MIL-S-83576(USAF)
1 November 1974

MILITARY SPECIFICATION

SOLAR CELL ARRAYS, SPACE VEHICLE, DESIGN AND TESTING, GENERAL SPECIFICATION FOR

1. SCOPE

This specification establishes the general design, fabrication, performance, and testing requirements for solar cell panels (6.3.4) and solar cell arrays (6.3.5) to be installed on space vehicles to convert solar energy into electrical energy as part of the vehicle electrical system.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-T-152	Treatment, Moisture and Fungus Resistant, of Communications, Electronic, and Associated Electrical Equipment
MIL-F-7179	Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures and Parts; General Specification for
MIL-S-45743	Soldering, Manual Type, High Reliability, Electrical, Electronic Instrument, Communication and Radar, for Aerospace and Control Systems, Procedure for

MIL-C-83443	Cells, Solar, Silicon, General Specification for
MIL-W-83575	Wiring Harness, Space Vehicle, Design and Testing (USAF)

STANDARDS

Military

MIL-STD-130	Identification and Marking of Parts
MIL-STD-143	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-889	Dissimilar Metals
MIL-STD-891	Contractor Parts Control and Standardization Program
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-STD-1540	Test Requirements for Space Vehicles

PUBLICATIONS

Bulletins

MIL-BU-400	Airborne Electronic and Associated Equipment, Applicable Documents.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials (ASTM)

E 490 Specification for the Solar Constant and Air Mass Zero Solar Spectral Irradiance

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103).

3. REQUIREMENTS

3.1 General

3.1.1 Order of precedence. The solar cell arrays shall conform to the requirements of this specification and the applicable documents referenced herein. In any conflict between this specification and the applicable documents referenced herein, this specification shall prevail. In any conflict between this specification and the type or detail specification for a particular space vehicle, the type or detail specification shall prevail.

3.1.2 Commonality. A primary objective in the design shall be to maximize commonality and thereby minimize the variety of parts and related tools required in the fabrication, installation, and maintenance of the vehicle electrical system. However, identical electrical connectors or other identical parts shall not be used on a space vehicle where inadvertent interchange could cause possible malfunction.

3.2 Design requirements

3.2.1 Selection of parts, materials, and processes. Selection of parts, materials, and processes shall be in accordance with the selection procedures of MIL-STD-891. The parts, materials, and processes selected shall be of sufficient proven quality to allow the equipment to meet the functional performance, reliability, and strength requirements during the space vehicle life cycle including all environmental degradation effects. The use of toxic materials shall be avoided. Metals shall be of the corrosion resistant type, or shall be suitably treated to resist corrosion when subjected to the requirements of this specification. Protective methods and materials for cleaning, surface treatment and applications of finishes and protective coating shall be in accordance with MIL-F-7179. Dissimilar metals, as defined in MIL-STD-889, shall not be used in intimate contact without a protective treatment sufficient to inhibit electrolytic corrosion. Materials used shall minimize permanent, induced, and transient magnetic fields. No radioactive, fluorescent, or phosphorescent materials shall be used. Materials which are nutrients for fungus shall be treated with a fungicidal agent in accordance with MIL-T-152. Selection of parts, materials, and processes shall consider outgassing effects in the thermal vacuum environment of space as well as the susceptibility to damage or deterioration from space radiation. The selection of parts, materials, and processes shall be based upon data obtained from tests conducted on prototype or representative hardware. This test data may be limited in scope to those areas where similar designs and environments have not been previously evaluated. The test data shall confirm the critical design and process parameters and shall include environmental testing of prototype panel test sections (3.4.5). The tests shall be directed towards selecting optimum parts and materials and towards developing manufacturing processes and process control techniques that will ensure successful and repeatable hardware fabrication. Evaluations of adhesive cure cycles, panel outgassing effects, and design margins are typical of the data that shall be used in selecting parts, materials, and processes.

3.2.1.1 <u>Standard parts, materials, and processes</u>. Parts, materials, and processes described in this specification and by specifications listed in MIL-BU-400 for which there is an existing qualified source are standard. All other parts, materials, and processes are nonstandard and approval of the procuring activity is required for each vendor source. Standard parts, materials, and processes shall be given first priority for use in the equipment.

3.2.1.2 <u>Nonstandard parts, materials, and processes</u>. When this specification and the documents referenced herein fail to provide a suitable specification or standard, the contractor shall select other specifications or standards in accordance with MIL-STD-143, subject to the approval of the procuring activity prior to their use. Parts, components, materials, and processes conforming to contractor specifications may be used, provided each contractor specification is approved by the procuring activity, and provided no suitable military specification exists. The contractor shall provide substantiating test data and, when required by the procuring activity, shall provide samples for testing. The use of contractor specifications shall not constitute waiver of government inspection. Request for the approval of nonstandard parts, materials, and processes shall be in accordance with MIL-STD-891. When a detail or general military specification exists for the class of material required, the contractor specification shall reference the existing military specification and set forth only the needed new requirements and deviations.

3.2.2 Panel performance. The electrical power output of the solar cell panel at a temperature of 25 ± 2 degrees Celsius (deg C) shall be greater than 140 watts per square meter (W/sq m) when uniformly irradiated normal to the surface at one solar constant at air mass zero spectral conditions in accordance with ASTM E 490 (1 353 W/sq m).

3.2.3 Electrical interconnections.

3.2.3.1 Cell interconnections. The interconnections between cells shall be either annealed copper, aluminum, Kovar, molybdenum, silver, or other suitable material having a conductivity equivalent to or greater than a 22 gauge AWG annealed copper wire. A minimum of two interconnections per cell or a continuous interconnect tab shall be used to assure electrical redundancy. Stress relief shall be incorporated to minimize stress on the cell contacts. The intercell connections shall be capable of withstanding a 150-gram pull in any direction with no visual or electrical indication of poor contact or loosening from the cells. The soldering, ultrasonic bonding, or welding techniques used in assembly shall be compatible with the solar cell contact materials, the electrical interconnect material, and the specified space vehicle environment.

3.2.3.1.1 Soldering. Soldering shall be in accordance with MIL-STD-454, Requirement 5, except that manual soldering shall be in accordance with MIL-S-45743.

3.2.3.1.2 Welds. Electrical interconnection resistance welds shall be in accordance with MIL-STD-454, Requirement 24.

3.2.3.2 Harness. The electrical wiring harness between the solar cell panel output bus and the spacecraft interface connector for electrical power shall be in accordance with MIL-W-83575. A separate telemetry wiring harness in accordance with MIL-W-83575 shall be supplied as required to interconnect panel mounted instrumentation to the spacecraft telemetry subsystem.

3.2.4 Nuclear detonation resistance. When a nuclear detonation environment is specified in the type or detailed specification for the space vehicle, or by the procuring activity, the radiation spectrum as a function of time including electromagnetic pulse effects shall be considered in the design. In general, all materials used in the fabrication of the solar cell panels and solar cell arrays that may be subjected to nuclear detonation envrionments should utilize elements with atomic numbers not exceeding 14, except that elements having atomic numbers from 15 to 32 may be used in alloys up to 5 percent concentration and those with atomic numbers from 32 to 50 in alloys up to 1 percent concentration by weight.

3.2.5 Solar cells. Unless otherwise specified in the type or detailed specification for the space vehicle or by the procuring activity, solar cells shall be as specified in MIL-C-83443. (Refer to 6.2c and 6.4)

3.2.6 Diodes

3.2.6.1 Blocking or isolation diodes. Isolation diodes may be used with each solar cell module (6.3.3) or panel to prevent batteries from feeding the solar cells during solar eclipse and modules from feeding other modules if a difference in output exists among the modules due to shadowing, cell mismatch, open circuits or shorts in the modules.

3.2.6.2 Bypass diodes. Bypass diodes may be used at the module level if required to provide protection against the generation of hot spots on the solar cell array due to partial shadowing, open circuit cells, or interconnect failure.

3.2.6.3 Zener diodes. Zener diodes may be used at the panel level to limit what would be higher than specified voltage from the solar cell panel due primarily to low temperature operation that occurs immediately following solar eclipse.

3.2.7 Synthetic oil. Any synthetic oil, grease, or similar substance including silicone oils and grease, which may prevent the use of adhesives specified, shall not come into contact with any portion of the solar cells, solar cell modules, solar cell panels, or solar cell array. Such oils and grease cannot adequately be cleaned from solar cells or other materials once applied. Natural oils are permissible if required.

3.2.8 Solar cell panel

3.2.8.1 Insulation. Insulation shall be provided over all metal or electrically conductive surfaces of the panel substrate prior to mounting solar cells, diodes, non-insulated wiring, bus strips, or other electrical components. Either polyimide, glass, or fiberglass insulating material may be used. The insulation resistance measured between the mounted solar cells and the conducting substrate material (if it exists) shall be at least 10 megohms when measured at 500 volts dc. Insulating materials or finishes having a resistivity greater than 1000 megohm centimeters shall not be used in space vehicles except in applications or small areas where charge buildup will not be excessive.

3.2.8.2 Solar cell bonding. The solar cells shall be flat mounted and bonded to the electrically insulating substrate material using a suitable methyl phenyl silicone adhesive or equal. The adhesive shall be applied on a controlled weight basis. A monitored vacuum and temperature cure cycle shall be utilized to ensure a satisfactory bond. Low outgassing adhesives shall be used when required to meet system cleanliness and contamination control requirements. The solar cells may be interconnected and assembled into modular form prior to installation on the panel substrate.

3.2.8.3 Radiation protection. Provisions shall be made to protect the solar cell panels from radiation damage. Protection from low energy proton degradation of the solar cells shall be accomplished by proven design techniques such as thoroughly coating all exposed areas on all edges and on the top around the cover glass of all solar cells with sufficient adhesive to mask the radiation. For typical adhesives, 0.07-millimeter (mm) thickness provides protection of the active cell area from low energy proton damage. When edge etching of all solar cells is accomplished to provide the low energy proton radiation protection, care shall be taken to ensure that all critical N-doped material has been removed from the edges by the etching process and that adequate adhesive or other masking material is applied to the top of the cells around the cover glass. Diodes or other solid state devices used in the solar cell panel shall be protected from radiation damage by their case design, shielding, or by their mounting location.

3.2.9 Structural design. Structural design parameters and design margins shall be confirmed by static load tests conducted on a full size structural model of the solar panels used on the the space vehicle. The structural model shall be fabricated using prototype or production drawings, materials, and tooling. At least 5 percent of the solar cell panel area, including any critical areas, shall have active solar cells mounted and connected so their output can be monitored. The remaining 95 percent of the solar cell panel area on the structural model may have simulated or inactive solar cells mounted.

3.3 Environmental requirements

3.3.1 Maximum predicted environments. Solar cell panels shall be designed to operate within specifications during (or following if appropriate) environmental levels that exceed the maximum predicted environmental levels by the design margin. These maximum predicted environments shall be determined in accordance with MIL-STD-1540 for all operational modes in the solar cell panels service life including ground handling, storage, transportation, ground testing, launch, injection, and on-orbit operations. For each operational mode, the significant operating configurations of each panel shall be determined, such as: (a) stowed or deployed; (b) irradiated by the sun, partially irradiated, or not irradiated; and (c) supplying maximum power or supplying no power. For each operational mode the maximum and minimum environmental limits to which the solar cell panels will be subjected shall be determined for the random vibration spectrum, sinusoidal vibration, acoustic spectrum, thermal conditions, thermal gradients, vacuum, linear acceleration, radial acceleration, handling shocks, pyro shocks, humidity, high and low energy protons, high and low energy electrons, and other radiation.

3.3.2 Random vibration and acoustic noise. The solar cell panels and the entire solar cell array of a space vehicle shall be designed to operate within specifications following (and during if appropriate) a random vibration or acoustic noise environment that is 6 decibels (dB) above the maximum predicted levels to provide the required design margin of safety. This design environment shall persist for 3 times the exposure duration associated with the maximum environmental amplitudes, but for not less than three minutes. A random vibration design environment shall be used except where mechanical vibration of the unit cannot suitably simulate imposition of the service dynamic environment such as with equipment configurations typified by expansive proportions of surface area to volume. For these cases, an acoustic design environment 6 dB above the maximum predicted acoustic noise environment, but not less than 144 dB, shall be used. Where random vibration is used, the design level shall be 6 dB above the maximum predicted vibration environment, but not less than 12 g rms overall.

3.3.3 Sinusoidal vibration. Sinusoidal vibration design levels 6 dB above the maximum predicted sinusoidal vibration levels shall be used to provide the required design margin of safety. This maximum environment shall persist for three times the exposure duration associated with the maximum environmental amplitudes but not less than 3 minutes along each of the three axes.

3.3.4 Shock. The solar cell panels and the entire solar cell array of a space vehicle shall be designed to operate within specifications following (and during if appropriate) transient and pyro shocks at least 6 dB over the maximum predicted levels.

3.3.5 Acceleration. The solar cell panels and the entire solar cell array of a space vehicle shall be designed to operate within specifications following (and during if appropriate) exposure to acceleration of 1.25 times the maximum predicted levels. Unless otherwise specified, launch and injection accelerations shall be simulated by an acceleration ramp along the direction of the space vehicle axis that starts at -1 g and increases linearly to at least +20 g in 3 minutes then drops to 0 g in 10 seconds.

3.3.6 Thermal vacuum. The solar cell panels and the entire solar cell array of a space vehicle shall be designed to operate within specifications at any temperature within the thermal design range, at an ambient pressure less than 0.00133 pascals. The thermal design range is from 6 deg C above the maximum predicted temperature to 6 deg C below the minimum predicted temperature. The thermal design range shall not be less than from -34 deg C to +71 deg C. The maximum rate of transition between high and low temperatures shall be at an average rate of at least 20 deg C per minute or at the maximum rate to be experienced during operational use if that is greater. The equipment shall operate satisfactorily when the ambient pressure drops from one atmosphere pressure to 0.00133 pascals in 3 minutes.

3.3.7 Humidity. The solar cell panels and the entire solar cell array of a space vehicle shall be designed to operate satisfactorily after exposure to 100 per cent relative humidity for 6 hours at ambient temperature.

3.3.8 Radiation. Each solar cell panel and the entire solar cell array of a space vehicle shall be designed to operate within specifications after exposure to "flight" level radiation environments for the service life of the array. The time line of the "flight" levels shall include a representative number of time periods at the maximum predicted radiation levels to ensure a satisfactory design margin.

3.4 Assembly and fabrication requirements

3.4.1 Contamination control. The materials, processes, and facilities used shall ensure that the solar cell array will meet the requirements of MIL-STD-1246 (level 500A).

3.4.2 Cleaning. Prior to any bonding to the insulating substrate, the substrate surface shall be cleaned and rinsed. A water-break-free condition (6.3.6) or equivalent may be used to indicate adequate cleaning. Solar cells, bus strips, and other parts to be bonded to the substrate shall also be thoroughly cleaned. The cleaning process used shall not adversely affect the substrate, parts, or materials used. The cleaned surfaces shall not be handled with bare hands. Clean nylon or lint-free gloves or finger cots shall be used when handling the clean items to prevent recontamination. Completed solar cell panel assemblies shall be thoroughly cleaned prior to acceptance testing.

3.4.3 Handling. Holding fixtures shall be used to support the substrate during solar cell panel fabrication. When solar cells are interconnected or assembled into modular form prior to installation on the panel surface, special handling platens and procedures shall be established to ensure that excessive stress will not be introduced into the cell interconnections by the handling and manufacturing processes used. All panel move operations shall be made with extreme care to prevent damage to solar cells, cell covers, and interconnections.

3.4.4 Panel protection. External surfaces of solar cell panels shall have protective covers at all times except when active fabrication or testing operations prohibit. Prior to final assembly, covers of polyethylene film are satisfactory for surface protection if supported adequately. After final assembly of the solar cell panels, protective containers with covers and handling frames shall be used until the panels are installed on the spacecraft.

3.4.5 Panel test sections. To adequately control and evaluate the materials and processes used in manufacturing solar cell arrays for flight vehicles, representative panel test sections shall be fabricated at the same time as flight panels. Panel test sections shall use materials and processes identical to those used in flight panels. The panel test sections shall be selected by the contractor to be representative of the shapes, materials, and fabrication methods used on the particular space vehicle. These panel test sections are the basic test items for certain development and qualification tests, as well as the acceptance tests specified. Although complete panels must be used for some tests to be cost effective and to facilitate testing, the use of panel test sections that are smaller than the complete space vehicle solar cell panels is desirable for many tests. Each panel test section shall include at least one solar cell test module, and shall be fabricated on the typical substrate or mounting structure using production materials and processes. The solar cell modules to be mounted on the panel test sections shall be representative of the series and parallel interconnections of the solar cells being used on the flight hardware. The test module shall not be smaller than 12 cells in series. The test module would use typically the number of cells in parallel that is representative of the flight hardware. Unless otherwise specified, the size of solar cell modules in the manufacturing process or in the final space vehicle panels shall be at the supplier's option. Where cell groups or parallel cells (6.3.2) are not used in manufacturing or in the final arrays the solar cell test module on the panel test sections shall be at least two series strings of 12 cells each (24 cells total).

3.5 Test plans and procedures. The contractor shall establish procedures for performing all tests specified in accordance with a detailed test plan approved by the procuring activity. Since test sections of the solar cell panels are to be utilized in the testing program, the contractor shall clearly list and identify in the test plan the size and configuration of each test section to be tested, the number of each of the test sections to be fabricated, and the tests planned for each unit. Testing of solar cell panels and solar cell arrays in the various environments shall simulate the significant operating configurations of the panels when exposed to the environment such as: (a) stowed or deployed, (b) irradiated by the sun, partially irradiated, or not irradiated, and (c) supplying maximum power or supplying no power. An informal test plan for development tests shall be established by the contractor to determine design margins and failure modes when the equipment is exposed to environments in excess of the design requirements.

3.6 Identification and marking. Each solar cell panel shall be marked and serialized for identification in accordance with MIL-STD-130. The identification shall be applied directly upon the rear of the panel by stenciling, silk screening, or an equivalent process. Plastic or metal foil name plates may be applied with an appropriate adhesive. Metal stamping, vibro penning, acid etching, embossing, casting, or molding, or similar marking methods shall not be used on the solar cell panel.

3.7 Operability

3.7.1 Reliability. The reliability design requirements shall be such that the overall vehicle reliability requirements are met under the most severe acceptance testing, storage, transportation, preflight testing, and operational environments.

3.7.2 Interchangeability. Any two or more solar cell panels or solar cell arrays bearing the same part number shall possess such functional and physical characteristics as to be equivalent in performance and durability and shall be capable of being changed, one for another, without alterations of the items themselves or of adjoining items.

3.7.3 Maintainability. The solar cell panels and solar cell arrays shall be designed so as not to require any scheduled maintenance or repair during their service life. The design, however, shall permit removal and replacement of individual cells, rows of cells, cell interconnections, and diodes as may be required. The solar cell panels may be removable from the integrated space vehicles to provide access to the spacecraft interior.

3.7.4 Service life. The service life of the solar cell panels and solar cell arrays shall be the same as the service life of the vehicle on which they are mounted plus 2 year storage under controlled conditions.

3.8 Workmanship. All details of workmanship concerned with the fabrication and installation of solar cell panels and solar cell arrays shall be controlled such that the finished item is of sufficient quality to ensure proper operation, safety, and service life.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspections and tests. Unless otherwise specified, the supplier is responsible for the performance of all test and inspection requirements as specified herein. Unless otherwise specified, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the government. The government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of tests and inspections. The test and inspection requirements specified herein are classified as follows:

a. Part, material, and process controls (4.3)

b. Qualification tests (4.4)

c. Physical configuration audit (4.5)

d. Acceptance tests (4.6)

4.3 Part, material, and process controls. To ensure reliable solar cell arrays, all parts and materials shall be adequately controlled and inspected prior to fabrication. During fabrication the tools and processes, as well as parts and materials, shall be adequately controlled and inspected. Each solar cell array assembly shall have inspection records and test records maintained by serial number to provide traceability. Complete records shall be maintained and be available for review during the service life of the assembly. The records shall indicate all relevant test data, all rework or modifications, and all installation and removals for whatever reason. The configuration and workmanship of the completed hardware shall be verified by inspection. The dimensions, weight, finish, identification markings, and cleanliness shall be inspected prior to all tests and prior to installation.

4.4 Qualification tests. Qualification tests shall consist of all tests necessary to determine that the equipment meets all requirements of this specification and the contract. Qualification tests shall verify the ability of the equipment to perform satisfactorily under all adverse combinations of environments and operating conditions that are specified or that may be encountered during the service life of the space vehicle. Qualification tests shall be performed in accordance with MIL-STD-1540 on each type of unit of equipment representative of the hardware to be supplied under the contract. Qualification tests at the temperature extremes should be initiated with the high temperature to avoid possible damage from moisture which might be present on the test unit.

4.5 Physical configuration audit. A physical configuration audit of the first equipment produced with production tooling and procedures shall be conducted by the contractor at a time and location acceptable to the procuring activity. There shall be no discrepancies among the equipment, the fabrication tooling used, the released drawings, the test data, the inspection records, and the specification requirements. First article approval is valid only on the contract under which it is granted, unless extended by the procuring activity to other contracts.

4.6 Acceptance tests. Acceptance tests shall consist of all tests deemed necessary to determine that the equipments are equivalent in performance and construction to the approved first article. The flight panel or array acceptance tests shall be in accordance with MIL-STD-1540 and shall also include as a minimum the following:

a. Insulation resistance measurements

b. Resistance of electrical harness (voltage drop)

c. Output power of modules and panel totals

d. Calibration of panel instrumentation

e. Verification by test or inspection of the adequacy of the low energy proton protection provided.

The representative panel test sections fabricated with the flight panels shall be given similar tests except the acoustic tests shall be performed at qualification levels and the temperature cycling shall be performed at qualification limits. Following these exposures, evaluation tests of the panel test sections shall be conducted to evaluate the adhesives, materials, and processes used to compare with the design or qualification unit results.

4.7 Light source. The source of irradiation used to determine the electrical performance of the solar cells, solar cell panels, and solar cell arrays shall be a xenon solar simulator with an irradiance normal to the test plane of 1 353 W/sq m over the entire test plane. It shall be calibrated for air mass zero conditions using primary or secondary standard solar cells to an accuracy of ±2 percent. These standard solar cells shall be similar to the solar cells which are used in the solar cell panels and solar cell arrays to be tested. It is a preferred alternative to use standard cells that have the same cover glass, coatings, and spectral response as the units to be tested. The irradiance uniformity shall be ±4 percent over the test plane as indicated by the short circuit current of a solar cell representative of those being tested. The irradiance variation in 30 minutes for any 4 sq cm unit area shall not exceed ±2 percent over the full test area. The repeatability of all calibration factors from day to day shall be within ±2 percent maximum. The test plane shall be of a size that is adequate to test the largest solar cell panel. The use of an alternative light source such as tungsten light or sunlight requires approval of the procuring activity.

4.8 Rejection and retest. Equipment which has been rejected may be reworked or have parts replaced to correct defects, and may then be resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection and the action taken to correct the defects found in the original shall be furnished the government representatives. Units rejected after retest shall not be resubmitted without the specific approval of the procuring activity.

4.9 Modifications and rework. Solar cell arrays shall be modified or reworked with the same high quality assurance provisions and criteria as original fabrication. Inspection and retesting shall not be limited to the rework, changes, or modifications. The complete panel, including the changes or rework, must be retested.

5. PREPARATION FOR DELIVERY

Requirements for packaging, packing, and marking for shipment shall be as specified in the contract.

6. NOTES

6.1 Intended use. The solar cell panels and solar cell arrays covered by the specification are intended to be used on space vehicles to convert solar energy into electrical energy. This specification is intended for reference in space vehicle specifications or contracts to incorporate those requirements which are common to most space vehicle solar cell arrays. Variations may be approved by the procuring activity if they are cost effective and if they enhance the complete electrical system or the complete space vehicle. The procuring activity should be advised of any deviations desired by the contractor with sufficient engineering information to substantiate the deviation requested. Deviations from this specification may be granted only by the procuring activity.

6.2 Ordering data. The contract should specify:

a. Title, number, and date of this specification and of the related space vehicle system.

b. Applicable environmental conditions for determining the maximum and minimum predicted environmental levels for each operational mode including nuclear detonation environments, if any.

c. The solar cell requirements if MIL-C-83443 does not provide a suitable cell. In general, solar cells should exceed the minimum basic requirements given in 6.4 below.

d. Preparation for delivery requirements

e. Data requirements. Data requirements of this document are not to be considered deliverable unless specified on the contract Data Requirements List (DD Form 1423) referencing the appropriate data item from the Department of Defense Authorized Data List, Index of Data Item Descriptions, (TD-3).

6.3 Definitions.

6.3.1 Definitions for chips, nicks, pinholes, voids, blisters, magnetic and nonmagnetic materials, and synthetic oils are given in MIL-C-83443.

6.3.2 Solar cell group. A solar cell group is a number of parallel connected solar cells. Typically 2, 3, 4, or more solar cells may be connected in parallel to make a cell group.

6.3.3 Solar cell module. A solar cell module is a series connected assembly of solar cells or solar cell groups. A typical module may be a 4 by 12 cell matrix (48 cells total) having 4 parallel cells in each group and 12 groups of cells in series. In another design, the module may be a single series string, for example, of 52 cells.

6.3.4 Solar cell panel. A solar cell panel is a major assembly of the electrical power generating subsystem of the space vehicle. It is the parallel array of solar cell modules or the series and parallel assembly of solar cell modules that generates the desired electrical output that is brought directly to the electrical power control subsystem. The power control subsystem uses the solar cell panel electrical output to charge batteries and to supply power to space vehicle utilization loads. Typically the solar cell panels are rectangular and are formed on flat or cylindrical surfaces of the space vehicle. The panels, however, may be formed to almost any shape on flat, cylindrical, conical, or any combination of surfaces of the space vehicle.

6.3.5 Solar cell array. The solar cell array for a space vehicle is the total assembly of all of the solar cell panels as mounted on the space vehicle.

6.3.6 Water-break-free condition. An atomizer with distilled water is used to atomize a mist of distilled water on the surface under test. If the water gathers into discrete droplets within 25 seconds, then the surface shows a "water break" and it shall be considered as having failed the test. If the water forms a continuous film by flashing out suddenly over a large area, then this shall be considered presumption of the presence of an impurity on the surface, and the surface shall be considered as having failed the test. When the water droplets coalesce into a continuous film of water without a sudden flashout and forms a lens, then the surface shall be considered satisfactorily cleaned.

6.4 Solar cell basic requirements. The basic minimum requirements for solar cells typically used in space vehicle solar cell arrays are indicated in this section.

6.4.1 Type. The solar cells are usually silicon, N on P junction type with cover glass.

6.4.2 Base resistivity. For space vehicles operating at altitudes below 350 kilometers (km) with design service lives of less than 1 year and not subject to nuclear radiation, the solar cells used typically have a base resistivity of 2±1 ohm-centimeters (ohm-cm). For all other space vehicles the solar cells used typically have a base resistivity between 7 and 14 ohm-cm.

6.4.3 Performance. The power output of each of the solar cells (with cover glass) at a temperature of 25 ±2 deg C should be greater than 140 W/sq m when uniformly irradiated at one solar constant under air mass zero spectral conditions (1 353 W/sq m). The selection of solar cell type shall be based upon measured performance of typical solar cells. The required performance data shall be obtained using solar cells with the cover glass mounted. The required data for type selection includes:

a. Correlation of measured spectral response with data from the cell manufacturer

b. Correlation of performance data from the cell manufacturer with a calibrated light source or actual sunlight. This would include open circuit voltage, short circuit current, and the voltage and current at maximum power.

c. The effect of angle of incidence on performance

d. The effect of temperature on performance

e. Thermal emittance and solar absorptance test data including thermal properties

f. Production lot performance characteristics that indicate average lot performance as well as the distribution of the performance of cells in a lot

6.4.4 Defects. The solar cells should be free from such defects as surface scratches, nicks, chips, and cracks, except edge chips which may be no larger than 0.5 mm deep by 4.0 mm long and corner chips or nicks which may have a hypotenuse less than 1.5 mm. Typically any blisters or looseness of the grids or contacts is cause for rejection. Any discontinuity on the primary N contact surface is typically cause for rejection. The grid lines are considered as part of the N contact except minor discontinuities that do not affect cell performance are allowable.

6.4.5 Solar cell cover glass. Each solar cell should have a fused silica (Corning Glass 7940 or equal) cover glass to provide protection from radiation degradation and to reduce cell operating temperatures. The cover glass should have a surface quality of 80-50 in accordance with MIL-O-13830, "Optical Component for Fire Control Instrument, General Specification Governing the Manufacturing, Assembly, and Inspection of." Each cover glass should be marked by a corner crop, notch, or Dykem stain for identification. Except for the possible identification corner crop or notch, the cover glass should not have a corner chip with a hypotenuse greater than 1.5 mm or an edge chip that projects into the face more than 0.5 mm. Any bubbles should be less than two-thirds the thickness of the cover glass in diameter and no more than two bubbles should be visible to the unaided eye for each square centimeter of area. Bubbles less than one-third the thickness of the cover glass are usually disregarded. The cover glass thickness should be based upon the planned satellite orbit and service life, but not less than 0.15 mm.

6.4.5.1 Coatings. The cover glass should have an antireflection coating applied to the exposed side. Infrared and ultraviolet reflective coatings are used at the supplier's option; however, when either or both are used, they should comply with the other requirements stated herein. The transmission when measured in air of the coated cover glass shall average greater than 93 percent for wavelengths between 0.450 and 1.100 micrometers. Pinholes, voids, lint marks, or splatter marks in the coatings should have a surface quality of 80-50 in accordance with MIL-0-13830. Coating should be uniform.

6.4.5.2 Cover glass bonding. The cover glass should be bonded to the solar cells with optical grade silicone resins such as General Electric RTV-602 adhesive or Dow Corning XR-63-489 adhesive, or equal. Low outgassing resins should be used when required to meet system cleanliness and contamination control requirements. After bonding, bubbles in the adhesive should not exceed a diameter of 0.7 mm and there should not be more than 1 bubble visible to the unaided eye for each 2 sq cm. The installed cover glass should cover a minimum of 98 percent of the active surface area of the solar cell.

6.5 Panel instrumentation. Each solar cell panel should have two temperature sensors mounted such that they measure representative solar cell temperature to an accuracy of ±3 deg C in the range from -50 deg C to +120 deg C. Each solar cell panel should also include instrumentation to measure the total voltage and current output of the panel.

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Air Force -19
(Project No. 1820-F001)

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specifications may be used, provided each contractor specification is approved by the procuring activity, and provided no suitable military specification exists. The contractor shall provide substantiating test data and, when required by the procuring activity, shall provide samples for testing. The use of contractor specifications shall not constitute waiver of government inspection. Request for the approval of nonstandard parts, materials, and processes shall be in accordance with MIL-STD-891. When a detail or general military specification exists for the class of material required, the contractor specification shall reference the existing military specification and set forth only the needed new requirements and deviations.

3.2.2 Panel performance. The electrical power output of the solar cell panel at a temperature of 25 ± 2 degrees Celsius (deg C) shall be greater than 140 watts per square meter (W/sq m) when uniformly irradiated normal to the surface at one solar constant at air mass zero spectral conditions in accordance with ASTM E 490 (1 353 W/sq m).

3.2.3 Electrical interconnections.

3.2.3.1 Cell interconnections. The interconnections between cells shall be either annealed copper, aluminum, Kovar, molybdenum, silver, or other suitable material having a conductivity equivalent to or greater than a 22 gauge AWG annealed copper wire. A minimum of two interconnections per cell or a continuous interconnect tab shall be used to assure electrical redundancy. Stress relief shall be incorporated to minimize stress on the cell contacts. The intercell connections shall be capable of withstanding a 150-gram pull in any direction with no visual or electrical indication of poor contact or loosening from the cells. The soldering, ultrasonic bonding, or welding techniques used in assembly shall be compatible with the solar cell contact materials, the electrical interconnect material, and the specified space vehicle environment.

3.2.3.1.1 Soldering. Soldering shall be in accordance with MIL-STD-454, Requirement 5, except that manual soldering shall be in accordance with MIL-S-45743.

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DOCUMENT IDENTIFIER AND TITLE MIL-S-83576(USAF) Solar Cell Arrays, Space Vehicle, Design and Testing, General Specification For

NAME OF ORGANIZATION AND ADDRESS

CONTRACT NUMBER

MATERIAL PROCURED UNDER A

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