February 14, 1992
FAST-SPEC-006

SPECIFICATION FOR THE FAST SOLAR ARRAY PANELS

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

REVIEW SHEET FOR

FAST-SPEC-006

SPECIFICATION FOR THE FAST SOLAR ARRAY PANELS

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APPROVAL SHEET FOR

FAST-SPEC-006

SPECIFICATION FOR THE FAST SOLAR ARRAY PANELS

This is a project controlled document. Any changes require the approval of the project configuration control board.

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Specification for the FAST Solar Array Panels

1.0 SCOPE

This specification defines the performance, design, assembly, inspection, test, and delivery requirements for solar panels intended for use on the FAST spacecraft.

2.0 APPLICABLE DOCUMENTS

The following documents, of the issues in effect on the date of the contract, form a part of this specification. When conflicts occur between this specification and the documents listed herein, the requirements of this specification shall apply.

2.1 SPECIFICATIONS

Federal Specification QQ-S-571	Solder; Tin Alloy; Lead-Tin Alloy; and Lead Alloy
MIL-P-11268	Parts, Materials and Processes Used in Electronic Equipment
MIL-W-22759	Wire, Electric, Fluoropolymer-Insulated, Copper or Copper Alloy
GSFC S-740-88-999	Performance Assurance Requirements (PAR) for the Small-Class Explorer (SMEX) Spacecraft
GSFC 311-P-18	Thermistor, Insulated, Negative Temperature Coefficient
GSFC S-311-P-4	GSFC Connectors, Electrical, Subminiature, Polarized Shell, Rectangular
MIL-S-19500	Semiconductor Device, General Specification for

2.2 STANDARDS

MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts

2.3 PUBLICATIONS

NHB-5300.4 (3A-1)	NASA Reliability and Quality Assurance Publication, Requirements for Soldered Electrical Connections
NASA TN D-7362	A Compilation of Outgassing Data for Spacecraft Materials
ASTM-E-834-81	Determining Vacuum Chamber Gaseous Environment Using a Cold Finger
NHB-6000.1C	Requirements for Packaging, Handling, and Transportation

3.0 REQUIREMENTS

3.1 GENERAL DESCRIPTION OF THE FAST SOLAR ARRAY

The FAST solar array will consist of two solar array structures, designated Panel A and Panel B. The spacecraft looks like a cylindrical can. In over-simplified terms, structure A forms the top "half" of the cylindrical can and structure B forms the bottom "half" of the cylindrical can. Each structure therefore consists of faceted sides, Part 1, and a flat end, Part 2. The side part of Panel A is designated A-1 and is subdivided into 9 facets; the end part of Panel A is designated A-2; the side part of Panel B is B-1 and is subdivided into 9 facets; the end part of Panel B is B-2. The general relationship between Panels A, B, their ends, and facets is provided in Figure 1. The facets and end parts are shown in Figures 2 through 20. Please keep in mind that, although the facets for Panel A are shown separately, they form a single structure with each other and the end part of Panel A. The same is true of Panel B. The FAST solar array shall have a conductive front surface connected to spacecraft ground, including the cover outer surfaces, the intercell gaps, and any other areas not covered by solar cells.

3.1.1 Mechanical Interface Description

3.1.1.01 Substrates

Each of two government-furnished flight panel substrates will consist of an aluminum honeycomb core, an aluminum rear face sheet coated with thermal paint, and an aluminum front face sheet insulated with micaply.

3.1.1.02 Component "Height"

Contractor mounted parts and subassemblies shall extend less than 0.100 inch off of the front and less than 0.150 inch off of the rear facesheet surfaces with the exception of the terminal board assemblies and connectors.

3.1.2 Electrical Interface Description

3.1.2.01 Panel-to-Spacecraft Harnessing

The rear of Panel A shall have two contractor-installed connectors at the end of 200-mm long pigtail harnesses. One connector shall carry primary and one connector shall carry redundant array power, array power return, shunt power, shunt power return, and thermistor signals as defined in Tables 1 and 2. The same harnessing configuration applies to Panel B.

3.2 DESIGN DATA

The Design Data specified herein define the preliminary design of the FAST solar array panels. The contractor shall complete the detailed critical design by including the cell interconnect, the cover interconnect, the cover interconnection methods, the means to make the cover surface and the intercell gap surface conductive and all other undefined items. Due to severe shadowing on the array for which the design has already been optimized, only minor changes in cell circuit layout may be considered. The contractor may optimize the layout for a specific interconnector design, increase cell sizes, and reduce the regions provided for bus bars, feed-throughs, etc. to extend any circuit into regions allowed for solar cells as shown in Figures 1 through 18.

All contractor-supplied drawings shall be complete detailed specifications of all hardware and wiring. The review and approval of these drawings by the GSFC shall not release the contractor from design verification responsibilities.

3.2.1 Front (Cell Side) Layout of Flight and Qualification Panels

The flight panel front layouts shall be in accordance with contractor prepared and GSFC approved drawings. The conductive-coated covers shall be electrically interconnected to create a conductive surface, including intercell gaps and other areas not covered by solar cells. The contractor shall propose three methods for creating a conductive surface. The three methods shall be incorporated into the qualification panel layout as described below. At the conclusion of thermal cycle testing on the qualification panel, a method for creating a conductive surface shall be proposed by the contractor for the flight panels. The method selected for the flight panels must be approved by the GSFC prior to implementation. The solar cells shall be bonded to the substrate insulator.

The solar cell layout of the flight panels shall be in accordance with Figures 2 through 19.

The qualification panel front layout shall be in accordance with contractor prepared and GSFC approved drawings. The contractor shall manufacture one qualification panel to a contractor proposed, GSFC approved layout. The size of the GFE insulated qualification panel substrate shall be 12" x 18". The solar cell layout shall include a minimum of six solar cell circuits. The contractor shall use three pairs of circuits to test three different cover interconnect schemes (i.e., two circuits for each different scheme). The contractor shall accurately simulate the proposed flight panel design in all other respects.

3.2.2 Panel Wiring and Rear Layout

The flight and qualification panel wiring shall be in accordance with contractor prepared and GSFC approved drawings. On all panels, the solar cell interconnects shall make at least three connections between solar cells. There shall be at least two connections to turn-around terminations. There shall be at least two connections to each conductively coated cover.

For Panel A and Panel B, a single positive and negative connection from each cell string shall feed through from the front to the rear of the structure and then run to and terminate at one of two terminal boards. The contractor shall locate one terminal board on facet 3 and the other on facet 4. The contractor shall locate these terminal boards as close to the spacecraft X-Y plane (defined as the interface between Panel A and Panel B as pictured in Figure 1) as practicable. The contractor shall route each wire in the shortest practical path from the contractor drilled feed through to the closest terminal board. Each terminal board shall receive input from approximately half of the strings on the structure.

The positive and negative connection from each string shall be flat bonded to the surface of the panel at intervals not exceeding 3 inches and shall be as close to each other as practical.

Each negative connection from a cell string shall terminate at a terminal post which shall be connected to all other negative terminal posts on the terminal board. The negative terminal posts on the two terminal boards on Panel A shall be connected together. The same shall be true of the two terminal boards on Panel B. Each positive connection from a circuit shall terminate at a terminal post which shall be connected to the anode of a blocking diode. Each diode cathode shall be connected to a terminal post which shall be connected to all other cathode terminal posts on the terminal board. The cathode terminal posts on the two terminal boards on Panel A shall be connected together. The same shall be true of the two terminal boards on Panel B.

The diode terminal boards shall not extend more than 0.35 inches from the surface of the back face sheet. The clearance requirement shall not apply to the 200-mm pigtails. Thermistor outputs shall be routed as twisted pairs to the terminal board. The terminal board outputs shall be routed to the panel output connectors in accordance with Tables 1 and 2.

For Panel A and Panel B, the contractor shall wire shunt dissipators to the terminal boards the contractor shall locate on facets 3 and 4 in accordance with Tables 1 and 2.

The contractor shall mount the 16 government supplied shunts on the back of Panels A-1 and B-1 as follows: one shunt each on the back of facets 1, 2, 5, 7, 8, and 9 and two shunts on the back of facet 6 on Panel A-1; one shunt each on the back of facets 2, 5, 6, 7, 8, and 9 and two shunts on the back of facet 1 on Panel B-1. The contractor shall locate the cell string feed through holes and position of the shunts so that power or thermistor wires do not penetrate the shunts. Harnesses shall be located at least one inch from the shunts.

3.2.2.1 Qualification Panel Rear Layout

The rear layout of the qualification panel shall be in accordance with contractor prepared and GSFC approved drawings. The rear wiring for the strings shall be routed from the feed-through holes to a flight-type terminal board. The terminal board shall have an output connector as specified for the flight panels. The wires, connectors, and diode terminal board shall be bonded to the rear substrate face sheet in flight configuration. The qualification panel shall have flight-type temperature sensors wired to the terminal board. The temperature sensors shall be bonded to the qualification panel as specified for the flight panels. In addition, the qualification panel shall carry two flight-type shunt dissipators (kapton encapsulated foil heaters) bonded to the rear face sheet and wired to the output connector. The shunt dissipators shall be powered during the high-temperature portions of qualification panel temperature cycling.

3.3 PANEL REQUIREMENTS

3.3.1 Weight

The weight of the completed solar array Panel A minus the weight of the government furnished insulated substrate shall not exceed 8.60 kg. The weight of the completed solar array Panel B minus the weight of the government-furnished insulated substrate shall not exceed 6.40 kg.

3.3.2 Center of Mass and Moments of Inertia

The contractor shall compute the center of mass and the moments of inertia about the axes defined in Figure 1and described below for the type A and type B panels based upon the preliminary design and the as built configuration.

The origin for each panel for this moment of inertia computation shall be its center of mass. The +X-axis is perpendicular to facet 1. The -Y-axis is perpendicular to facet 8 (the +Y-axis runs through the side opposite facet 8 composed of facets 3 and 4). The +Z-axis is perpendicular to Panel A-2.

3.3.3 Circuit Insulation Resistance

After circuit assembly, each of the two panels shall have an insulation resistance greater than 100 megohms between any point on the substrate and any point on a cell, interconnect, diode, wire, connector contact, terminal or any circuit point.

3.3.4 Substrate Grounding

For Panel A and Panel B, the solar array panel design shall provide two connections per facet, two connections for A-2, and two connections for B-2 for substrate grounding. These connections shall be routed to the terminal boards and shall ground the front and rear facesheets. These connections shall be electrically connected together at the terminal boards, and a connection from each terminal board to its output connector shall be provided for substrate ground in accordance with Tables 1 and 2. In addition, the connector shells shall be grounded to the substrate.

3.3.5 Equipotential Surface Characteristics

The potential difference between any two points on the FAST solar array front surface caused by the charged particle environment of the FAST orbit (350 X 4200 Km, 83° inclination) shall not exceed 100 millivolts in the presence of a current of one microampere. The equipotential surface shall be grounded to the substrate for each facet on each panel using a contractor proposed, GSFC approved method.

3.3.6 Beginning-of-Life (BOL) Electrical Power Output

Under air-mass-zero (AM0) illumination and at a panel temperature of 28 °C, the current-voltage output from solar array panels on the anode side of the diode shall exceed the values specified in Table 3. The measured current-voltage curve shall not exhibit any anomalies caused by high series resistance, broken cells, broken interconnect, or any other defect.

All current and voltage loss factors with justification including losses due to the conductive surface shall be provided by the contractor.

3.3.7 Qualification Panel BOL Current-Voltage Output

The qualification panel circuits shall perform with equivalent or higher AM0 efficiencies as required for the flight panel circuits. The qualification panel current-voltage curve shall not exhibit any anomalies caused by high series resistance, broken cells, broken interconnect, or any other defect.

3.3.8 End-of-Life (EOL) Electrical Power Output

The contractor shall supply predictions for Voc, Isc, Vmp, and Pmax at 101°C under AM0 illumination after exposure to all environments specified under requirement 3.6 of this document for Panel A-2 and Panel B-2.

The contractor shall supply predictions for Voc, Isc, Vmp, and Pmax at 45°C under AM0 illumination after exposure to all environments specified under requirement 3.6 of this document for each facet on Panel A-1 and each facet on Panel B-1.

Current and voltage degradation factors with justification shall be provided by the contractor for each environment.

3.3.9 Magnetic Field

All components and materials assembled on the flight solar array panels shall be nonmagnetic.

The stray magnetic field of the solar array panels shall be minimized by alternating the current direction of solar cell strings on the front of each panel as specified in Figures 2 through 19. In addition, the positive wire from each circuit shall retrace the cell interconnector current path such that the stray magnetic field is cancelled as in Figure 21. Silver-expanded metal shall be used to provide magnetic compensation wiring directly under (but electrically insulated from) each circuit. From that point, the positive and negative wires from any solar cell string to any diode or connector shall feed through the substrate and be bonded immediately adjacent to each other on the back of the substrate.

The total stray magnetic field from all panels and facets measured at a distance of 3.5" from the front surface of any facet (at any point on that facet) for any sunlight incidence angle shall not exceed 7.85 gammas.

3.4 COMPONENT AND SUBASSEMBLY REQUIREMENTS

3.4.1 Solar Cells

3.4.1.01 Solar Cell Type

The FAST solar array panels shall consist of space-flight-qualified gallium arsenide on germanium single junction solar cells. At a minimum the vendor shall present design data consisting of the results of charged particle irradiation (electron and proton), ultraviolet light exposure, temperature and humidity testing, and reverse-bias testing on the cells.

3.4.1.02 Solar Cell Contacts and Grids

Each solar cell shall have vacuum-deposited contacts and grids. The contacts and grids shall consist of contractor-proposed materials. The bond between the deposited layers of the contacts and the solar cell shall be sufficient in strength to pass the tape pull test specified in Section 4.2.3.18 of this document. The n-contact and p-contact shall be weldable or solderable without degrading the cell power output by more than 1.0 percent.

3.4.1.03 Solar Cell Antireflective Coating

Each solar cell shall have a multilayer antireflective (AR) coating covering the entire active cell surface, but not encroaching onto the top contact surface such that solderability or weldability shall be compromised. The AR coating shall be optimized to minimize reflections at the cover adhesive / solar cell interface over the spectral response range of the solar cell. Adherence of the AR coating to the cell shall be sufficient in strength to pass the AR coating durability test specified in Section 4.2.3.15 of this document.

3.4.1.04 Solar Cell Absorptance

The average absorptance of the cells on each panel over the AM0 solar spectrum shall be equal to or less than 0.89 when used with the cover specified in requirement 3.5.2 of this document.

3.4.1.05 Solar Cell Dimensions

Solar cells shall be nominally sized to the dimensions provided in Figures 1 through 18. The cells shall have a nominal thickness of 0.005 inches.

3.4.1.06 Solar Cell Electrical Performance

The bare solar cells for Panels A and B shall meet the following requirements at 28°C and 1 sun Air-Mass Zero (AM0). The minimum lot average voltage at maximum power shall be equal to or greater than 0.87 volts. The minimum lot average maximum power shall be equal to or greater than 0.0241 watts per square centimeter of cell area.

3.4.1.07 Solar Cell Matching

The contractor shall match solar cell performance to meet the panel electrical specifications provided in Table 3.

3.4.1.08 Solar Cell Bonding

Solar cells shall be bonded to the substrate insulator surface using either DC 93-500, GE RTV 566, MN R2568, or a contractor-proposed, GSFC approved adhesive. Primer and catalysts shall be used in accordance with the adhesive manufacturer's specification for this application. A minimum adhesive layer thickness of 0.005 inch shall be required. A minimum adhesive coverage of 90 percent of the cell area shall be required. There shall be no looseness of the cells and no evidence of improper adhesive use on any panel.

3.4.1.09 Solar Cell Mechanical

Prior to assembly, the solar cells shall have no imperfections exceeding the limits specified herein. After assembly,no more than 1% of the cells shall exceed the specifications below, with the exception of cell cracks: there shall be no crack in any cell after panel assembly or else that cell shall be replaced. There shall be:

no crack in the cell.

no deep scratch on the cell surface which may be mistaken for a crack.

no twin plane in the cell.

no edge chip projecting more than 0.025 inch into the cell or more than 0.150 inch along the edge of the cell.

no corner chip with an hypotenuse greater than 0.060 inch.

no combination of corner chips or edge chips exceeding 0.5 percent of the active area of the cell.

no gap, separation, corrosion, or inclusion causing a discontinuity in the n-contact.

no looseness of the grids or contacts.

no discoloration or blemishes on the cell surface or in the cell coating that may reduce reliability or make inspection and application of the cover difficult.

3.4.2 Cover

An optically transmissive glass shall cover each solar cell to protect the cell against charged-particle irradiation and micrometeoroid impacts during the FAST mission.

3.4.2.01 Cover Material

The covers shall be produced from fused silica glass.

3.4.2.02 Cover Dimensions

Each solar cell coverglass which is assembled to a facet on Panel A-1 or Panel B-1 shall be 0.060 inch ± 0.002 inch thick. Each solar cell coverglass on Panel A-2 or Panel B-2 shall be 0.030 inch ± 0.002 inch thick. The size of the covers shall be such that 100 percent of the active surface area of each cell shall be covered.

3.4.2.03 Cover Ultraviolet Reflective Coating

The cover shall have an ultraviolet reflective (UVR) coating on the outer surface (but underneath the conductive coating) to reduce the thermal absorptance and minimize darkening of the cover adhesive. The cutoff wavelength of the UVR coating (the wavelength at which the transmittance is 50%) shall be 0.350 micron ± 0.015 micron. The coating shall be optimized for maximum transmission of light through the cover/adhesive interface for wavelengths above 0.350 micron. The coating shall minimize transmission of light for wavelengths below 0.350 micron.

3.4.2.04 Cover Conductive Coating

The solar cell cover shall include a conductive indium-tin-oxide (ITO) coating of a resistance sufficient to meet the overall solar array requirement of Section 3.3.5 (accounting for the conductive coating, cover interconnect resistance, and resistance of the interconnect to cover bond).

3.4.2.05 Cover Transmittance

The covers shall exhibit a maximum average transmittance of 1 percent between 200 and 320 nanometers wavelength. The covers shall otherwise exhibit transmittance characteristics which are consistent with meeting the requirements of this specification in its entirety.

3.4.2.06 Cover Emittance

The minimum average cover normal emittance shall be 0.82, when used with the solar cell specified in requirement 3.4.1 of this document.

3.4.2.07 Cover Orientation

The cover shall be oriented by means of an edge stain or etched triangle to allow differentiation between the top and bottom surfaces. Each cover shall be installed on a cell with the ITO/UVR coated side exposed and the uncoated side bonded to the cell.

3.4.2.08 Cover Bonding

Coverglasses shall be bonded to the solar cells using DC 93-500 or McGhan-Nusil CV-2500. No primer shall be used for this application. There shall be no looseness of the covers on any cell on any panel. There shall be no bubble, void, or foreign material in the cover adhesive in excess of 0.050 inch in diameter. The combined area of all bubbles, voids, and foreign material shall not exceed the equivalent area of one bubble 0.05 inch in diameter.

3.4.2.09 Cover Mechanical

Prior to assembly, the cover shall have no imperfections which exceed the limits specified herein. After assembly, no more than 3% of the covers shall exceed the specifications below. Should such an imperfection expose less than 0.5% of the active cell area of a solar cell, the contractor shall coat the area with the cover adhesive. Imperfections exposing more than 0.5% of the active area of any single cell must be repaired by replacing the glass. There shall be:

no strain pattern in the cover visible to the unaided eye.

no crack in the cover regardless of the extent of lateral penetration.

no bubble in the cover exceeding 0.005 inch in diameter and no more than one bubble per square centimeter for diameters less than 0.003 inch.

no scratch on the cover greater than 0.003 inch in width.

no edge chip projecting more than 0.010 inch into the edge cover or more than 0.024 inch along the edge of the cover.

no corner chip with hypotenuse greater than 0.020 inch.

3.4.3 Interconnects

3.4.3.01 Interconnect Materials

The contractor shall propose the interconnect materials. The interconnects shall be capable of surviving the atomic oxygen environment of the FAST orbit.

3.4.3.01 Interconnect Design

Several types of interconnects shall be required: cell to cell interconnects, cover to cover interconnects, string termination interconnects and substring to substring (turn-around) interconnects.The contractor shall propose the design for each type of interconnect. All solar cell interconnects shall make redundant series connections to solar cells and shall be designed to minimize the effect of a cracked cell. Cell-to-cell interconnects shall make a minimum of 3 connections between solar cells. Because of thermally induced expansion and contraction of the intercell gaps, the interconnect design shall incorporate optimum stress-relief for the thermal environment specified in requirement 3.5.3.

3.4.3.03 Cell to Cell, String Termination, and Turnaround Interconnect Soldering

Should soldering be proposed as the method of connecting the interconnects to solar cell contacts, this requirement shall apply in lieu of requirement 3.5.3.04. Interconnect soldering shall be accomplished with minimum solder usage to avoid stresses due to differential thermal expansions between the interconnect, solder, contact, and solar cell. Soldering shall be accomplished such that solder wicking back along the interconnect shall be minimized. Interconnect solder joints shall be sufficient in strength to pass the pull test specified in Section 4.2.3.18 of this document. The solder shall be either Sn-Pb-Ag 62/36/2 in accordance with Federal Specification QQ-S-571 or a contractor-proposed, GSFC approved alternate. Soldering shall be in accordance with applicable portions of NHB 5300.4 (3A-1).

3.4.3.04 Cell to Cell, String Termination, and Turnaround Interconnect Welding

Should welding be proposed as the method of connecting the interconnects to solar cell contacts, this requirement shall apply in lieu of requirement 3.5.3.03. Parallel gap welding shall be the method used to connect the interconnects to the solar cell contacts. The contractor's existing weld schedule shall yield interconnect welds having sufficient strength to pass the pull test specified in Section 4.2.3.18 of this document. The contractor shall supply the weld schedule parameters and existing test and flight data on welded interconnects as partial verification of this requirement. The contractor's product assurance plan shall include inspection procedures for welded interconnects.

3.4.3.05 Interconnect Mechanical

No more than 2 percent of the total number of interconnections on any string and no more than 1 of the interconnections on any single cell shall exhibit any of the following imperfections:

sharp bends, twists, buckles, or creases in the interconnect.

tears, cracks, or breaks in the interconnect.

lifting, fracturing, or loosening of the interconnect weld / solder joint.

solder or adhesive blocking, bridging, plugging, or encroaching on any part of the stress-relief loop.

cracks or voids in any atomic oxygen resistive grouting or conformal coating.

foreign matter or contamination on the interconnect or within the interconnect weld/solder joint.

3.4.4 Wiring

The contractor shall provide all the wiring required to interface the solar cell circuits, shunt dissipators, temperature sensors, and cover conductive surfaces. Electrical connections, feed throughs, tie points and wiring in general shall conform to applicable portions of MIL-P-11268.

3.4.4.01 Wire Type

Extruded TFE Insulated AWG # 26 silver-coated copper wire, in accordance with MIL-W-22759/11, shall be used to conduct current between circuit points from string terminations up to input terminal posts on the terminal boards. Extruded TFE Insulated AWG # 22 silver-coated copper wire, in accordance withMIL-W-22759/11, shall be used to conduct current between and from output terminal posts on the terminal boards to the output connectors. All positive wires shall be red. All negative wires shall be black. The government furnished shunt dissipators will have leads that are 120 inches long.

3.4.4.02 Wire Soldering

All soldering shall be performed in accordance with NHB 5300.4(3A-1).

3.4.4.03 Wire Feedthroughs and Stress Relief

A clear teflon jacket shall be added wherever abrasion may be a problem and shall be used for feed throughs. The contractor may propose an alternate method of preventing abrasion. Stress-relief shall be incorporated between wire tie points to avoid strains, particularly on the solar cell contacts at string terminations.

3.4.4.04 Wire Bonding

All wire bonding shall be performed with a silicone adhesive.

3.4.4.05 Wiring Mechanical

There shall be:

no sharp bends, twists, buckles, or creases in the wire.

no delamination or looseness of the wire bonding.

no chafing or abrasion of the wire insulation.

no cracks or breaks in the wire.

no cracking, fracturing, or loosening of the wire solder joints.

no contamination or foreign matter in the wire solder joints.

3.4.5 Connectors

3.4.5.01 Connector Type

All connectors shall be nonmagnetic, rack and panel, sub-miniature, rectangular, polarized shell type with crimp removable contacts in accordance with GSFC S-311-P-4/7. Similarly, the contacts used shall be in accordance with GSFC-S-311-F-4/8. Each panel shall have two output connectors. Each shall have 26 contacts (311P407-2S-B-15)). Pin assignments are presented in Tables 1 and 2.

3.4.5.02 Connector Savers

To minimize the number of times that flight connectors are mated and demated, a connector saver shall be required for each flight connector. The contractor shall design and construct the connector savers to interface between the flight connector and any mating test or ground support equipment. The connector savers shall be mated with the flight connectors once and remain mated. All other connections shall be made to the connector saver.

3.4.5.03 Connector Potting

The connectors shall not be potted.

3.4.6 Terminal Boards

3.4.6.01 Diode Type

All isolation (blocking) diodes shall be high reliability type JAN TXV 1N5811 qualified to the applicable detailed specification of MIL-S-19500. At a diode temperature of 25°C, the forward voltage of each diode shall be equal to or less than 0.65 volt at the maximum solar cell short circuit current; and the leakage current shall be equal to or less than 5.0 microamperes at the maximum panel open circuit voltage at beginning of life and minimum in-flight temperature.

3.4.6.02 Resistor Type

A resistor shall be connected in parallel with each thermistor. All resistors to be connected in parallel with thermistors shall be part number RLR07C1002FS and shall have a resistance of 10Kohms.

3.4.6.03 Mounting Configuration

Each diode and each resistor shall be mounted between two terminal posts. To minimize stresses due to thermally induced expansion and contraction, both leads of the part shall contain a stress relief loop. The length of the leads from the body of the diode shall not exceed 0.75 inch to ensure excellent power dissipation capability. Soldering of the diode leads to the terminal posts shall be in accordance with applicable sections of NHB 5300.4 (3A-1). The diode terminal posts shall be structurally and thermally anchored to a thermally radiative surface. The diode body shall be bonded to the radiative surface with an adhesive proposed by the contractor and approved by GSFC.

3.4.6.04 Terminal Board Layout

The contractor shall be responsible for the critical design of the terminal boards. GSFC will perform the thermal analysis of the terminal boards based on the contractor's design. The contractor shall provide complete detailed drawings of the terminal boards specifying locations for all components. Detailed terminal board assembly procedures shall be a part of the required assembly plan. The terminal boards shall be insulated and bonded to micaply bonded to the rear substrate face sheet with an adhesive proposed by the contractor and approved by the GSFC. Following installation and wiring, electrical components on the terminal boards shall be conformally coated.

3.4.7 Temperature Sensors

3.4.7.01 Sensor Type

All temperature sensors shall be thermistor type S-311-P-18-01T76R acceptance tested to NASA GSFC Specification S-311-P-18, Revision E. The thermistor configuration procured by the contractor shall have individual TFE teflon insulated AWG # 28 stranded 76-centimeter long leads. Each thermistor shall have a resistance of 2252 ohms ± 1 % at 25 °C. Calibration data for each thermistor shall be provided to the GSFC with the panels.

3.4.7.02 Sensor Mounting

A sensor shall be mounted on facet 3 of Panel A-1 in such a fashion that it measures the temperature of the solar cell to which it is closest to within ±2°C tolerance under operating conditions. This shall require that the sensor be mounted to the back of the front face sheet through an insert from the back of the panel. The second temperature sensor shall be mounted on facet 3 in such a way that it measures the temperature of the rear face sheet. Similarly, the third sensor shall be mounted on the end part of the panel (A-2) in such a fashion that it measures the temperature of the solar cell to which it is closest to within ± 2°C tolerance under operating conditions. The fourth sensor shall be mounted on the end part of the panel (A-2) in such a way that it measures the temperature of the rear face sheet. The sensor thermistor bonding adhesive shall be proposed by the contractor and approved by the GSFC.

Panel B shall have four thermistors mounted in the same fashion as the Panel A specification.

3.4.7.03 Sensor Wiring

The positive and negative connections of the temperature sensors shall be routed as a twisted pair from the sensor to the terminal board. Each sensor shall be electrically connected in parallel with a resistor on the terminal board.

3.4.8 Insulated Substrate

The solar array substrates shall be furnished by the GSFC.

3.5 ENVIRONMENTAL REQUIREMENTS

3.5.1 Storage Temperature and Humidity

Each of the two flight panels shall meet the requirements of this specification after storage in the shipping containers for three years at a temperature of 30°C and a relative humidity of 60 percent with no degradation in performance. An accelerated test (4.2.3.19) shall be performed to verify this requirement.

3.5.2 Acceleration, Vibration and Acoustic Noise

No solar array panel shall suffer any damage or degrade in performance after exposure to the levels of acceleration, vibration, and acoustic noise resulting from the launch of the FAST spacecraft on a Pegasus rocket. The specific levels for acoustic testing of the flight panels to verify this requirement are specified in the test procedures 4.2.3.11. The contractor shall not vibration test the solar array.

3.5.3 Thermal

No solar array panel shall degrade in peak power output by more than 3 percent and no panel shall suffer any damage that may question the reliability of the panel to meet the requirements of this document after exposure in a vacuum to the total of 3000 temperature cycles between -90 degrees C and +101 degrees C.

The specific qualification and acceptance levels for thermal testing as partial verification of this requirement shall be as specified in the test procedures (Sections 4.2.3.08 and 4.2.3.13, respectively).

3.5.4 Ultraviolet Radiation

When subjected to a UV exposure equivalent to 1 year of illumination with AM0 sunlight, the current output of the solar cells with the covers and cover adhesive (as specified in this document) shall not degrade more than 2 percent.

3.5.5 Charged-Particle Radiation

When exposed to the omni directional, multi-energetic electron and proton environment for the 1-year FAST mission, the solar cells on A-1 and B-1(shielded by 60 mils thick fused silica glass) will experience a fluence equivalent to 2.39 X 10^{14} 1 Mev electrons/ at normal incidence for Voc and Pmax, and 1.95 X 10^{14} 1 Mev electrons/cm^2 for Isc. When subjected to this environment, the solar cell I-V parameters shall meet the following requirements.

The short circuit current shall not degrade more than 7.9 %

The open circuit voltage shall not degrade more than 5.1 %

The peak power shall not degrade more than 13.5%

The voltage at peak power shall not degrade more than 8.8 %.

When exposed to the omni directional, multi-energetic electron and proton environment for the 1-year FAST mission, the solar cells on Panels A-2 and B-2(shielded by 30 mils thick fused silica glass) will experience a fluence equivalent to 6.02 X 10^{14} 1 Mev electrons/ at normal incidence for Voc and Pmax, and 3.97 X 10^{14} 1 Mev electrons/cm^2 for Isc. When subjected to this environment, the solar cell I-V parameters shall meet the following requirements.

The short circuit current shall not degrade more than 11.1 %

The open circuit voltage shall not degrade more than 7.5 %

The peak power shall not degrade more than 20.7%

The voltage at peak power shall not degrade more than 7.8 %.

The contractor shall provide existing data (degradation versus irradiation dosage) for the proposed cells as verification of this requirement.

3.5.6 Atomic Oxygen

The FAST solar array panels and components shall be protected against oxidation in the atomic oxygen environment of the FAST orbit. The solar array panels shall not degrade in peak power output by more than 1.0 percent and shall not suffer any deterioration that may question the reliability of the panel to meet the requirements of this specification after exposure for 1 year in a 350 X 4200 km orbit with an inclination of 83°. Special consideration shall be given to the selection of cell and cover interconnect materials and designs. Analysis and existing test or flight data shall be required to verify this requirement.

3.5.7 Micrometeoroids and Space Debris

The solar cells shall be sufficiently shielded such that negligible degradation due to impacts from hypervelocity micrometeoroids and space debris shall be experienced during 1 year in the earth orbit specified in herein.

3.5.8 Shadowing

The solar cell circuit layouts are optimized for minimum power loss when irregular shadow patterns fall across segments of any panel. No solar array panel shall degrade in peak power output more than 3 % as a result of the panel being repeatedly shadowed. A worst case analysis shall be performed assuming that:

a. the panel temperature is -100 °C

b. the panel is under 1.035 AM0 illumination (perihelion, normal sun incidence)

c. only one cell in one string on the panel is shadowed

d. the operating voltage of the panel is the voltage at peak power.

Because there will be significant shadowing of the FAST solar array due to instruments and booms which protrude from the spacecraft body. The contractor shall provide reverse voltage characteristics of the proposed cell as partial verification of this requirement in accordance with 4.2.3.20.

3.6 PRODUCT ASSURANCE REQUIREMENTS

The contractor's product assurance program shall be in compliance with GSFC S-740-88-999, Performance Assurance Requirements (PAR) for the Small-Class Explorer (SMEX) Spacecraft.

3.6.1 Reliability

The design reliability of the FAST solar array panels shall exhibit a high degree of probability that the panels shall perform as specified for 1 year in earth orbit after acceptance testing, after shipment, and after storage for up to 3 years. Worst-case analysis shall be performed for critical parameters that could degrade performance. All parameters and environmental stresses shall be set to realistic worst case limits and the adequacy of design margins shall be substantiated. Failure modes, effects and criticality analysis shall be performed to identify potential failures and their effects, so that susceptibility to such failures and their effects can be eliminated. Potential critical failure modes that could be caused by a single element shall be identified and eliminated.

3.6.2 Cleanliness and Contamination Control

The solar array panels shall be designed, have their materials selected, and be manufactured, tested, handled, and stored in a manner which will prevent contamination of the FAST spacecraft. At delivery, each solar array panel shall meet a cleanliness level of 750 and a nonvolatile residue level of B in accordance with MIL-STD-1246. The contractor's product assurance plan shall outline the program for meeting this requirement. Special consideration shall be given to adhesives and their use. All solar array panel adhesives shall exhibit no more than 1.0 percent total mass loss and no more than 0.1 percent collected volatile condensible materials from outgassing in a vacuum, as identified in NASA TN D-7362. Adhesives shall be stored in refrigerated spaces and shall not have a shelf life greater than the manufacturer's specification for this application. The contractor shall maintain an adhesive log which shall be made available to the GSFC upon request.

4.0 VERIFICATION

The contractors shall verify that all requirements are met. The methods of verification shall be verification by analysis, verification by similarity, verification by inspection, and verification by test. The contractor shall provide a verification matrix defining the methods of verification for each specific requirement.

4.1 VERIFICATION BY ANALYSIS AND SIMILARITY

Where it has been specified or implied in Section 3 to provide analysis, the contractor's proposed verification matrix shall indicate verification by analysis in addition to any other method of verification required for that specific requirement. Where it has been specified or implied in Section 3 to provide existing test and flight data, the contractor's proposed verification matrix shall indicate verification by similarity in addition to any other method of verification required for that specific requirement. In those cases where no inspection or test is proposed to verify a specific requirement, the proposed verification by analysis and verification by similarity for that specific requirement shall be complete in detail.

4.2 VERIFICATION BY INSPECTION AND TEST

4.2.1 Qualification Panel Inspections and Tests

The required inspections and tests for the qualification panel and the order in which these inspections and tests shall be conducted are specified below.

Intermediate Sequence	Procedure
Visual Inspection	4.2.3.01
X-Ray Inspection	4.2.3.02
Adhesion Check (As Required)	4.2.3.03
Electrical Performance	4.2.3.04

Circuit Insulation Resistance	4.2.3.05
Continuity Check (As Required)	4.2.3.06
Diode Performance (As Required)	4.2.3.16
Conductive Cover/Interconnect Resistance	4.2.3.21
Damage and Repair	4.2.3.07
Intermediate Sequence	
Vibroacoustics	4.2.3.11
Intermediate Sequence	
Rapid Temperature Cycles 1 through 10	4.2.3.08
Intermediate Sequence	
Rapid Temperature Cycles 11 through 500	
Intermediate Sequence	
Rapid Temperature Cycles 501 through 1000	
Intermediate Sequence	
Rapid Temperature Cycles 1001 through 3000	
Intermediate Sequence	

The qualification panel shall pass each inspection and test specified above in accordance with the pass/fail criteria specified in each inspection and test procedure. The results of each qualification panel inspection and test shall be recorded for permanent retention and shall be included in the QAR report delivered with the qualification panel.

4.2.2 Flight Panels Acceptance Inspections and Tests

Each flight panel shall be subjected to the following sequence of acceptance inspections and tests.

Intermediate Sequence	Procedure
Visual Inspection	4.2.3.01
Adhesion Check (As Required)	4.2.3.03
Electrical Performance	4.2.3.04
Circuit Insulation Resistance	4.2.3.05
Continuity Check (As Required)	4.2.3.06
Diode Performance (As Required)	4.2.3.16
Conductive Cover/Interconnect Resistance	4.2.3.21
Panel Weight	4.2.3.10
Vibroacoustics	4.2.3.11
Intermediate Sequence	
Thermal Vacuum Bakeout	4.2.3.12
Thermal Vacuum Cycles 1 through 25	4.2.3.13
Intermediate Sequence	

Each flight panel shall pass each inspection and test specified above in accordance with the pass/fail criteria specified in each inspection and test procedure. The results of each inspection and test on each flight panel shall be recorded for permanent retention.

4.2.3 Inspection and Test Procedures

The procedures for all the necessary inspections and tests are not specified herein. Those procedures that are specified herein are general in nature. These procedural specifications shall serve as a reference point for the contractor proposed test plan which shall be complete and in detail.

4.2.3.01 Visual Inspection

A detailed visual inspection shall be performed on all components and subassemblies, the completed qualification panel and the completed flight panels. All visual inspections shall be performed with the unaided eye and under a minimum of eight power magnification. Optional inspections, determined advisable by the contractor, shall be performed at the contractor's discretion. All areas open to question as a result of the inspections shall be re-examined under whatever magnification is necessary to resolve the question. The use of a higher magnification than specified here does not relieve the contractor of the responsibility for defects found.

Pass/Fail Criteria: Any defect or imperfection which is out-of-limit of any specification in Section 3 of this document is cause for failure.

4.2.3.02 X-Ray Examination

If the solar array panel design is such that the gaps between solar cells are grouted, x-ray examination shall be performed where specified in Section 4.2.1. This shall be required to check for defects in interconnects hidden within the grouting material. Regardless of the design, the qualification panel shall be subjected to x-ray examination after completing all other testing to inspect the portion of the interconnects hidden under the solar cells. X-Ray examination shall be used at any time to inspect questionable areas where visual inspection and electrical tests have failed to resolve the question.

Pass/Fail Criteria: Same as for visual inspection.

4.2.3.03 Adhesion Check

Where the visual inspection of a panel has discovered any portion of a single cell displaying delamination from the substrate insulator, the contractor shall check the adhesion of all the cells on that panel. The contractor shall use a suction test or tap test to check the adherence of the solar cell circuits to the substrate insulator. During assembly a test sample of each adhesive mix shall be prepared and retained for inspection by the GSFC incase questions develop.

Pass/Fail Criteria: Requirement 3.4.1.08

4.2.3.04 Electrical Performance

A large area pulsed solar simulator shall be used to determine the current-voltage (I-V) characteristics of the qualification panel and the two flight panels. The solar simulator shall utilize a pulsed xenon flash which shall be calibrated to AM0 illumination at the plane of the panel under test. This intensity calibration shall be accomplished with a calibrated balloon flight standard cell having a spectral response closely matching the cells on the panel under test. The temperature of the standard cell and the panel under test at the time of the I-V measurements shall be maintained as close to the reference temperature (28 °C), as possible. The rate of change of the electronic load during any I-V measurement shall be consistent with the response time of the solar cells under test.

The contractor shall test each circuit separately at the anode side of the diode and then calculate the resulting power for the end plate or facet under test.

The contractor shall test each circuit's diode for conduction and shall check the parallel diodes on a single terminal board for leakage. These tests shall be to a contractor written and GSFC approved procedure. The tests will only give qualitative results.

The measured I-V data shall be corrected for temperature and intensity to obtain the I-V curve for a panel temperature of 28°C and AM0 illumination. The uncorrected measurements shall also be made available to the GSFC to investigate any anomalies that may occur in the I-V data.

Pass/Fail Criteria: The panels shall meet the requirements of this specification and shall degrade in power output less than three percent after all environmental exposures.

4.2.3.05 Circuit Insulation Resistance

The insulation resistance between the solar cell circuits and the substrate shall be determined by measuring the current flow between the substrate and each string termination (positive and negative) at 250 volts. The instrumentation shall be current limited at 3 microamperes.

Pass/Fail Criteria: Requirement 3.3.3

4.2.3.06 Continuity Check

Upon completing the assembly of each panel, a continuity check shall be performed to verify conformance to the applicable wiring diagram. Also, whenever an electrical performance test indicates a reduction or anomaly in the current-voltage output, a continuity check shall be performed to determine if shorts, open circuits, or any discontinuity in the wiring may be causing the anomaly.

Pass/Fail Criteria: Conformance with the contractor prepared wiring diagrams

4.2.3.07 Damage and Repair

The procedures to replace broken cells shall be qualified. The contractor shall break two cells on the qualification panel. Also, one of the cells shall be at the interior of a string and one of the cells shall be at a string termination. The cells shall be replaced using the contractor-prepared GSFC approved repair procedures.

Pass/Fail Criteria: The panel shall pass all qualification inspections and tests as a repaired unit.

4.2.3.08 Rapid Temperature Cycling

The qualification panel shall be subjected to a rapid temperature cycle test in a dry inert nitrogen environment. The panels shall be cycled for the total number of cycles and 10°C beyond the temperature extremes specified in Section 3.5.3. A current of 0.51 amperes shall be applied to the shunt dissipators during each cycle after the panel has stabilized at 10°C lower than the high temperature extreme for the test. If the application of current to the dissipator does not increase the panel temperature to the high temperature extreme for the test, the contractor shall adjust the nitrogen temperature until it does. At least 4 temperature sensors shall be distributed across the panel. The sensor reading the highest temperature shall not exceed the specified maximum temperature for the cycle. The sensor reading the lowest temperature shall not go below the specified minimum temperature for the cycle. The dwell time at the temperature extremes shall be at least 3 minutes. Temperature gradients across the panel shall be limited to ±10°C at the end of the dwell time. The rate of temperature change between the hot and cold limits shall not exceed 40°C per minute.

Pass/Fail Criteria: Any defects or reduction of power output outside the limits of the requirements of Section 3 shall be cause for failure.

4.2.3.09 Panel Weight

Upon receiving and inspecting the government-furnished insulated substrates, the weight of each substrate shall be measured and recorded in the appropriate log book and substrate receiving inspection records. After flight panel assembly, the weight of each completed flight panel shall be measured and recorded. The weight of a completed flight panel minus the weight of its substrate shall be the add-on weight.

Pass/Fail Criteria: The add-on weight shall not exceed the values specified in Requirement 3.4.1.

4.2.3.10 Substrate Insulation

In addition to a visual inspection and weight measurement, upon receiving the government-furnished substrates, the dielectric insulator of each panel shall be tested. The test shall be performed using a wet probe in accordance with MIL-STD-202, Method 302 using the following parameters:

a. The test voltage shall be 100 volts dc applied across the wet probe and the substrate.
b. The instrumentation shall be current limited at 20 microamperes.
c. The test time shall be sufficient to cover the entire insulator surface with the wet probe.

Pass/Fail Criteria: There shall be no sign of dielectric breakdown. The insulation resistance shall be greater than 100 megohms. (The contractor is not responsible for incoming failure of the substrate dielectric. The contractor is responsible for finding and reporting such a failure

4.2.3.11 Vibroacoustics

Each of the qualification solar array panels and each of the flight panels shall be suspended in a reverberant chamber and subjected to the acoustic noise environment specified in Table 5. The panel shall be mounted to a suspension system which results in a natural frequency of less than 25 Hz.

Pass/Fail Criteria: Requirement 3.5.2

4.2.3.12 Thermal Vacuum Bakeout

Each of the flight solar array panels shall be subjected to a thermal vacuum bakeout to ensure the proper curing and outgassing of the adhesives and prevent contamination of the FAST spacecraft. The panels shall be maintained at a temperature of 5°C higher than the high temperature extreme specified in Section 3.5.3 as measured by the hottest temperature sensor in a vacuum of 1.0×10^{-5} Torr or less for a period of 48 hours or until the quartz crystal monitor output has not changed for 1 hour. The temperature gradients across the panel shall be limited to ±10°C. The chamber shall be monitored during the last 8 hours of bake out for condensable contaminates in accordance with ASTM E 834-81. These data shall be submitted to the GSFC for permanent retention.

Pass/Fail Criteria: Requirement 3.6.2

4.2.3.13 Thermal Vacuum Cycling

Each flight panel shall be subjected to a thermal cycle test in a vacuum of 1.0×10^{-5} Torr or less. The panels shall be cycled 5°C beyond the temperature extremes specified in Section 3.5.3 for 25 cycles. After the panel has stabilized at +10°C below the high temperature extreme, a current of 0.51 amperes shall be applied to each of the shunt dissipators for the last 15 minutes of each cycle or until the panel reaches the high temperature extreme for the test, whichever comes first. If the panel does not attain the high temperature extreme for the test after 15 minutes on the first cycle, the contractor shall adjust the radiant heat source so that the panel attains this temperature on subsequent cycles. At least 8 calibrated temperature sensors, distributed over the panel, shall monitor the temperature. The sensor reading the highest temperature shall not go above the maximum hot temperature for the cycle. The sensor reading the lowest temperature shall not go below the specified minimum cold temperature for the cycle. The temperature gradients across the panels shall be limited to ±25°C. The dwell time at the temperature extremes shall be greater than 10 minutes. The rate of temperature change between cold and hot limits shall not exceed 30 °C per minute. As outlined in Section 4.2.2, the panels shall undergo a sequence of intermediate inspections and tests before the thermal vacuum test and after the final cycle.

Pass/Fail Criteria: Any defects or reduction of power output outside the limits of the requirements of Section 3 shall be cause for failure.

4.2.3.14 Cell Performance Classification

All solar cells shall be subjected to an electrical performance test and subsequent classification to requirements 3.4.1.06 and 3.4.1.07. The electrical current output of the solar cells shall be measured with a solar simulator at the maximum power voltage. The simulator shall be calibrated to provide an AM0 equivalent intensity at the plane of the cell. The simulator calibration shall be performed with or correlated to a balloon flight standard cell. The spectral response of the calibration cells shall closely match the spectral response of the cells under test. The junction temperature of each cell during the test shall be maintained at 28°C±.5°C.

Pass/Fail Criteria: Cells with Vmp or peak power below the requirement in 3.4.1.06 shall be rejected until the lot average Vmp and peak power attain the requirement.

4.2.3.15 Antireflective Coating Durability

A sample of 1.0 percent of each production lot shall be subjected to a contractor-proposed, GSFC approved AR-coating durability test. A 1.0 percent random sample of covers shall be subjected to a similar AR coating durability test by the contractor or cover subcontractor.

Pass/Fail Criteria: If there is evidence of the removal of the antireflective coating, a 10 percent Lot Tolerance Percent Defective (LTPD) as specified in MIL-S-19500 shall be similarly tested. If this second test correlates with the initial test results, the entire lot of cells shall be rejected.

4.2.3.16 Diode Performance

The blocking and bypass diodes shall be procured, qualified, and screened to the requirements of MIL-S-19500. The contractor shall check the forward voltage and the reverse current of each diode prior to and after its assembly on to the solar array panel and whenever there is reason to question the performance of the blocking diodes.

Pass/Fail Criteria: Requirement 3.4.6.01

4.2.3.17 Tape Pull Test

After contact deposition, but prior to cell performance measurements, 100 percent of the cell production lot shall be tested by applying Scotch Brand No. 810 tape (or an approved equivalent) to the cell n-contact surface. The tape shall be pressed to transparency and then pulled away from the contact using a uniform continuous pull perpendicular to the plane of the cell surface. The p-contact of the same cells shall be tested in the same manner. All solar cells shall be cleaned after the performance of this test so no residue of the tape adhesive remains on the solar cell surface. These cells may be used on the flight panels if cell performance tests and inspections are performed and passed after CIC assembly.

Pass/Fail Criteria: A solar cell with greater than 5 percent removal of its n or p metallization shall be rejected.

4.2.3.18 Welded / Soldered Contact Pull Test

The contractor shall subject a 1.0 percent random sample of cells from each contact deposition lot to a welded or soldered contact pull test. The contractor shall perform the test on both the n and p contacts using ribbon material identical to the interconnect material. The contractor shall use a welding or soldering technique identical to the interconnect welding or soldering technique intended for the flight hardware. The contractor shall not test welded or soldered joints which exhibit out of limit imperfections. The contractor shall reject defective weld or solder joints before testing. The contractor shall clamp the test cell to prevent movement so that the restraining force is distributed over at least 40 percent of the cell. The pull force shall be applied to the ribbon at a rate not exceeding 2.0 N/sec. The contractor shall record the maximum pull force achieved prior to failure. Should soldering be the method of connecting the interconnects to the contacts, the contractor shall meet the requirements of the applicable portions of MIL-T-10727.

Pass/Fail Criteria: If any tab separation force is less than 1.5 N, the contractor shall subject a second sample of 2 percent of the contacting lot to the same test. If this second test also shows any failure, the contractor shall reject and scrap the entire contact lot of cells.

4.2.3.19 Temperature-Humidity

The contractor shall randomly select a single cell from each contact evaporation lot for temperature-humidity environmental testing. The samples shall be exposed to a 90±5 percent relative humidity at 45±3°C for 30 days. None of these test solar cells shall be used on the flight panels. All of these cells shall be submitted to the GSFC for inspection regardless of their condition.

Pass/Fail Criteria: If any test cell exhibits a more than 1.5 percent decrease in peak power output under AM0 illumination at 28°C, an additional 2 percent sample from the same production lot shall be subjected to the same test. If any of these cells also exhibit a more than 1.5 percent power loss, the entire lot shall be rejected.

4.2.3.20 Dark Solar Cell Reverse Voltage Test

The contractor shall select ten cells having the same cell process specifications as the FAST solar cells except that they may differ in size. The contractor shall fix these cells to an insulated aluminum substrate with means for electrical connection. The contractor shall measure each cell's current-voltage curves at 28°C and AM0 illumination. The contractor shall place the cells in a dark chamber at less than -100°C at ambient pressure. The contractor shall reverse bias each cell for one minute with the current limited to 1.1 times the cell's nominal short circuit current and the reverse voltage to 50 volts. The contractor shall measure the voltage and current achieved on each cycle. The contractor shall repeat this test 10 times, each time remeasuring the cells IV curves at 28°C and AM0 before resubjecting the cell to reverse voltages at a temperature lower than -100°C.

After completion of the above, the contractor shall repeat the test for a total of 10,000 electrical cycles except that the time each cell is reverse biased shall be 2 seconds The contractor shall remeasure the cell performance at 28°C and AM0 after 100, 1000 and 5,000 cycles.

After completion of this, the contractor shall repeat the test for a total of 250,000 electrical cycles except that the time each cell is reverse biased shall be 2 seconds, the temperature shall be greater than 111°C and the voltage limit shall be 25 volts.

At any time the contractor may stop the test and remeasure the cell performance at 28°C and AM0. If the cells have failed the test at this point, or at a required measurement point, the contractor shall select an additional ten cells which have been screened by passing a reverse bias test of the manufacturer's specification. The manufacturer shall repeat the test.

Pass/Fail Criteria: The cells shall degrade no more than 3 percent in peak power.

4.2.3.21 Conductive Cover

The resistance between the center of each conductive cover and substrate ground shall be measured using a wet probe on the cover. The resistance between the center of any area not covered by a conductive cover and substrate ground shall be measured by a contractor proposed and GSFC approved method.

Pass/Fail Criteria: The resistance shall not change more than ±50% from that first measured and shall be less than 66,667 ohms for the first measurement.

5.0 PREPARATION FOR DELIVERY

5.1 PACKAGING

The GSFC shall supply 2 containers to ship the substrates(s) to the contractor. The contractor shall provide 2 new containers to ship the completed flight panels to the GSFC.

The contractor provided containers shall be gas-tight, resealable, and appropriate for back-fill with positive pressure of dry nitrogen gas whenever the panels are stored for more than two days.

For the qualification panel and the various deliverable component and subassembly samples, the contractor shall provide the packaging and preservation to assure that the items shall not be damaged or contaminated during shipping and storage. The packaging and preservation shall satisfy the intent of NHB 6000.1C. The contractor shall provide durable shipping containers for these deliverable items. .

5.2 MARKING

All shipping containers shall be marked in accordance with MIL-STD-129.

5.3 HANDLING AND TRANSPORTATION

All handling and transportation shall be accomplished with extreme care consistent with the fragile nature of the solar array panels. Transportation arrangements shall be coordinated in advance with the GSFC. The mode of transportation shall be subject to GSFC approval.

Table 1. Panel A Connector Pin Assignments

Located on Facet 3
Connector J1
P/N 311P407-2S-B-15
26 Socket, 22AWG Contacts
Nonmagnetic

Pin	Function
1	Panel A-2 Thermistor Positive
2	No Connection
3	Panel A-1 Thermistor Positive
4	No Connection
5	Shunt A1 Power
6	Shunt A3 Power
7	No Connection
8	Panel A Solar Array Power
9	No Connection
10	Panel A-2 Thermistor Return
11	No Connection
12	Panel A-1 Thermistor Return
13	Substrate Ground
14	Shunt A5 Power
15	Shunt A7 Power
16	No Connection
17	No Connection
18	No Connection
19	No Connection
20	No Connection
21	Shunt A1 Return
22	Shunt A3 Return
23	Shunt A5 Return
24	Shunt A7 Return
25	Panel A Solar Array Return
26	No Connection

Located on Facet 4
Connector J2
P/N 311P407-2S-B-15
26 Socket, 22AWG Contacts
Nonmagnetic

Pin	Function
1	Panel A-2 Thermistor Positive
2	No Connection
3	Panel A-1 Thermistor Positive
4	No Connection
5	Shunt B1 Power
6	Shunt B3 Power
7	No Connection
8	Panel A Solar Array Power
9	No Connection
10	Panel A-2 Thermistor Return
11	No Connection
12	Panel A-1 Thermistor Return
13	Substrate Ground
14	Shunt B5 Power
15	Shunt B7 Power
16	No Connection
17	No Connection
18	No Connection
19	No Connection
20	No Connection
21	Shunt B1 Return
22	Shunt B3 Return
23	Shunt B5 Return
24	Shunt B7 Return
25	Panel A Solar Array Return
26	No Connection

Table 2. Panel B Connector Pin Assignments

Located on Facet 3
Connector J1
P/N 311P407-2S-B-15
26 Socket, 22AWG Contacts
Nonmagnetic

Pin	Function
1	Panel B-2 Thermistor Positive
2	No Connection
3	Panel B-1 Thermistor Positive
4	No Connection
5	Shunt A2 Power
6	Shunt A4 Power
7	No Connection
8	Panel B Solar Array Power
9	No Connection
10	Panel B-2 Thermistor Return
11	No Connection
12	Panel B-1 Thermistor Return
13	Substrate Ground
14	Shunt A6 Power
15	Shunt A8 Power
16	No Connection
17	No Connection
18	No Connection
19	No Connection
20	No Connection
21	Shunt A2 Return
22	Shunt A4 Return
23	Shunt A6 Return
24	Shunt A8 Return
25	Panel B Solar Array Return
26	No Connection

Located on Facet 4
Connector J2
P/N 311P407-2S-B-15
26 Socket, 22AWG Contacts
Nonmagnetic

Pin	Function
1	Panel B-2 Thermistor Positive
2	No Connection
3	Panel B-1 Thermistor Positive
4	No Connection
5	Shunt B2 Power
6	Shunt B4 Power
7	No Connection
8	Panel B Solar Array Power
9	No Connection
10	Panel B-2 Thermistor Return
11	No Connection
12	Panel B-1 Thermistor Return
13	Substrate Ground
14	Shunt B6 Power
15	Shunt B8 Power
16	No Connection
17	No Connection
18	No Connection
19	No Connection
20	No Connection
21	Shunt B2 Return
22	Shunt B4 Return
23	Shunt B6 Return
24	Shunt B8 Return
25	Panel B Solar Array Return
26	No Connection

Table 3
Minimum Required Current-Voltage Output for FAST Solar Panels Taken on Anode Side of Protection Diodes at AM0 and 28°C

Panel	Voc (volts)	Isc (amperes)	Vmp (volts)	Pmax (watts)
A-1 Facet 1	44.10	1.269	38.37	45.63
A-1 Facet 2	44.10	0.748	38.37	26.91
A-1 Facet 3	44.10	0.431	38.37	15.50
A-1 Facet 4	44.10	0.431	38.37	15.50
A-1 Facet 5	44.10	0.700	38.37	25.17
A-1 Facet 6	44.10	1.269	38.37	45.63
A-1 Facet 7	44.10	0.586	38.37	21.08
A-1 Facet 8	44.10	0.969	38.37	34.85
A-1 Facet 9	44.10	0.538	38.37	19.35
A-2	52.92	1.663	46.04	71.80
B-1 Facet 1	44.10	0.712	38.37	25.61
B-1 Facet 2	44.10	0.508	38.37	18.29
B-1 Facet 3	44.10	0.305	38.37	10.97
B-1 Facet 4	44.10	0.305	38.37	10.97
B-1 Facet 5	44.10	0.508	38.37	18.29
B-1 Facet 6	44.10	0.712	38.37	25.61
B-1 Facet 7	44.10	0.407	38.37	14.63
B-1 Facet 8	44.10	0.814	38.37	29.27
B-1 Facet 9	44.10	0.407	38.37	14.63
B-2	52.92	1.663	46.04	71.80

Table 4. Cover Transmittance versus Wavelength

Wavelength (nanometers)	Transmittance
200 to 320	1% maximum average
355±15	50% absolute cutoff
400 to 450	85 % minimum individual
400 to 450	92 % minimum average
450 to 1100	94 % minimum individual
450 to 1100	96 % minimum average

Table 5. Accoustic Test Levels	
One-Third Octave Center Frequency (Hz)	Noise Level(dB) re: .00002 Pa Qualification
25	115.0
32	115.0
40	115.0
50	115.0
63	115.0
80	115.0
100	115.0
125	115.0
160	119.5
200	124.0
250	128.5
315	133.0
400	130.0
500	130.0
630	130.0
800	130.0
1000	130.0
1250	130.0
1600	127.0
2000	124.0
2500	121.0
3150	118.0
4000	115.0
5000	112.0
6300	109.0
8000	106.0
10000	103.0
Overall	140.0

Figure 1.
FAST Spacecraft Configuration

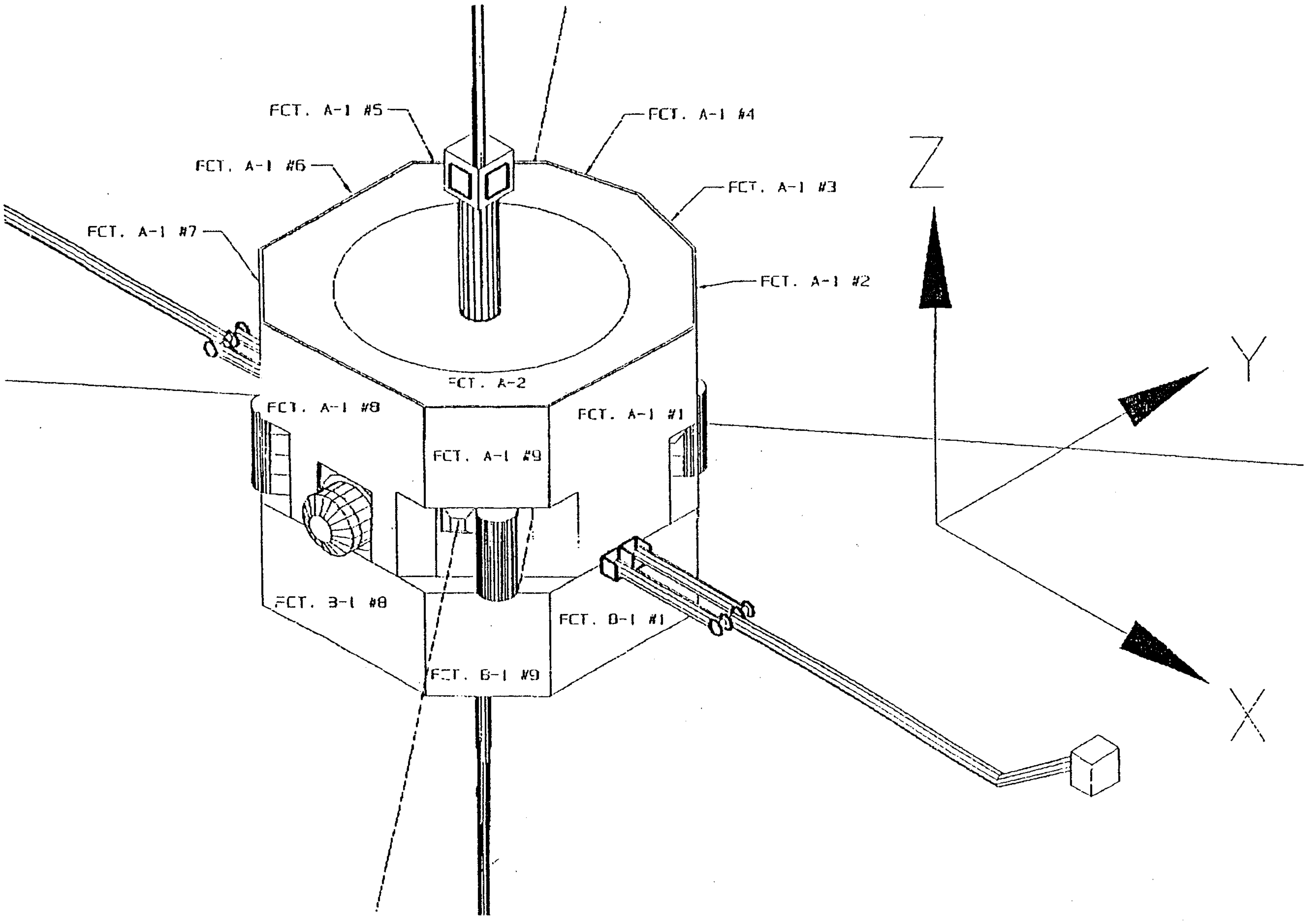

Figure 2.
Panel A-1 Facet # 1 & 6 Solar Cell Layout*
45 Series Cells per Circuit
* 1 & 6 are identical

Solar Cell Dimensions: Circuits A-H 0.7270" (series) x 0.8244" (parallel)
Circuits I-L 0.6863" (series) x 0.8244" (parallel)

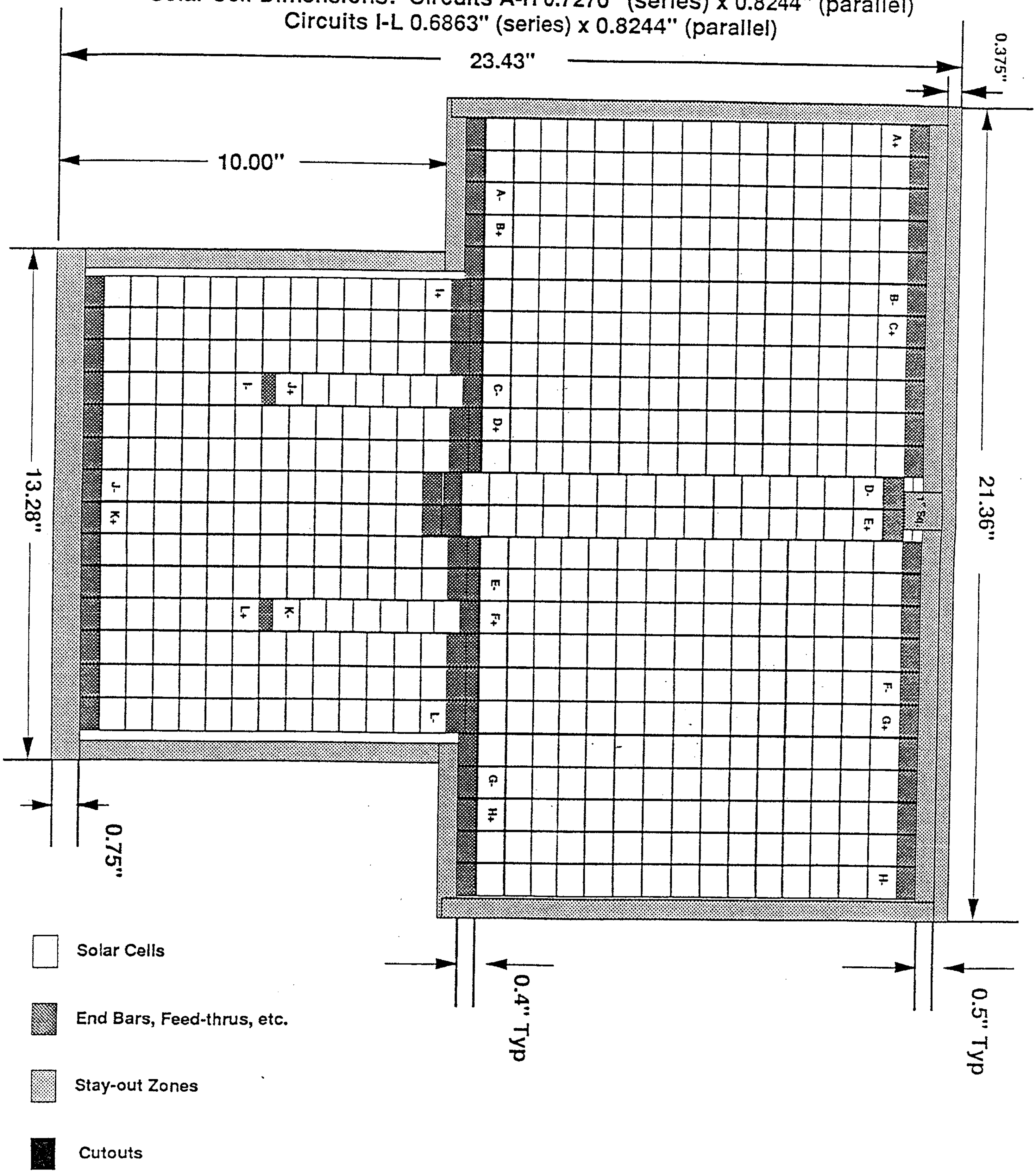

Figure 3.
Panel B-1 Facet #1 & 6 Solar Cell Layout*
45 Series Cells per Circuit

* 1 & 6 are identical

Solar Cells

Stay-out Zones

End Bars, Feed-thrus, etc.

Cutouts

Solar Cell Dimensions: 0.6863" (series) x 0.8244" (parallel)

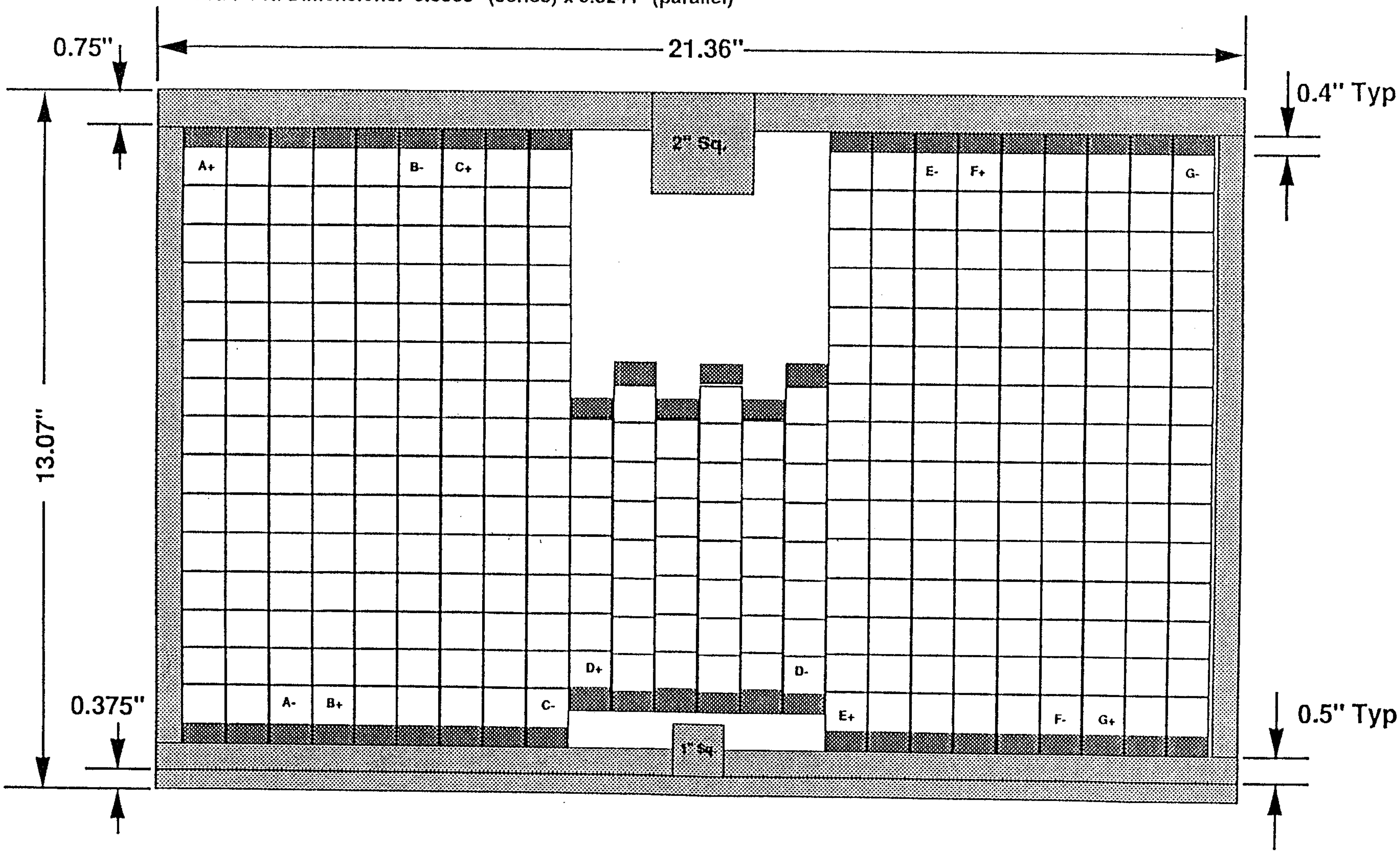

Figure 4
Panel A-1 Facet #2 & 5 Solar Cell Layout*
45 Series Cells per Circuit

* 2 & 5 are identical except for recessed panels

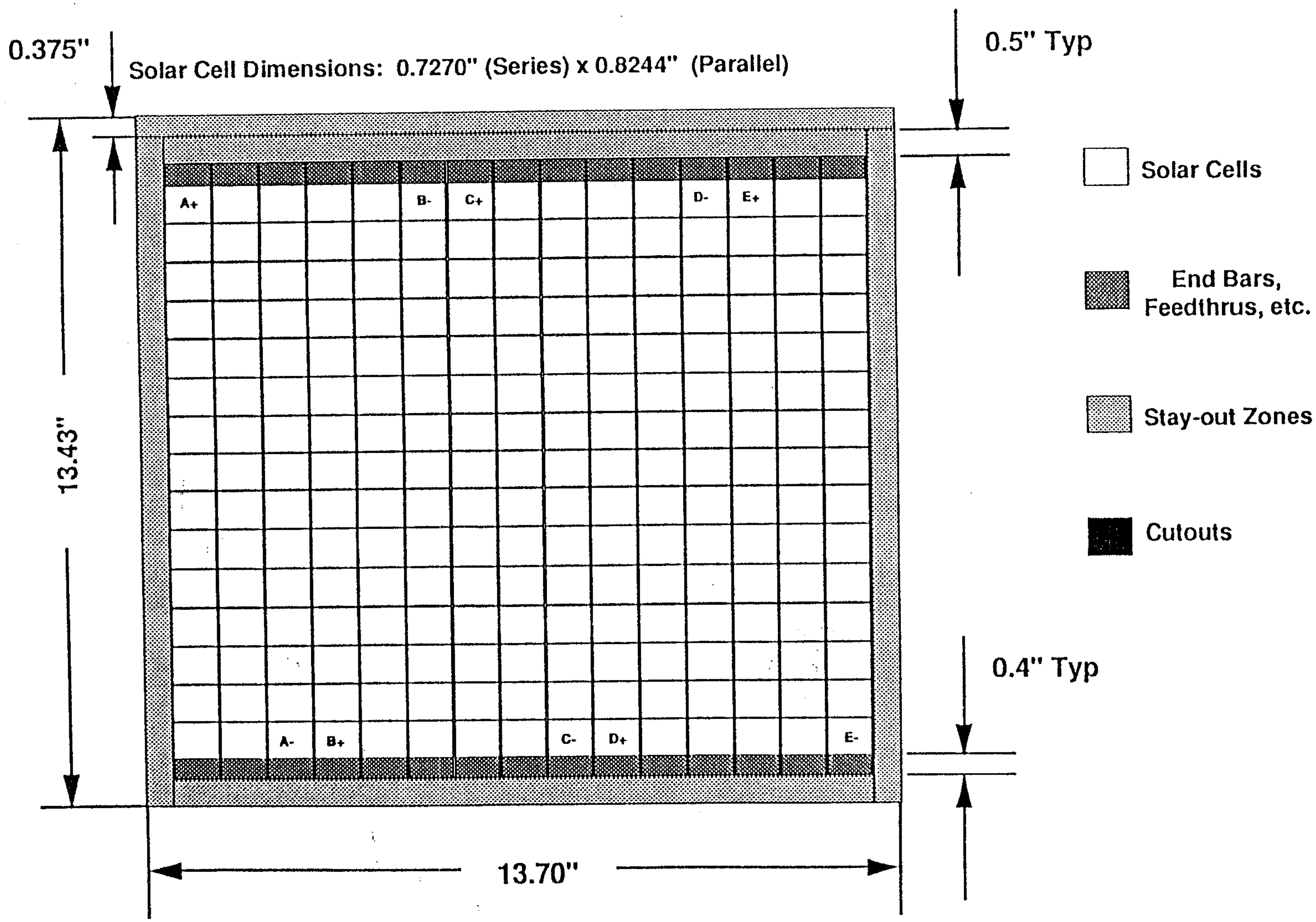

Figure 5.
Panel A-1 Facet # 2 Recessed Panel Layout
45 Series Cells per Circuit

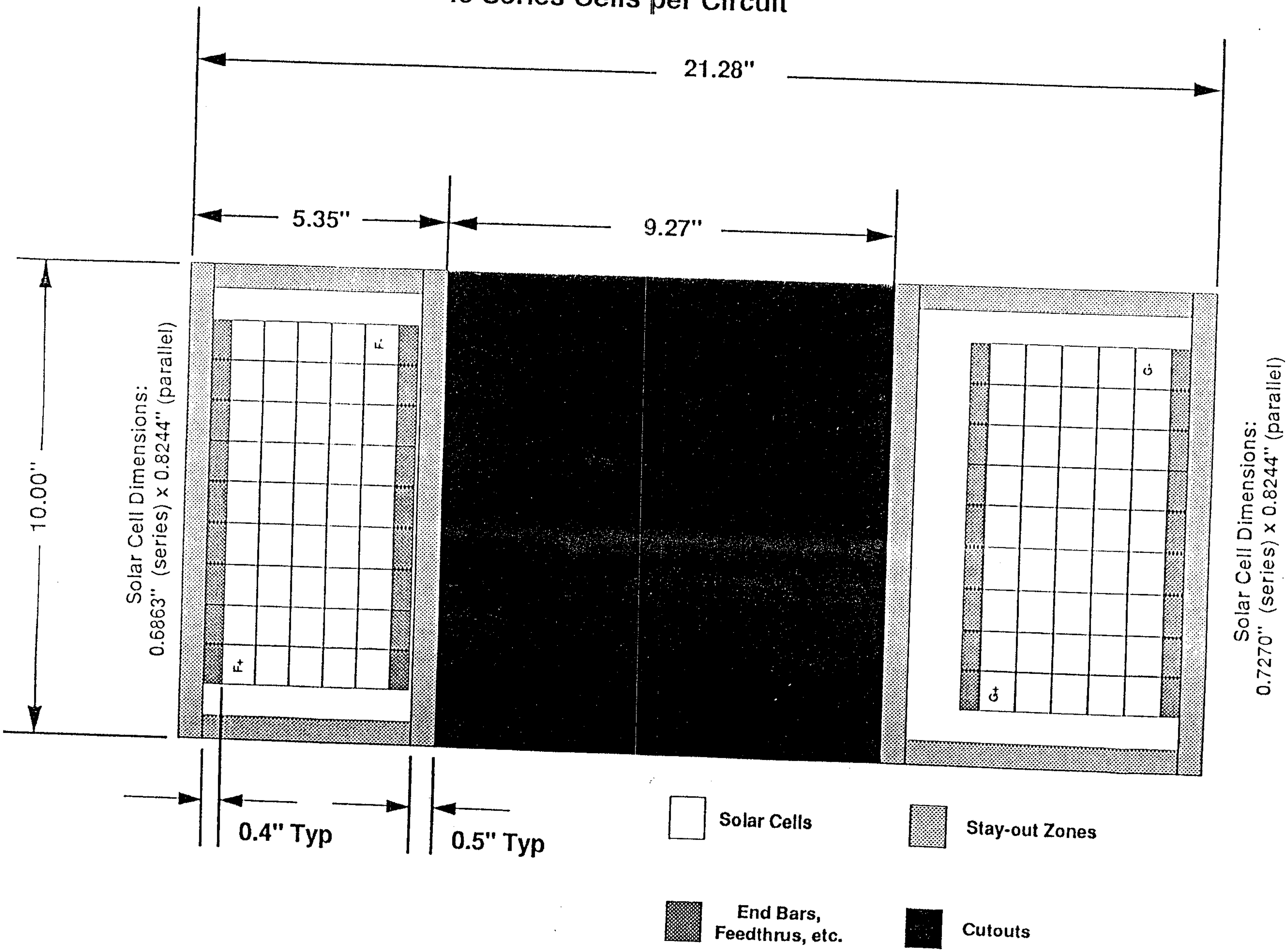

Figure 6.
Panel A-1 Facet # 5 Recessed Panel Solar Cell Layout
45 Series Cells per Circuit

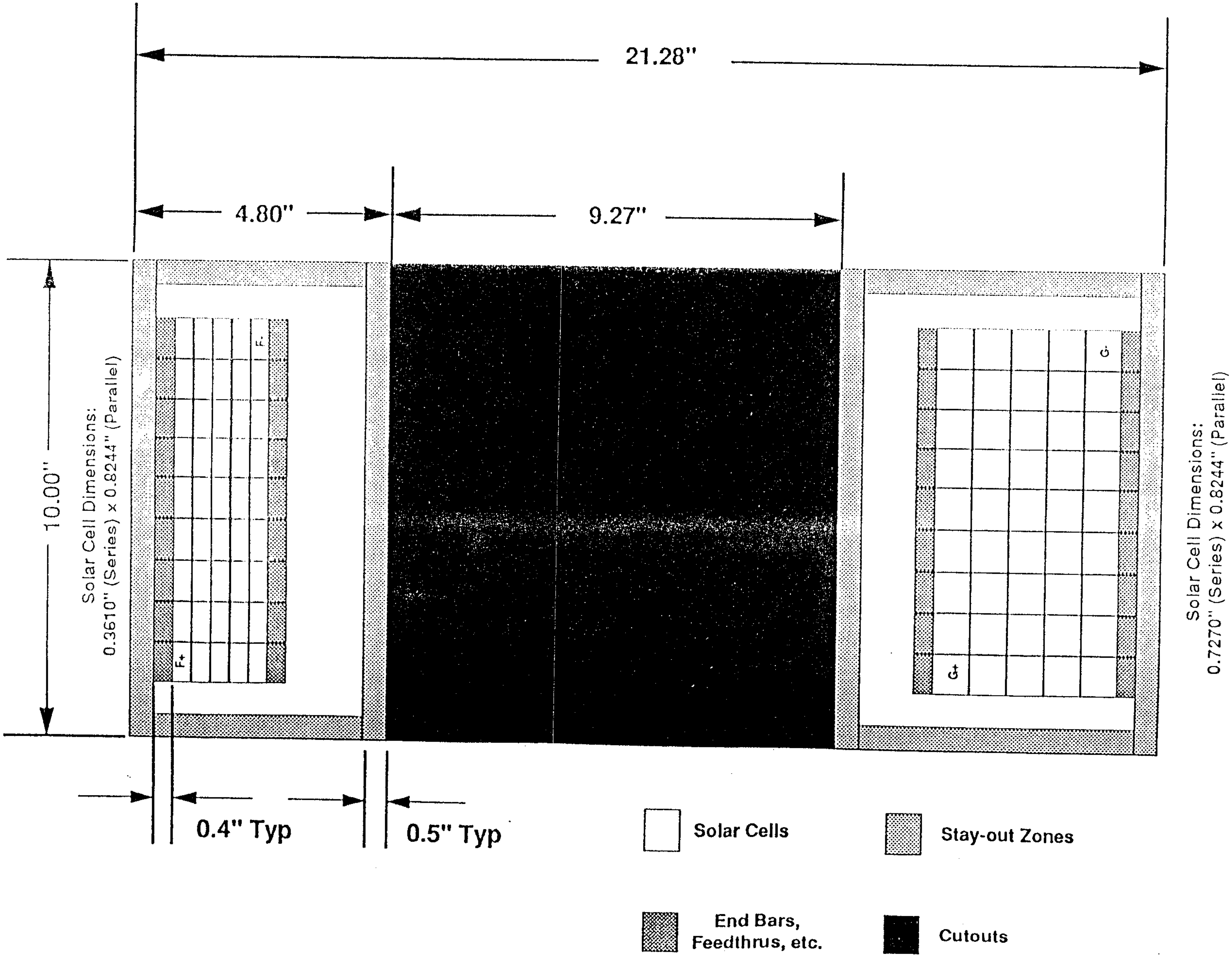

Figure 7.
Panel B-1 Facet #2 & 5 Solar Cell Layout*
45 Series Cells per Circuit

* 2 & 5 are Identical

Solar Cell Dimensions: 0.6863" (Series) x 0.8244" (Parallel)

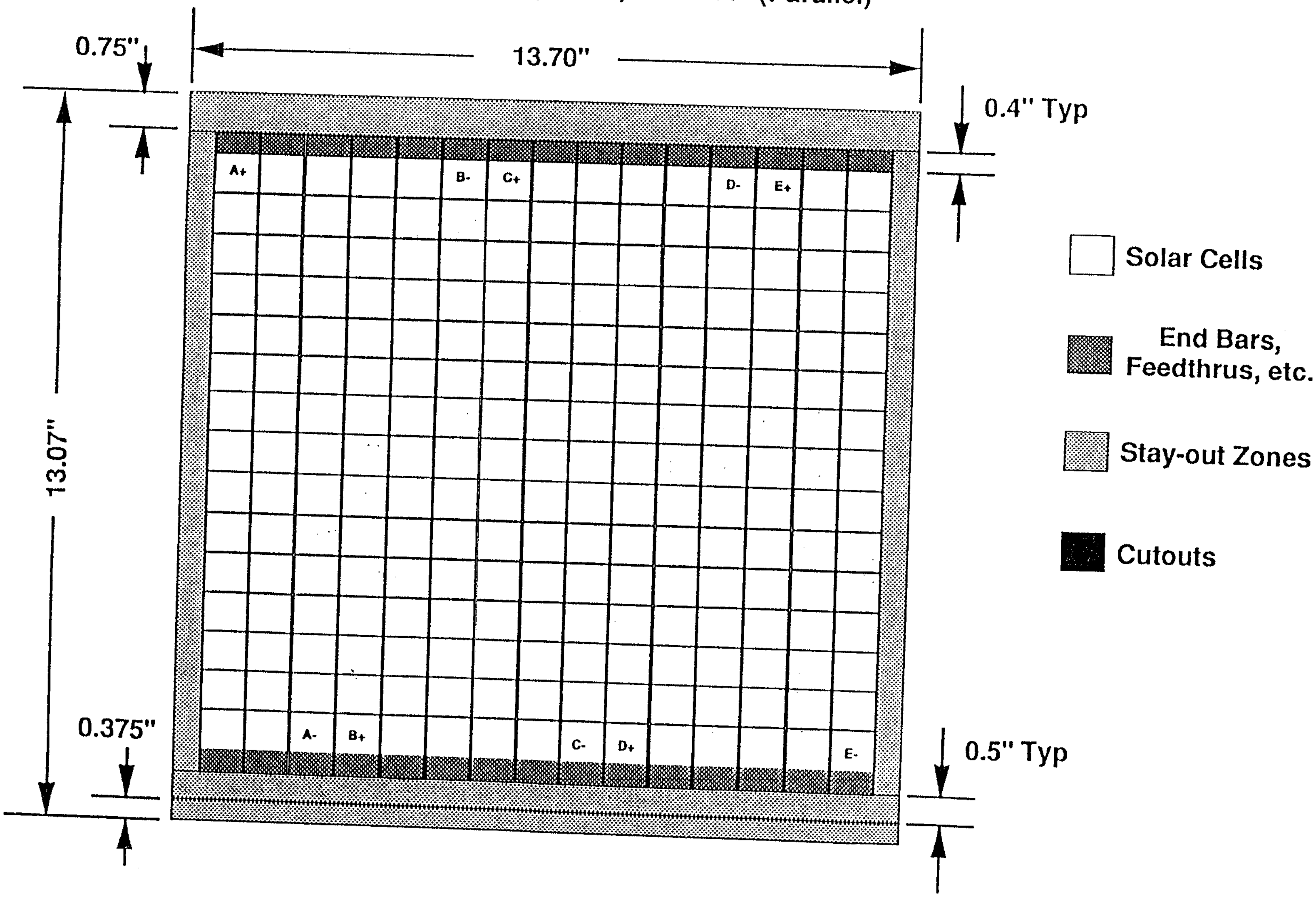

Figure 8.
Panel A-1 Facet # 3 Solar Cell Layout
45 Series Cells per Circuit

Solar Cell Dimensions: **0.7270" (Series) x 0.8244" (Parallel)**

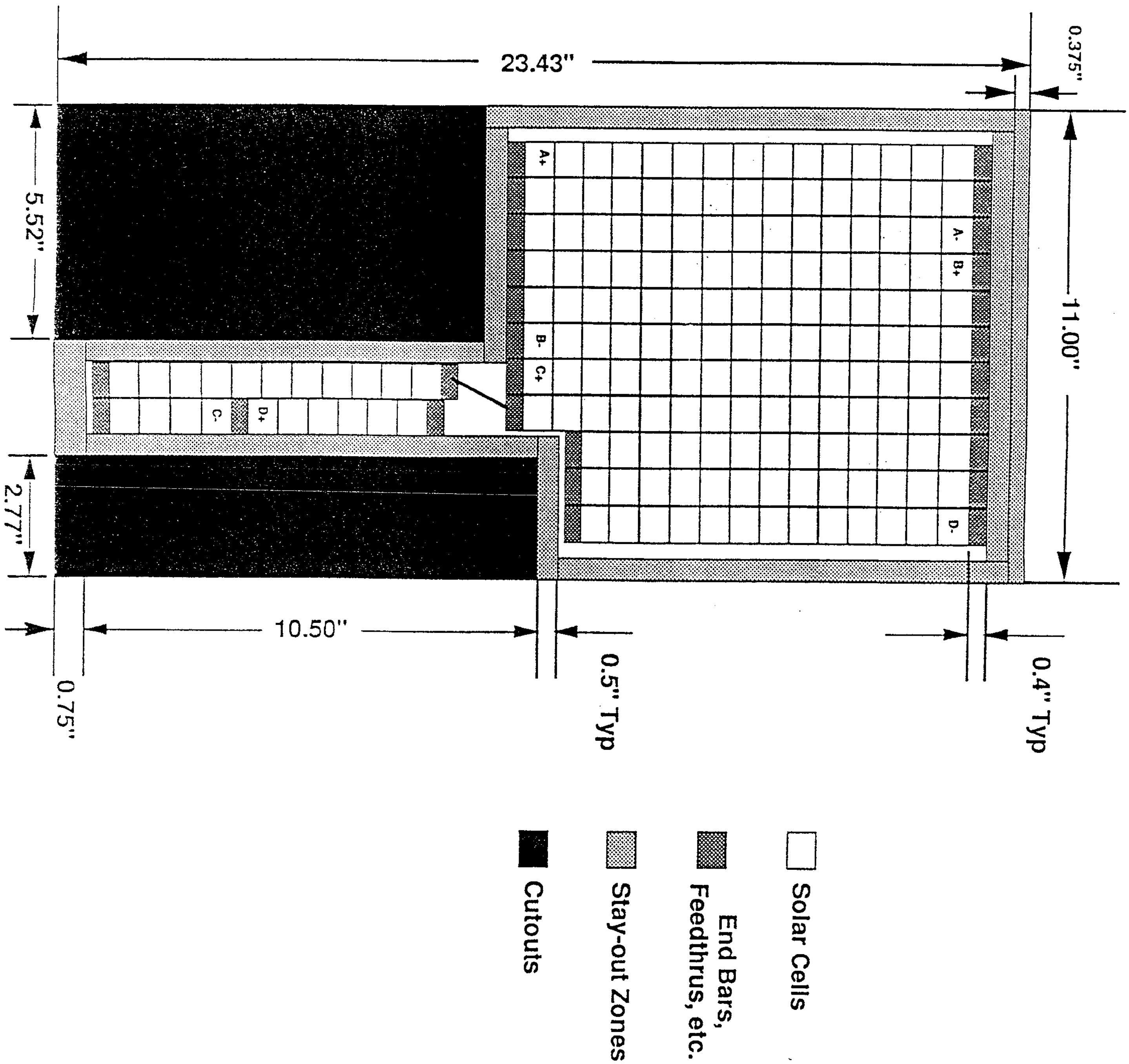

Figure 9.
Panel B-1 Facet #3 Solar Cell Layout
45 Series Cells per Circuit

Solar Cell Dimensions: 0.6863" (Series) x 0.8244" (Parallel)

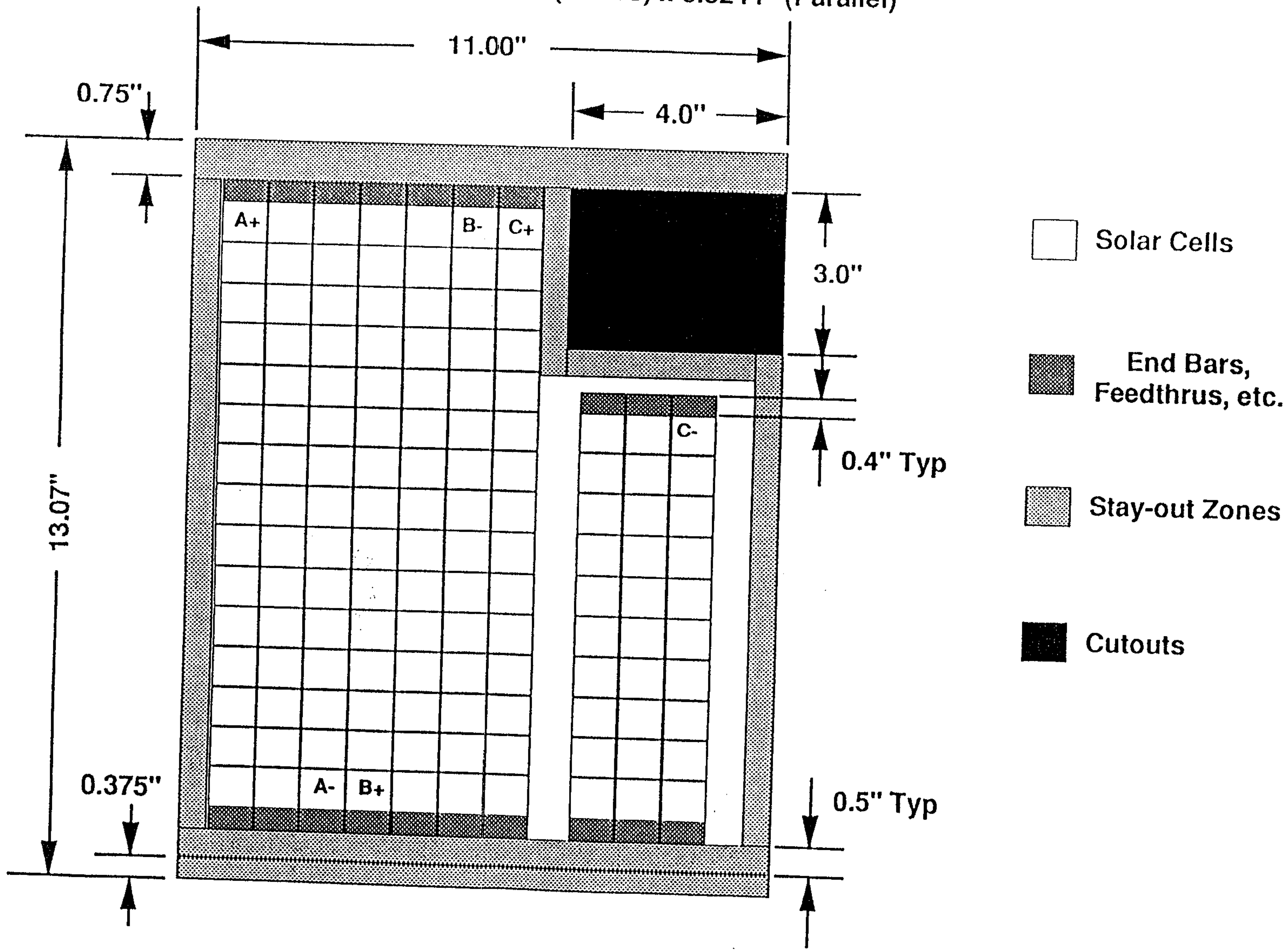

Figure 10.
Panel A-1 Facet # 4 Solar Cell Layout
45 Series Cells per Circuit

Solar Cell Dimensions: 0.7270" (Series) x 0.8244" (Parallel)

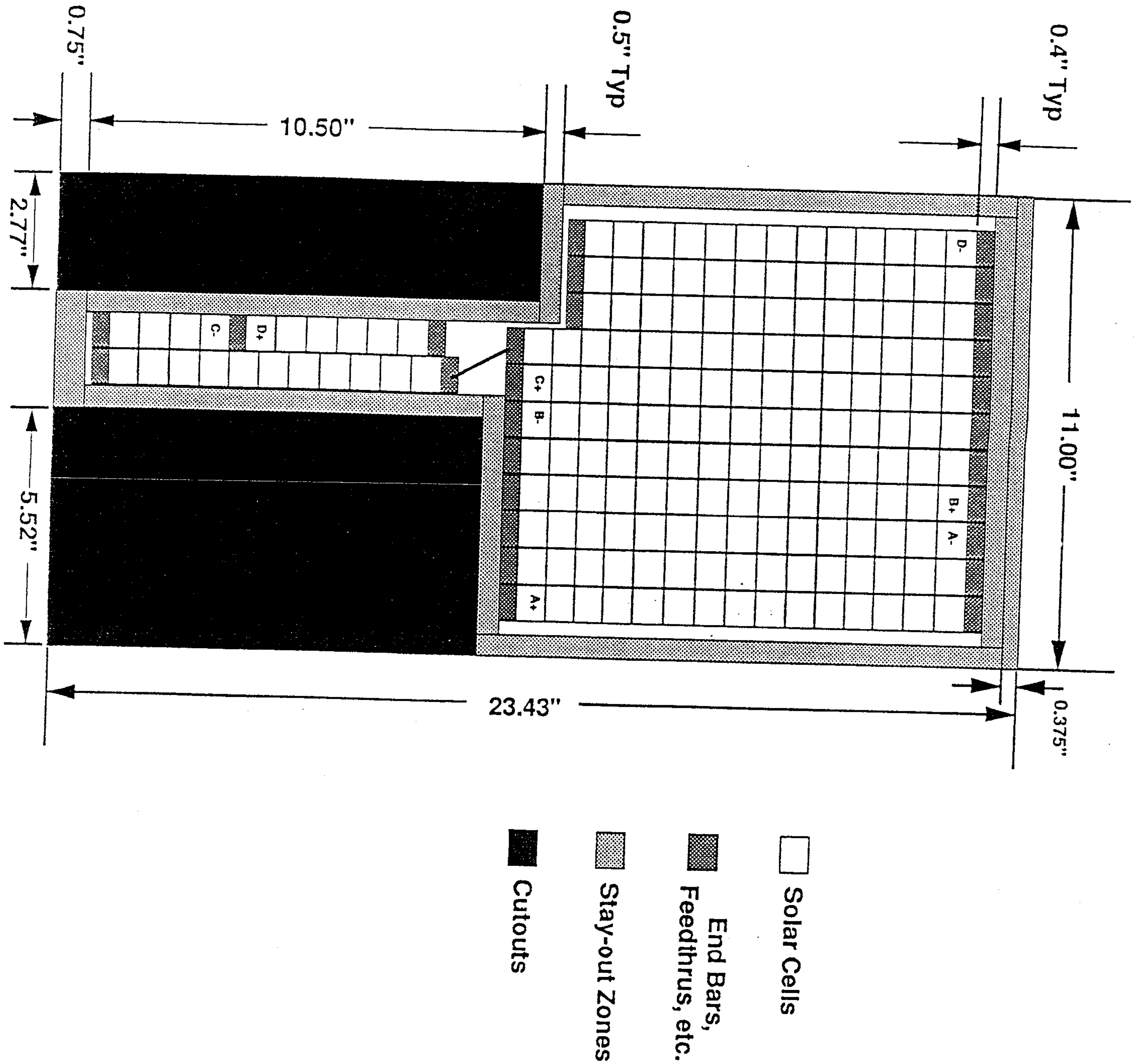

Figure 11.
Panel B-1 Facet #4 Solar Cell Layout
45 Series Cells per Circuit

Solar Cell Dimensions: 0.6862" (Series) x 0.8244" (Parallel)

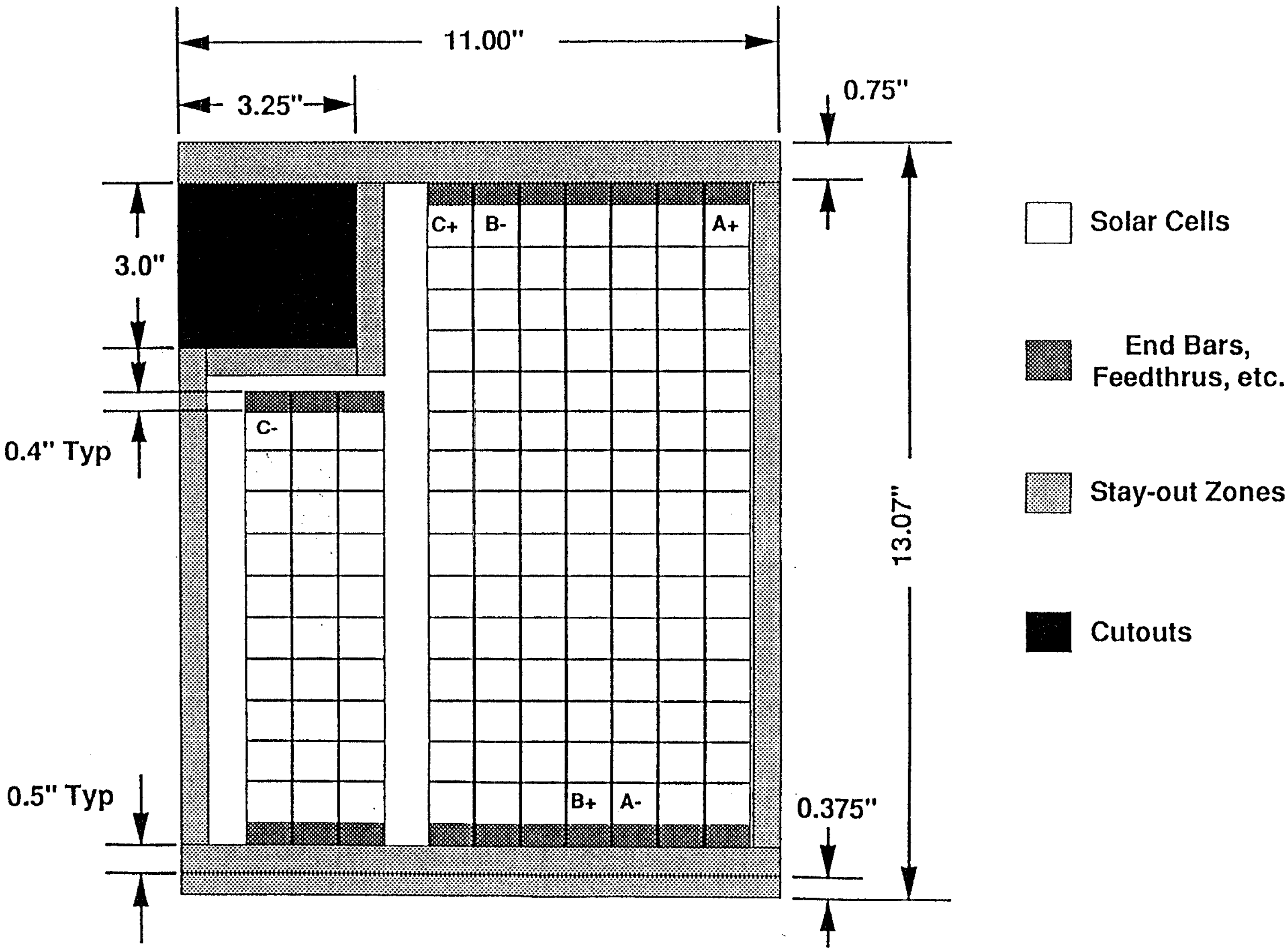

Figure 12.
Panel A-1 Facet #7 & 9 Solar Cell Layout*
45 Series Cells per Circuit

* 7 & 9 are identical except for recessed panels

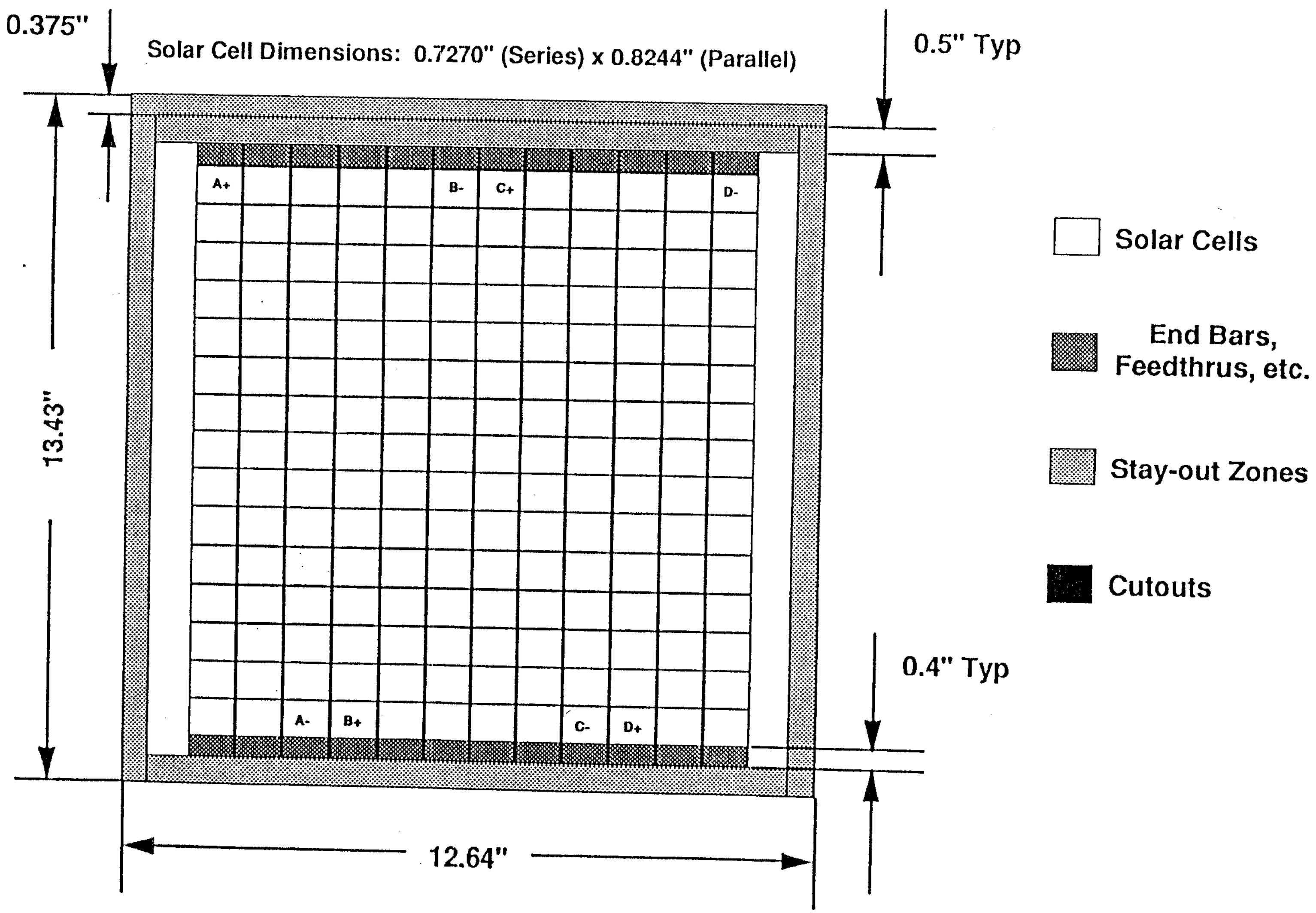

Figure 13.
Panel A-1 Facet # 7 Recessed Panel Solar **Cell Layout**
45 Series Cells per Circuit

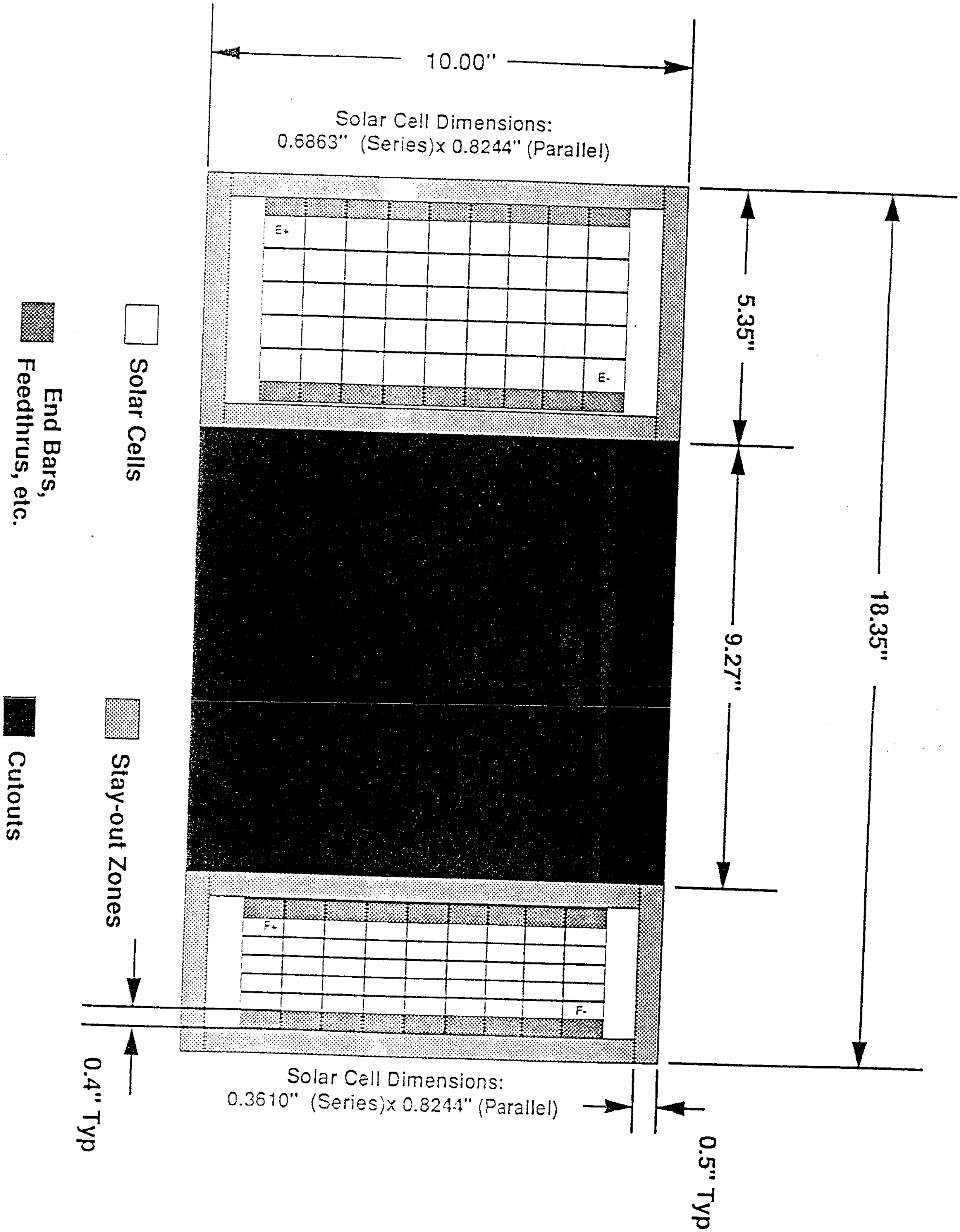

Figure 14.
Panel A-1 Facet # 9 Recessed Panel Solar **Cell Layout**
45 Series Cells per Circuit

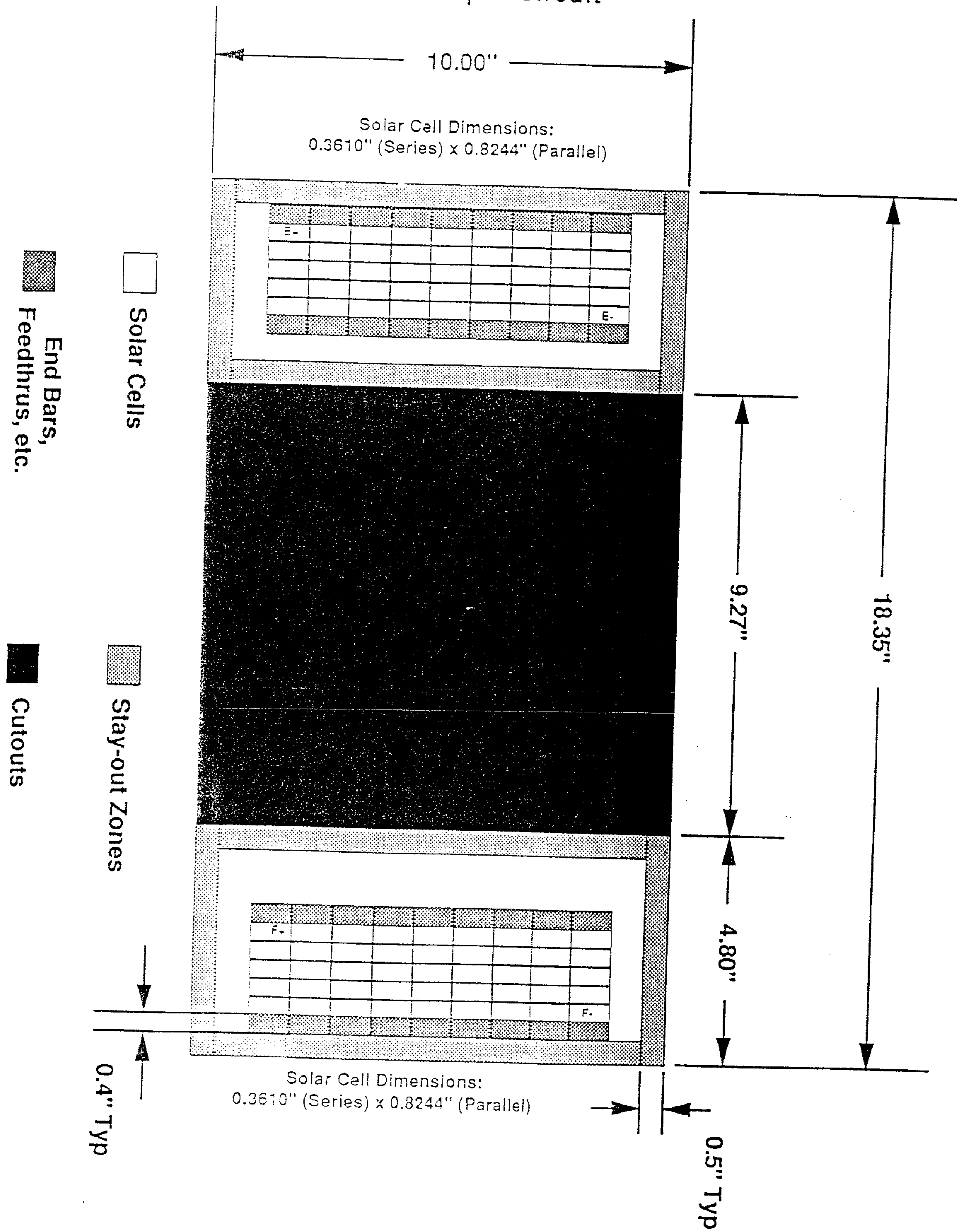

Figure 15.
Panel B-1 Facet #7 & 9 Solar Cell Layout*
45 Series Cells per Circuit

* 7 & 9 are Identical

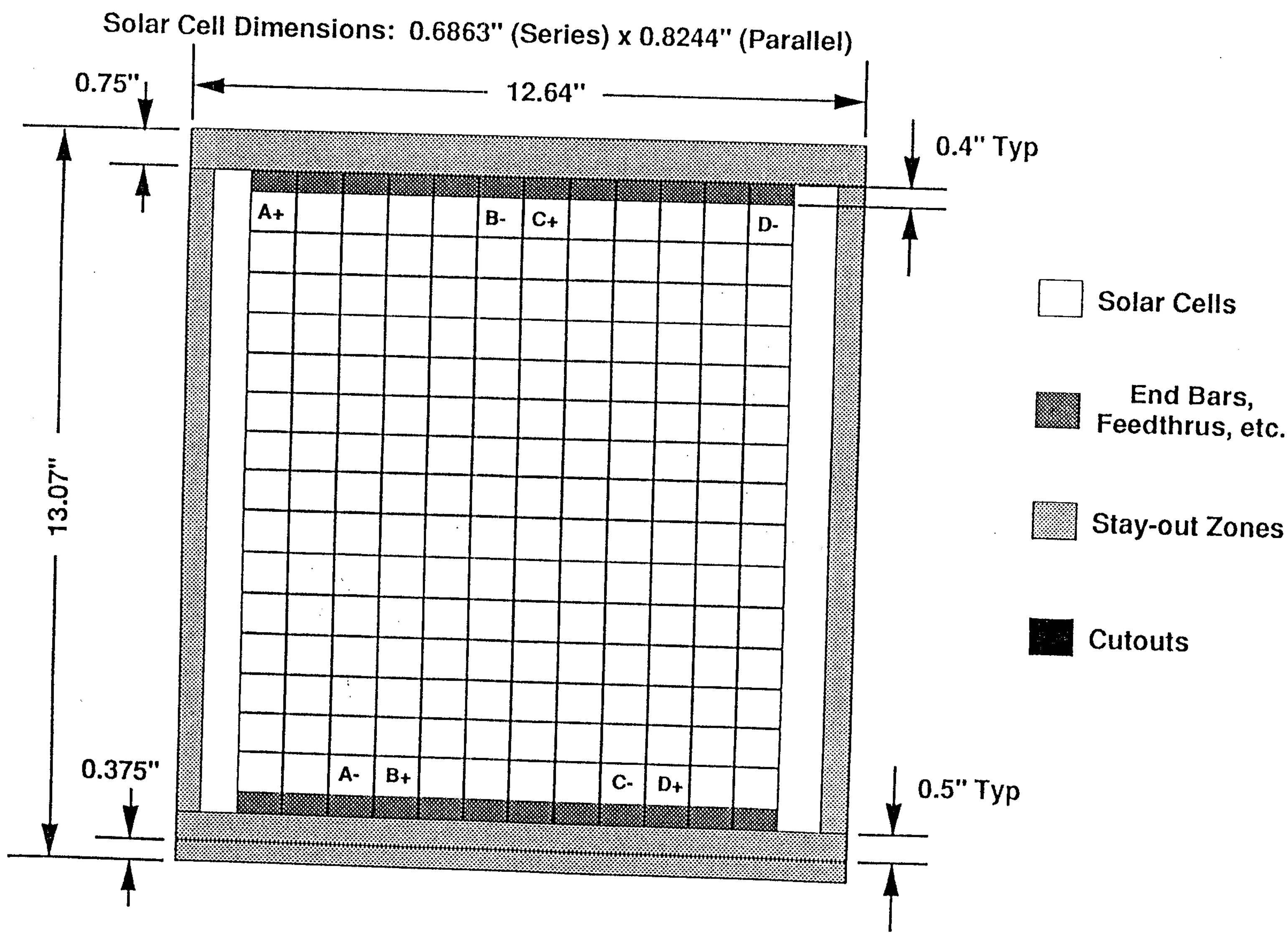

Figure 16.
Panel A-1 Facet # 8 Solar Cell Layout
45 Series Cells per Circuit

Solar Cell Dimensions:
Circuits A-H 0.7270" (Series) x 0.8244" (Parallel)
Circuits I, J 0.3610" (Series) x 0.8244" (Parallel)

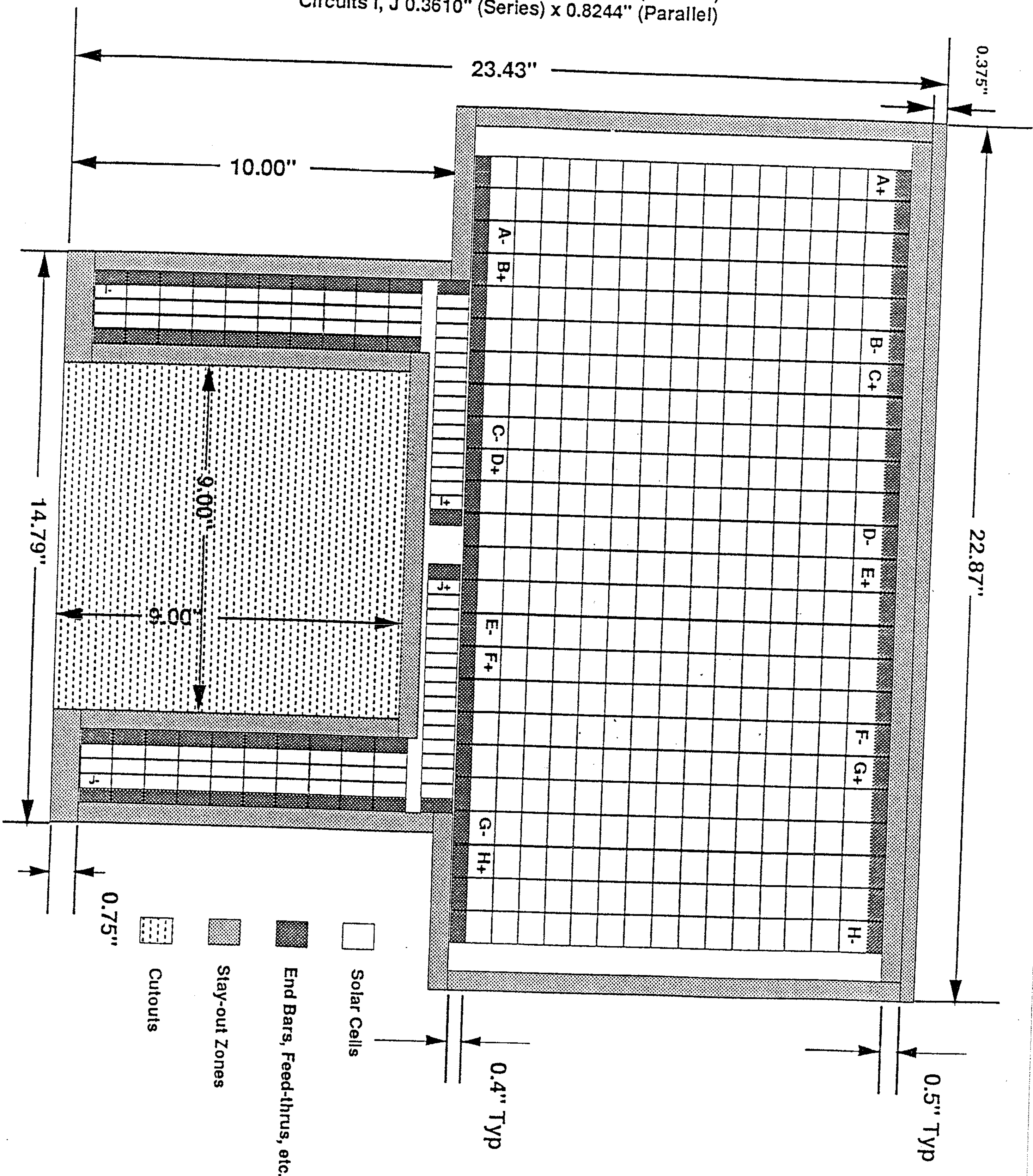

Figure 17.
Panel B-1 Facet #8 Solar Cell Layout
45 Series Cells per Circuit

Solar Cell Dimensions: 0.6863" (Series) x 0.8244" (Parallel)

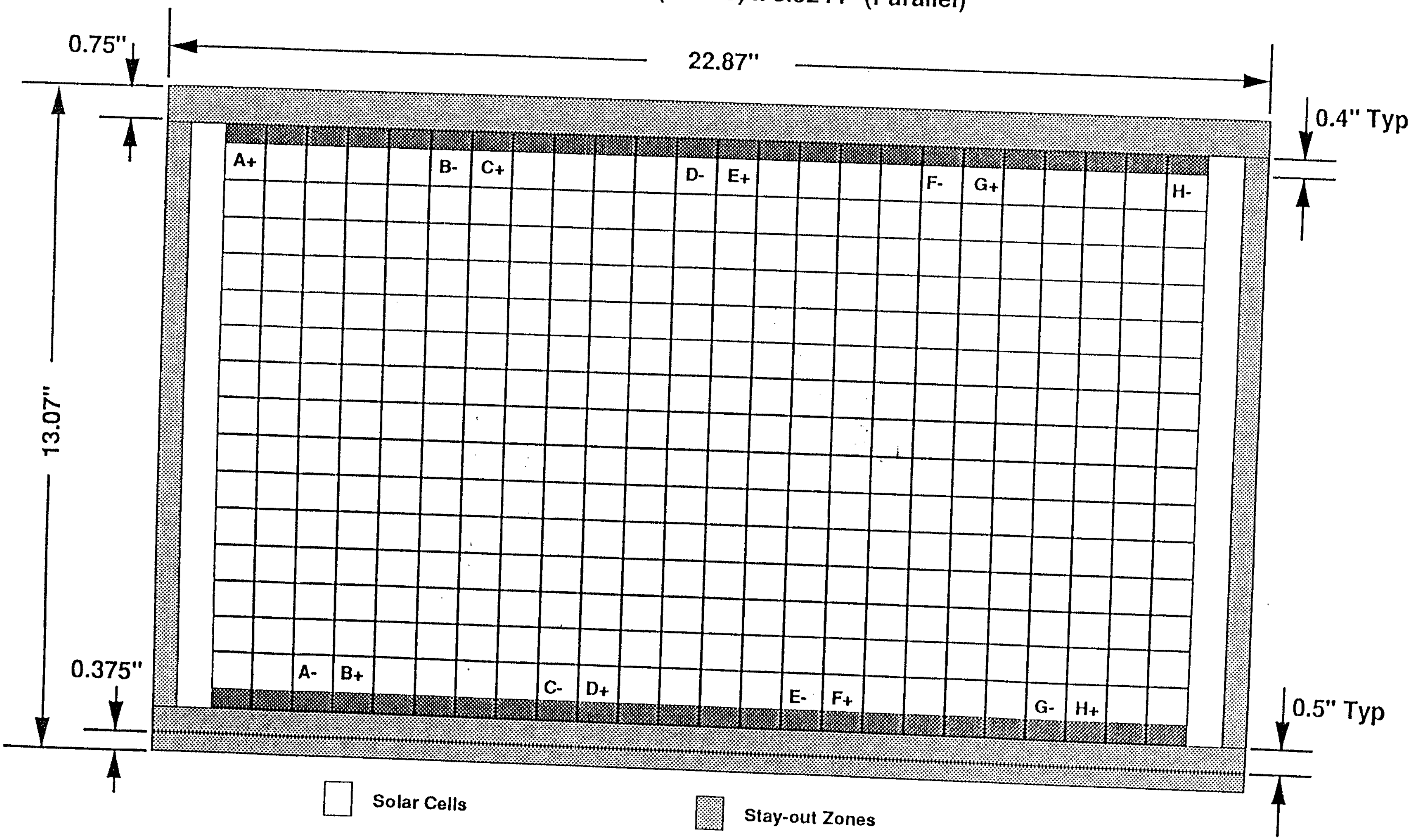

Figure 18. Panel A-2 Solar Cell Layout
54 Series Cells per Circuit

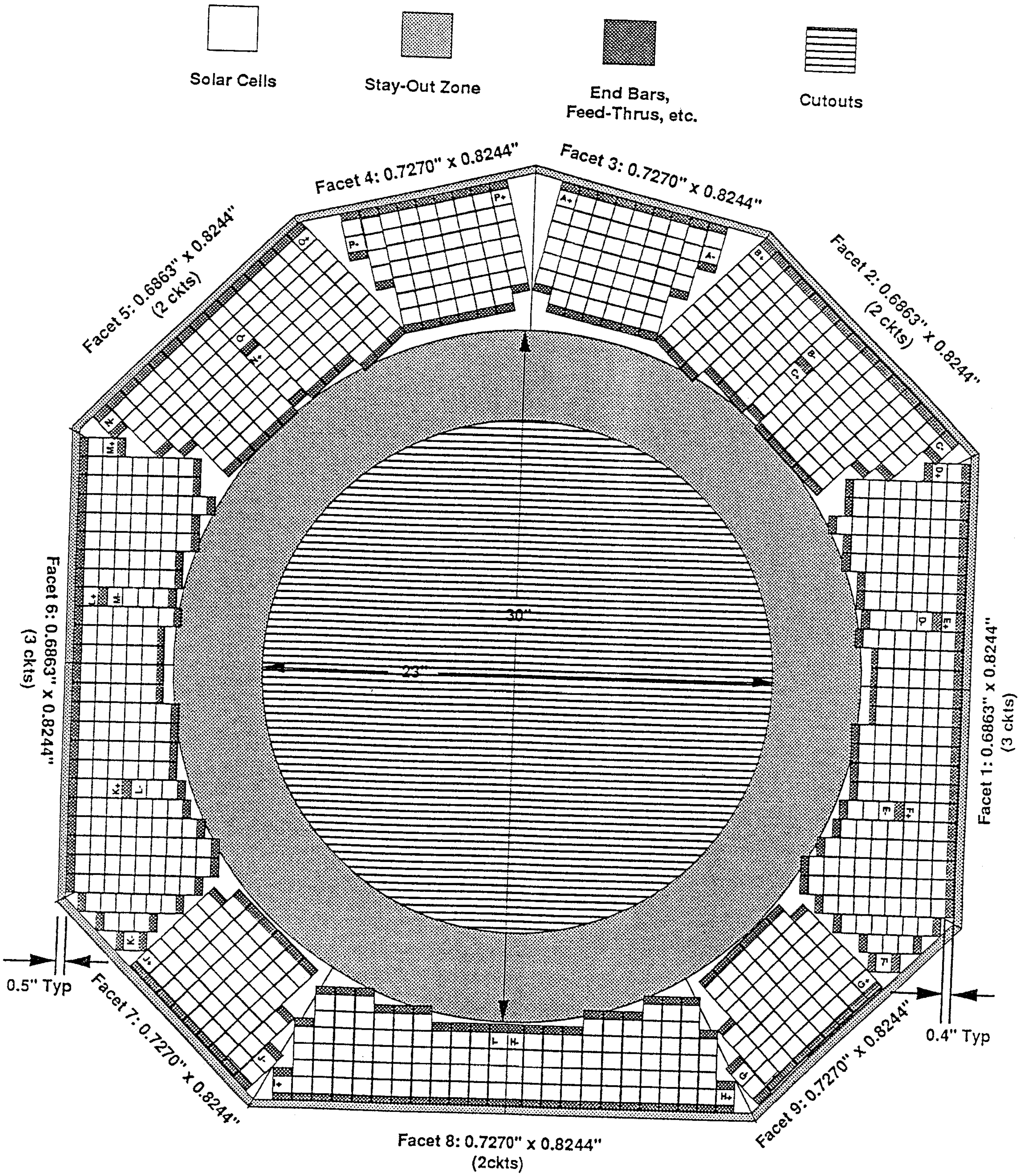

Figure 19. Panel B-2 Solar Cell Layout
54 Series Cells per Circuit

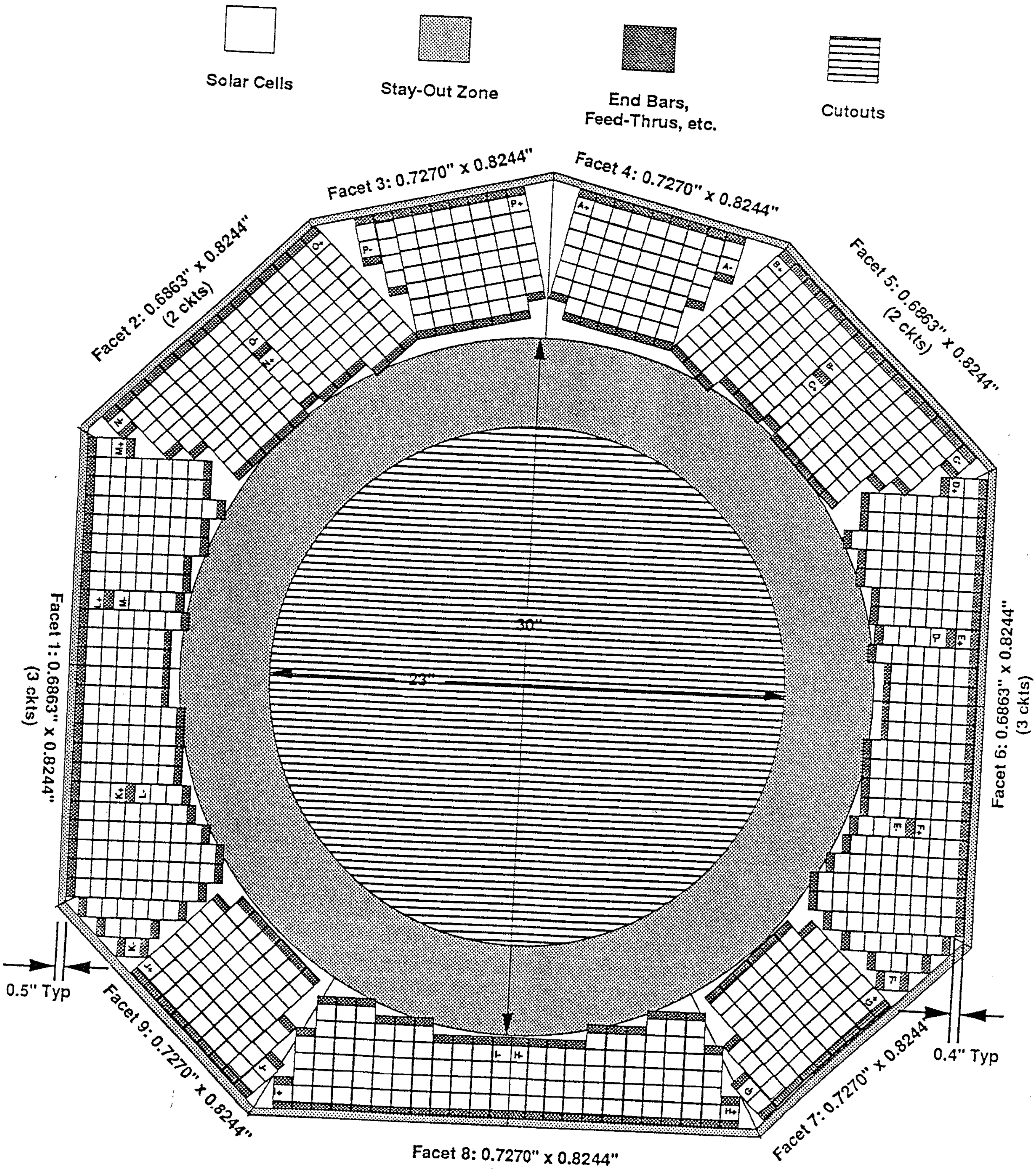

Figure 20 Panel A-2 and B-2 Dimensions

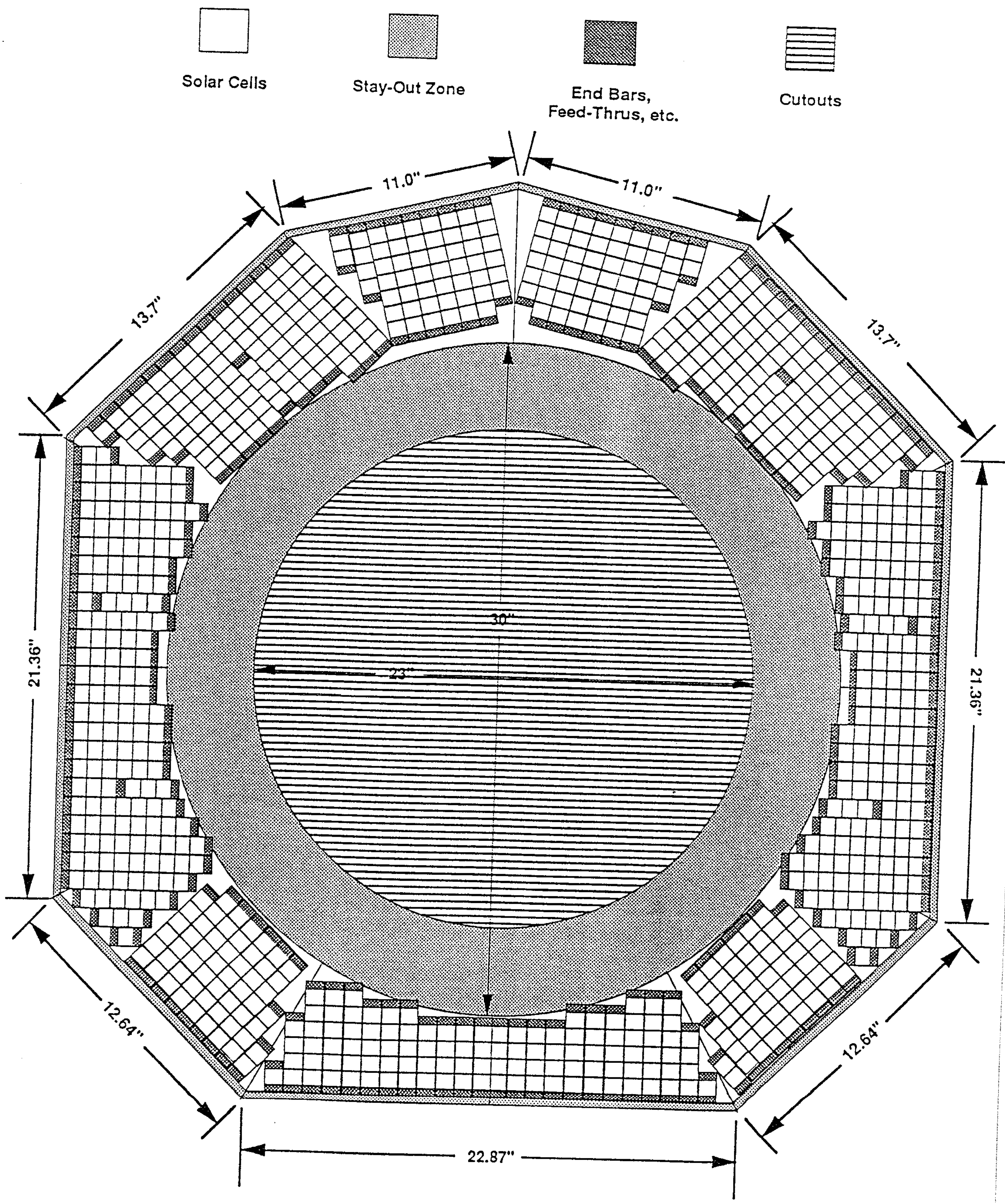

Figure 21. FAST Solar Array Cross-Section

(Not to Scale)