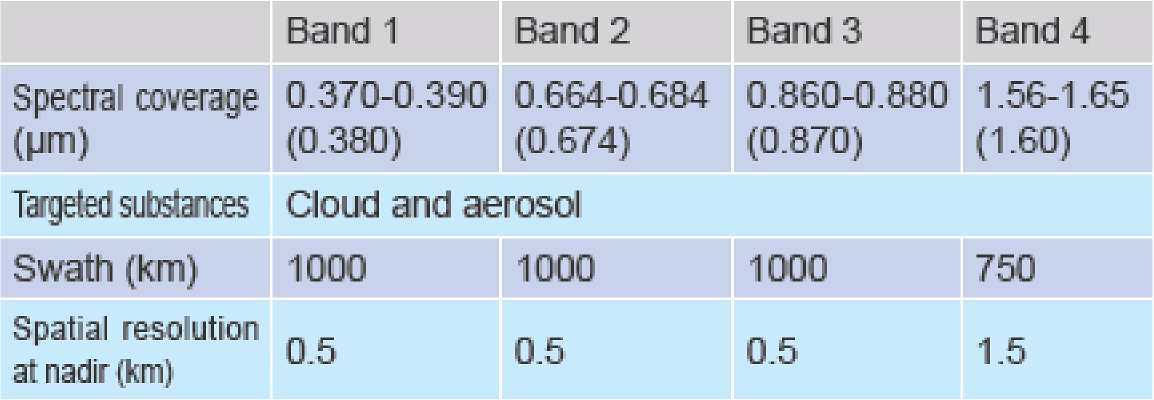
Over the three-day period, FTS takes fifty-six thousand measurements, covering the entire globe. Since the analysis is limited to areas under clear sky conditions, only two to five percent of the data collected are usable for calculating column abundances of CO_2 and CH_4. Nevertheless, the number of data point significantly surpasses the current number of ground monitoring stations, which is below 200. GOSAT serves to fill out the blanks in the ground observation network.

Table 1. Specifications of FTS



	Band 1	Band 2	Band 3	Band 4
Spectral coverage (μm)	0.758-0.775	1.56-1.72	1.92-2.08	5.56-14.3
Spectral resolution (cm^{-1})	0.2	0.2	0.2	0.2
Polarized light observation	Performed	Performed	Performed	Not Performed
Targeted gases	O_2	$CO_2 \cdot CH_4$	$CO_2 \cdot H_2O$	$CO_2 \cdot CH_4$
Angle of instantaneous field of view	15.8 mrad.(corresponds to 10.5 km when projected on the earth's surface)			
Time necessary for a single scanning (sec.)	4.0 , 2.0 , or 1.1 (depending on the scanning mode being used)			

Table 2. Specifications of CAI



	Band 1	Band 2	Band 3	Band 4
Spectral coverage (μm)	0.370-0.390 (0.380)	0.664-0.684 (0.674)	0.860-0.880 (0.870)	1.56-1.65 (1.60)
Targeted substances	Cloud and aerosol			
Swath (km)	1000	1000	1000	750
Spatial resolution at nadir (km)	0.5	0.5	0.5	1.5

Fabrication and Assembly Summary

Implant and Metal Thickness

SS DETECTOR DIAMETER 7 mm, Type 9

Si Substrate 50 micron

P-SIDE

Deep Implant Depth = 1 µm
Shallow Implant Depth = 0.1 µm

Metal Periphery Thickness = 1 µm
AA Metal Thickness = 0.1 µm

N-SIDE

Shallow Implant Depth = 0.1 µm

Metal Thickness = 1 µm

Active Implant Diameter = 7000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2
Chip Dimension = 10000 x 10000 μm^2

SS DETECTOR DIAMETER 4 mm, Type 9

Si Substrate 80 micron

P-SIDE

Deep Implant Depth = 1 µm
Shallow Implant Depth = 0.1 µm

Metal Periphery Thickness = 1 µm
AA Metal Thickness = 0.1 µm

N-SIDE

Shallow Implant Depth = 0.1 µm

Metal Thickness = 1 µm

Active Implant Diameter = 4000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2

Chip Dimension = 7000 x 7000 μm^2

SS DETECTOR DIAMETER 8 mm, Type 9

Si Substrate 80 micron

P-SIDE

Deep Implant Depth = 1 µm
Shallow Implant Depth = 0.1 µm

Metal Periphery Thickness = 1 µm
AA Metal Thickness = 0.1 µm

N-SIDE

Shallow Implant Depth = 0.1 µm

Metal Thickness = 0.3 µm

Active Implant Diameter = 8000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2

Chip Dimension = 10 000 x 10 000 μm^2

SS DETECTOR DIAMETER 18 mm, Type 9

Si Substrate 1500 micron

P-SIDE

Deep Implant Depth = 1 µm
Shallow Implant Depth = 0.1 µm

Metal Periphery Thickness = 1 µm
AA Metal Thickness = 0.1 µm

N-SIDE

Shallow Implant Depth = 0.1 µm

Metal Thickness = 0.3 µm

Active Implant Diameter = 18000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2

Chip Dimension (Flat-to-Flat) = 21500 µm
Number of Flats = 8

DS STRIP DETECTOR

Si Substrate 500 micron

P-SIDE

Deep Implant Depth = 1 μm
Shallow Implant Depth = 0.1 μm

Metal Periphery Thickness = 1 μm
AA Metal Thickness = 0.1 μm

N-SIDE

Deep Implant Depth = 1 μm
Shallow Implant Depth = 0.1 μm

Metal Thickness = 0.3 μm

Junction Side:

Number of Strips = 16
Active Implant Strip Width = 1150 μm
Active Implant Strip Length = 19900 μm
Strip Separation = 100 μm

Metal Bond Pad = 300 x 300 μm^2
(At each end)

Ohmic Side:

Number of Strips = 16

Active Implant Strip Width = 1150 μm
Active Implant Strip Length = 19900 μm
Strip Separation = 100 μm

Isolation Method P-Stops

Metal Bond Pad = 300 x 300 μm^2
(At each end)

Chip Dimension = 22900 x 22900 μm^2

Specifications

Silicon Detector Dimensions

50 micron 7 mm Diameter Detector

Active Implant Diameter = 7000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2
Chip Dimension = 10000 x 10000 μm^2

80 micron 4 mm Diameter Detector

Active Implant Diameter = 4000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2
Chip Dimension = 7000 x 7000 μm^2

250 micron 8 mm Diameter Detector

Active Implant Diameter = 8000 µm
Active Area Metal Bond Pad = 300 x 300 μm^2
Chip Dimension = 10 000 x 10 000 μm^2

500 micron Double Sided Strip Detector

<u>Junction Side:</u>
Number of Strips = 16
Active Implant Strip Width = 1150 µm
Active Implant Strip Length = 19900 µm
Strip Separation = 100 µm
Metal Bond Pad = 300 x 300 μm^2
(At each end)

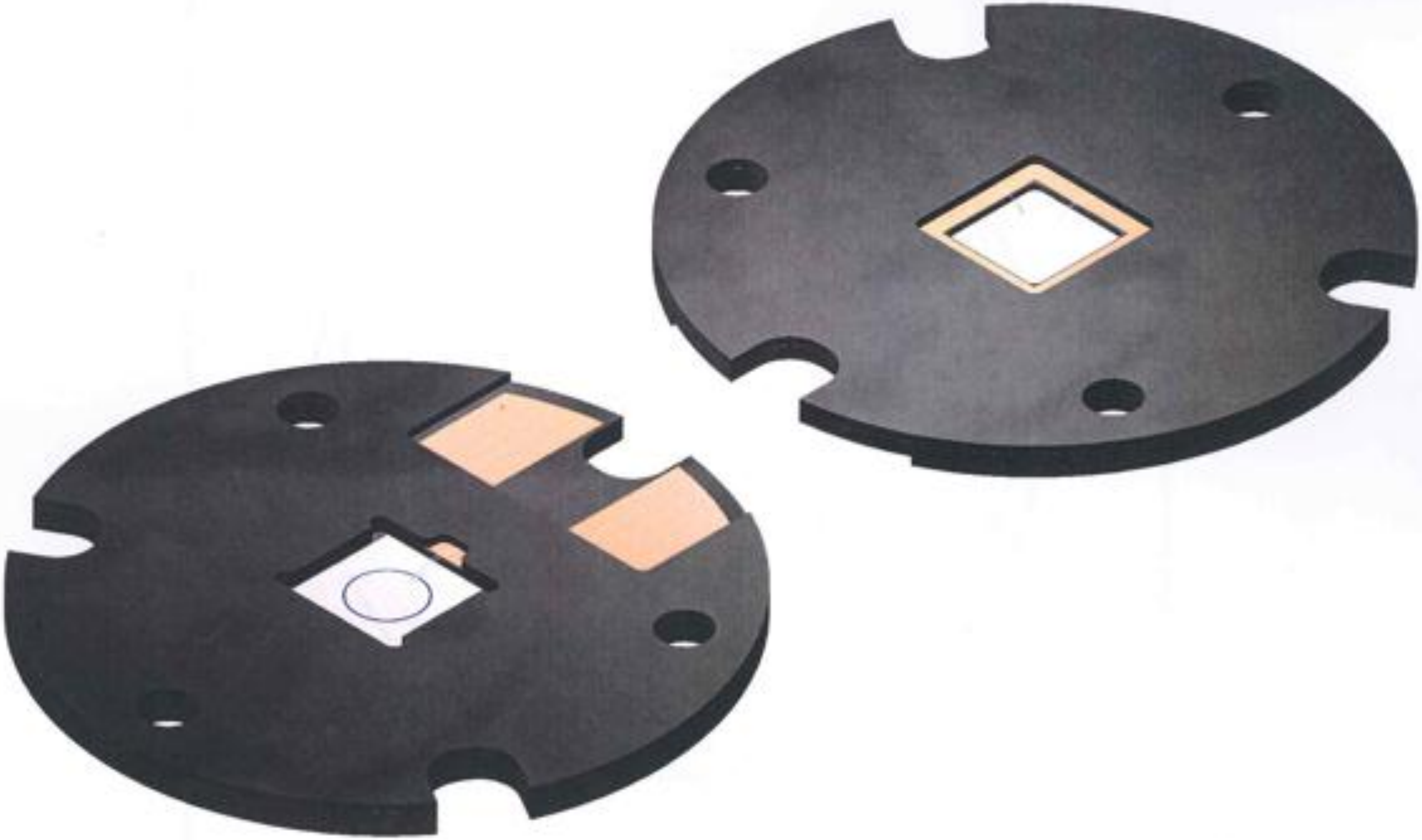
<u>Ohmic Side:</u>
Number of Strips = 16
Active Implant Strip Width = 1150 µm
Active Implant Strip Length = 19900 µm
Strip Separation = 100 µm
Isolation Method P-Stops
Metal Bond Pad = 300 x 300 μm^2
(At each end)
Chip Dimension = 22900 x 22900 μm^2

1500 micron 18 mm Diameter Detector

Active Implant Diameter = 18000 μm
Active Area Metal Bond Pad = 300 x 300 μm^2
Chip Dimension (Flat-to-Flat) = 21500 μm
Number of Flats = 8

Drg No A-2519

THIS DOCUMENT IS THE PROPERTY OF MICRON SEMICONDUCTOR LTD AND IS COMMERCIAL IN CONFIDANCE



awn
W
cked
.N
cked
te
s.
pd.
d
pd
st

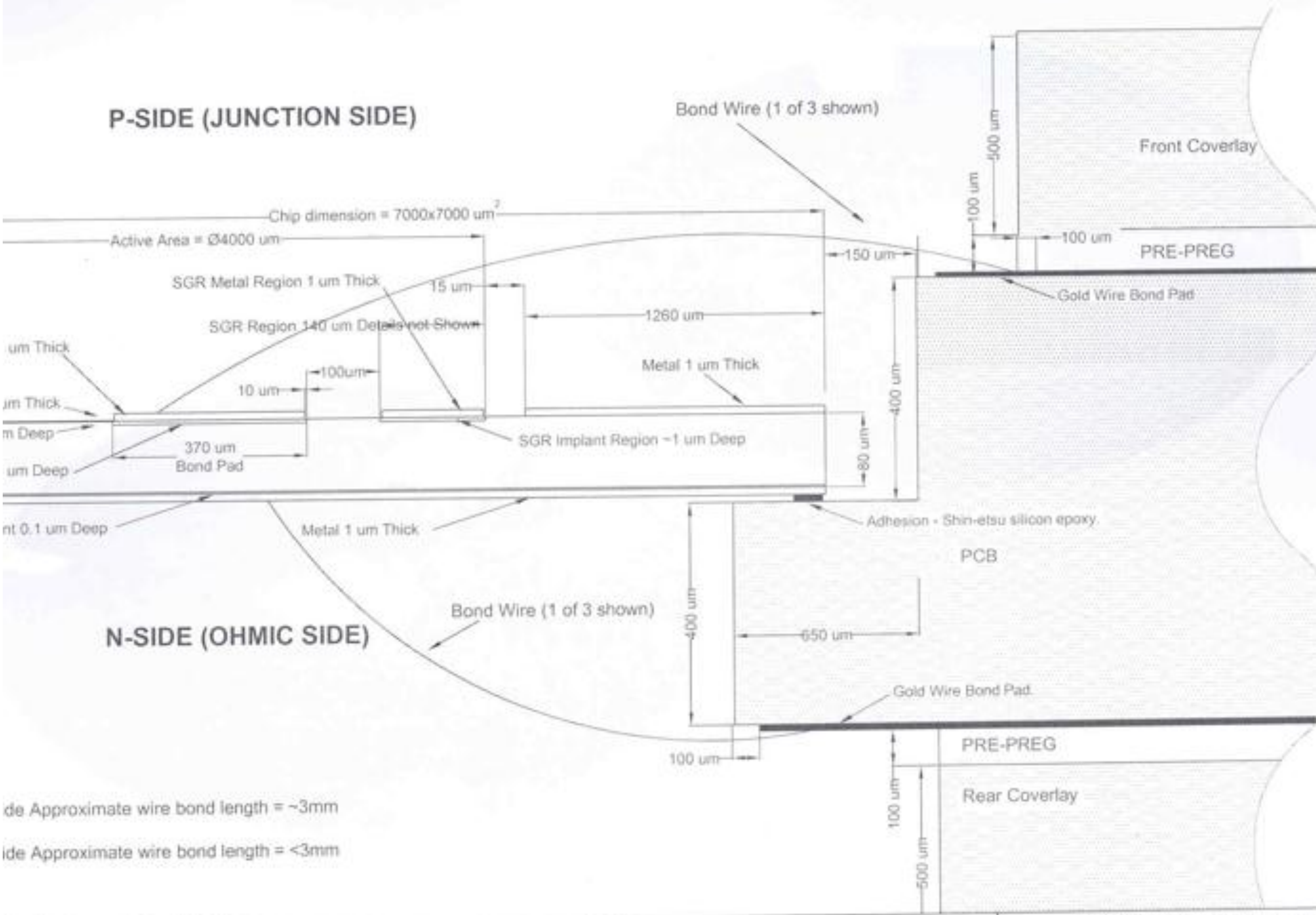
Issue	Date	Tolerances Unless Stated
1	17/12/02	Package O/D ± 0.1mm
		Package Hole ± 0.05mm
		Package Hole Pos'n ± 0.1mm
		Detector O/D ± 25.0μm

Details.
Light tight multi layer PCB.

Title.
MSD 004
3D Assembly.

MICRON SEMICONDUCTOR LIMITED
1 Royal Buildings, Marlborough Rd,
Sussex, Bn15 8UN, UK.
E-Mail microndesign@btconnect.com

Scale N/A	Dims In. mm	Drg No A-2519



de Approximate wire bond length = ~3mm

ide Approximate wire bond length = <3mm

od.

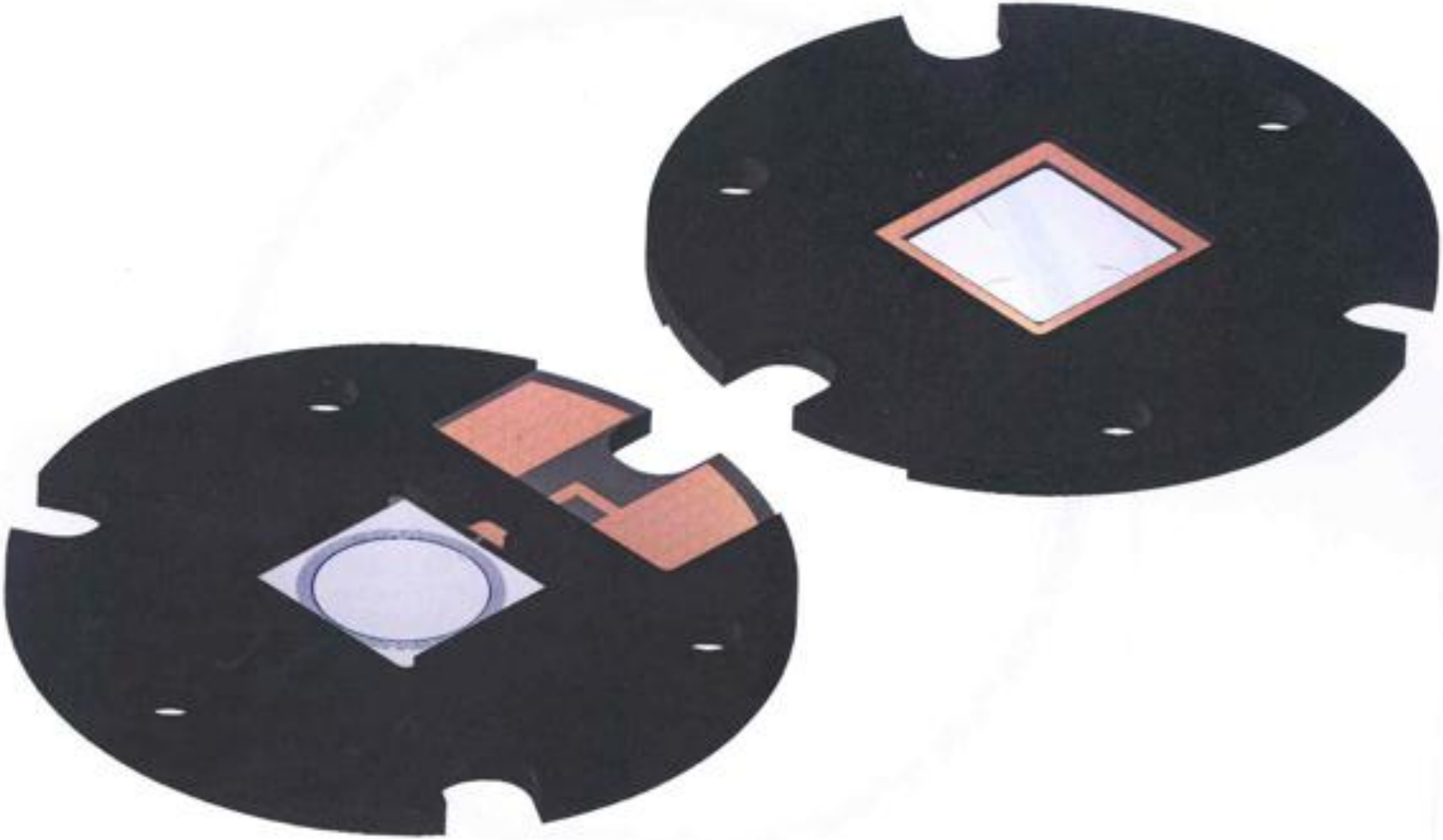
Tolerances Unless Stated.
± 0.0mm

Details.
PCB Material to be Black G10
with black ink.
NOT TO SCALE

Title.
Side Profile of B,B (see drawing
A-2469) 80 micron Ø4 mm Diode.
Detail of chip and PCB.

MICRON SEMICONDUCTOR LIMI
1 Royal Buildings, Marlborough Rd.
Sussex, BN15 8SJ. U.K.
E-Mail design@micronsemiconductor.co.uk

Dims In um
Drg. No. A-3



ssue	Date	Tolerances Unless Stated
1	19/06/03	Package O/D ± 0.1mm
		Package Hole ± 0.05mm
		Package Hole Pos'n ± 0.1mm
		Detector O/D ± 25.0µm

Details.

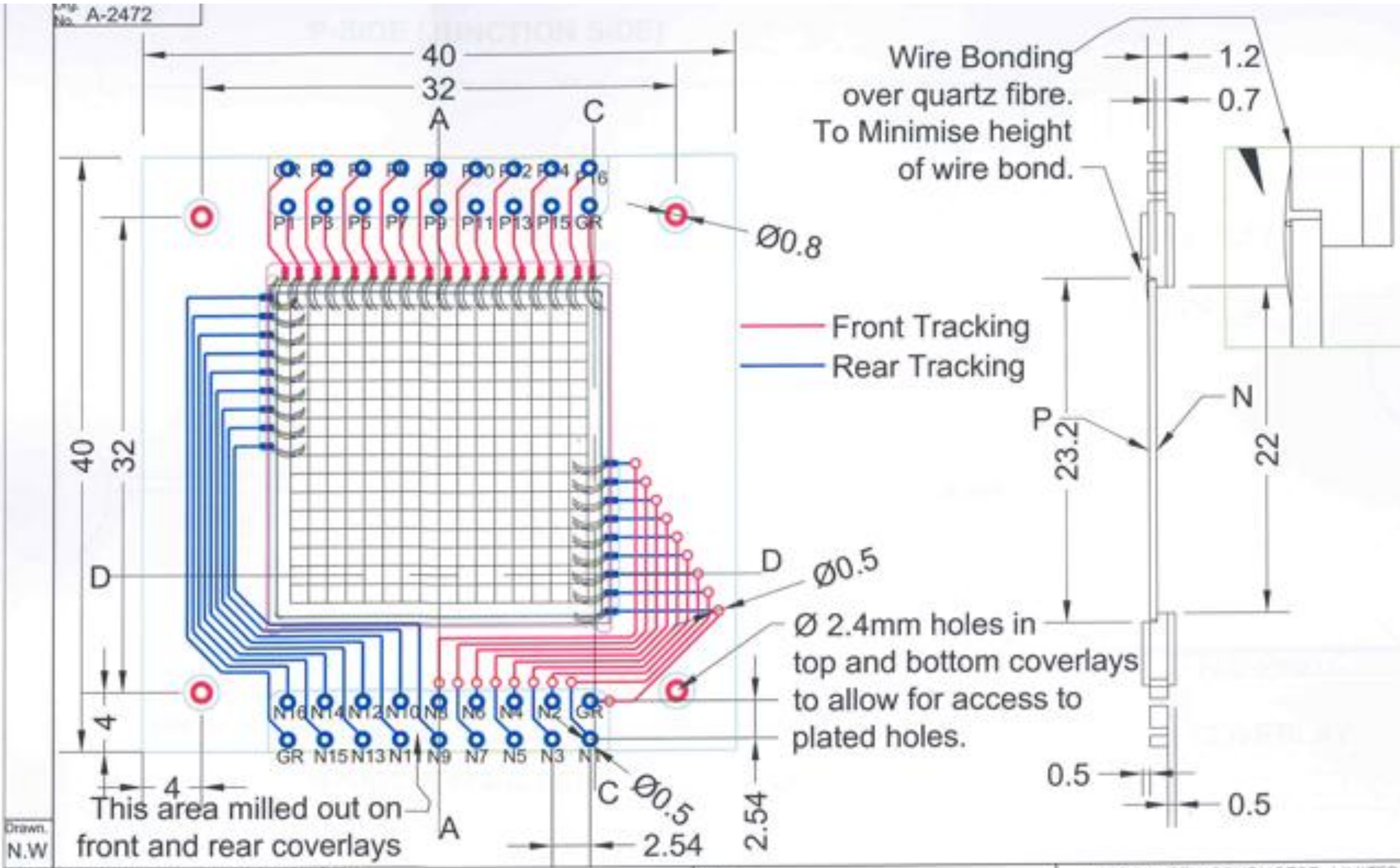
Light Tight Multi Layer PCB

Title.

NASDA MSD 008-250
3D Assembly.
P.O Number 203050034

MICRON SEMICONDUCTOR LIMITED
1 Royal Buildings, Marlborough Rd,
Sussex, Bn15 8UN, UK.

te	Tolerances Unless Stated	Details.	Title.	MICRON SEMICONDUCTOR LIMITED
2/02	Package O/D ± 0.1mm	Light tight multi layer PCB.	MSD 018 3D Assembly.	1 Royal Buildings, Marlborough Rd, Sussex, Bn15 8UN, UK. E-Mail microndesign@btconnect.com
	Package Hole ± 0.05mm			
	Package Hole Pos'n ± 0.1mm			
	Detector O/D ± 25.0μm			Scale N/A | Dims In. mm | Drg No A-2521



Drawn. N.W

Checked N.G

Issue.	Date.	Mod.
1	23/12/2002	

Des. Appd.

Customer

Tolerances Unless Stated. ± 0.1mm PCB

Scale. 3:1

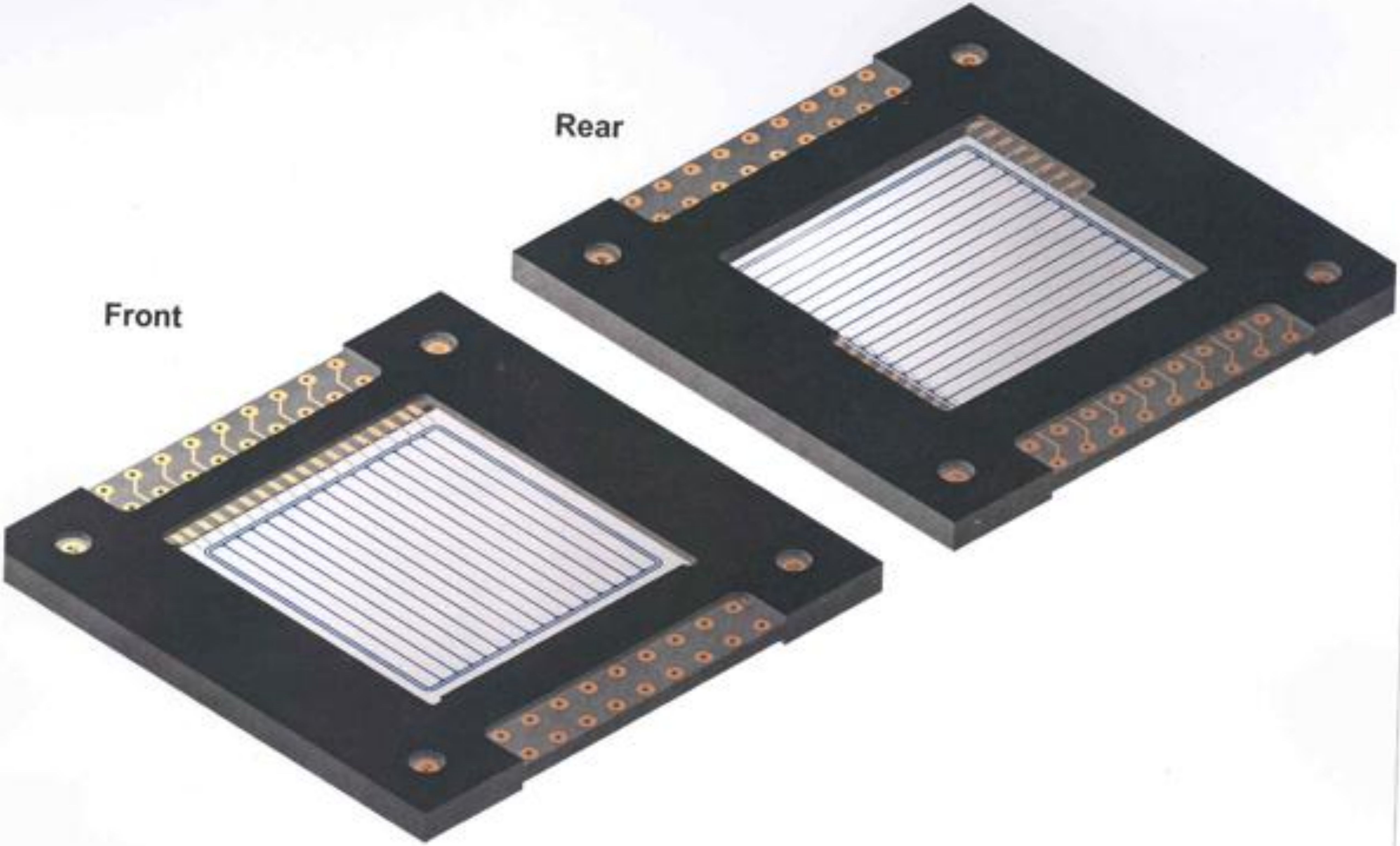
Details. 1x1.2mm Thick G10 Material With 0.5mm deep ledge from top. 2x0.5mm Thick Coverlays. All material to be black based resin. All tracking to be soft Gold on Copper.

Title. 500 Micron 20 x 20 x 0.5mm DSSD. For NASDA Space Project. Multi Layer PCB.

MICRON SEMICONDUCTOR LIMITED
1 Royal Buildings, Marlborough Rd.
Sussex, BN15 8UN, U.K.
E-Mail microngraphics@btconnect.com

Dims In. mm

Drg. No. A-2472



sue	Date	Tolerances Unless Stated
1	17/12/02	Package O/D ± 0.1mm
		Package Hole ± 0.05mm
		Package Hole Pos'n ± 0.1mm
		Detector O/D ± 25.0μm

Details.

Shipped with no connector as per customer request.

Title.

BB8 3D Assembly.

MICRON SEMICONDUCTOR LIMITED
1 Royal Buildings, Marlborough Rd,
Sussex, Bn15 8UN, UK.
E-Mail microndesign@btconnect.com

Summary

Silicon detectors are now an important part of science in studying space weather and relation to earths environmental conditions.

Micron Semiconductor Ltd has provided space qualified detectors to many missions with thicknesses from 9 microns to 2500 microns.

Larger projects with micro strips have been launched taking valuable data for the study of gamma bursts and supernova events eg Glast and Pamela

Micron is continuing with GOES-R requiring 800 sorted detectors from a multitude of launches requiring 2 years storage and 10 year operational geosynchronous equitorial orbit.

New missions involving the company are VISIONS studying electrons from an Alaska rocket launch using ultra thin window detectors and SOLAR PROBE a new NASA mission where the detectors get within 94% distance of the sun.