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EIGHTH QUARTERLY REPORT

FOR

SOLAR CELL RADIATION DAMAGE EXPERIMENT

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(28 MARCH 1971 - 27 JUNE 1971)

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Contract No. NAS 5-11677

Prepared by

HUGHES

HUGHES AIRCRAFT COMPANY
SPACE SYSTEMS DIVISION

for

GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland

HUGHES AIRCRAFT COMPANY
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SUBJECT: Eighth Quarterly Report
Solar Cell Radiation Damage Experiment
28 March through 27 June 1971
Contract NAS 5-11677

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

ATTENTION: Mr. R. L. Krenning, Code 245
Contracting Officer

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EIGHTH QUARTERLY REPORT

FOR

SOLAR CELL RADIATION DAMAGE EXPERIMENT

(28 MARCH 1971 - 27 JUNE 1971)

CONTRACT NO. NAS 5-11677

Goddard Space Flight Center

Contracting Officer: R. L. Krenning

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Prepared by

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for

GODDARD SPACE FLIGHT CENTER
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ABSTRACT

The primary objective of the Solar Cell Radiation Damage Experiment, scheduled for launch on the ATS-F spacecraft, is to provide high accuracy data permitting a technical evaluation of the effects of the space radiation environments on solar cells. The flight experiment and supplemental ground test program continues the work previously performed by Hughes and other experimenters, and will provide the design data required for extended spacecraft missions in synchronous orbit.

The flight experiment consists of a small solar panel mounted externally on the Environmental Measurements Experiment (EME) package, which will interface with the spacecraft. The solar panel has a total of 80 solar cells, representing 16 solar cell configurations. Thirteen solar cell configurations will be mounted to the rigid panel portion of the solar panel (infinite back-shielding), and three configurations will be mounted to the flexible panel (2 mils of a Kapton-fiberglass substrate). In addition, the experiment has two signal processor units required for data sampling and telemetry. The solar cell experiment will be activated at programmed intervals to obtain voltage-current data for each individual solar cell and to obtain temperature and calibration data.

In addition to the design and fabrication of the flight experiment, a ground test program will be run. Data resulting from this program will be used as an aid in selecting the solar cell configurations for the flight experiment. The program includes evaluation of the effects on solar cells and solar cell assemblies under an environment which simulates both synchronous electrons and low energy protons.

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INTRODUCTION

The Solar Cell Radiation Damage Experiment project began on 27 June 1969 under National Aeronautics and Space Administration Contract NAS 5-11677. The experiment will be configured for incorporation on the Environmental Measurements Experiment (EME) which will be mounted on the ATS-F spacecraft. The ATS-F spacecraft is planned for launch into synchronous orbit.

The primary objectives of the Solar Cell Radiation Damage Experiment are to isolate and identify the solar cell degradation mechanism(s) resulting from particulate radiation, and to obtain specific design data applicable to extended synchronous spacecraft missions.

The Solar Cell Radiation Damage Experiment consists of the following components:

1. A solar panel mounted to the Westinghouse EME, containing 5 solar cells each of 16 types and 5 thermistors.

2. Sixty-five solar cells (5 each of 13 types) will be mounted to the rigid substrate section of the solar panel, and 15 solar cells (5 each of 3 types) will be mounted to the flexible portion of the substrate. All 80 solar cells will be of the 2 x 2 cm configuration.

3. Two signal processor units that sequentially select the solar cells and load resistors and process the signal into the format for telemetry.

When activated, the flight experiment will provide 12 current voltage points for each solar cell and the temperature of each group of five identical solar cells. The periodic activation of the experiment and reduction of the solar cell data, in conjunction with data from the Environmental Measurements Experiment radiation spectrometers, will permit a comprehensive evaluation of the radiation effects on solar cells.

The supplemental ground test program will include low-energy proton and electron irradiation of state-of-the-art and advanced solar cell types. The results of the ground test program will aid in the final selection of the solar cell configurations for the flight experiment and the data required for future correlation of the flight test results.

FLIGHT EXPERIMENT

The experiment consists of a small solar panel and two identical signal processor units. The panel contains 65 solar cells on the rigid substrate and 16 solar cells on the flexible substrate (see Figure 1). The panel will be mounted to the external surface of the Environmental Measurements Experiment (EME). The EME package will be mounted to the external surface of the ATS-F spacecraft, which is planned to fly in synchronous orbit. The flight package will incorporate a total of 81 individual solar cells (one is a dummy for symmetry), with real-time telemetry providing 12 voltage-current data points for each individual solar cell and five temperature data points for sampling solar cell temperature. The experiment will require 24 seconds for complete data sampling and transmission. The experiment will operate at programmed intervals throughout the ATS-F mission life. The resulting data will be analyzed to identify and isolate the solar cell degradation mechanism(s) resulting from the synchronous radiation environment.

SOLAR CELL SELECTION

The final solar cell sample selection for the flight panel is shown in Table 1. Two by two cm silicon solar cells from a single manufacturer (Heliotek), will be selected for the flight experiment. One lot of coverslide adhesive, Sylgard 182, will be used for mounting the coverslides. The coverslides will be of Corning 7940 quartz, with the exception of the integral covers.

Each of the 16 configurations listed in Table 1 will contain five identical cell assemblies. Configurations 1 to 13 will be installed on the rigid portion of the panel, and Configurations 14 to 16 will be installed on the flexible portion of the panel. In the majority of cases, the selected cells will be boron-doped n/p, 10 ohm-cm resistivity, 12 mil thick, and will have solder-coated titanium-silver contacts. The fused silica covers will be bonded to the cells to very tight tolerances. This will eliminate the accidental occurence of gaps between the contact bars and coverslide edges. The exception is included in the following discussion.

Coverglass thickness is varied in the first four configurations. In a previous experiment (ATS-I), 6-mil covers were surprisingly the most effective in protecting cells against power degradation. It will be of interest to see if the ATS-F experiment has a similar outcome.

Configuration 5 will have a plain 3 mil 7940 quartz coverslide without either the ultraviolet filter or antireflective coating. Configurations 6 and 7 will be the integral coated solar cells using 7940 and 7070 quartz, respectively. Comparing Configurations 5 and 6 with 1, the amount of degradation to the ultraviolet filter, the antireflective coating and the coverslide adhesive will be ascertained. 7070 integral coated cells, Configuration 7, were chosen because 7070 can be deposited as thick as 12 mils, and is a very promising integral cover.

In Configurations 8 and 9, the base resistivity has been changed to 2 ohm-cm; the two configurations also have different cell thicknesses, 8 and 12 mils. Comparing Configuration 8 with 2, the effects of the environment on cell base resistivity can be studied. Comparing Configuration 8 with 9, the effect of the environment on cell thickness can be compared. Also, comparing Configuration 11 with 2, the effect of cell thickness can be studied (10 ohm-cm base resistivity common). The ninth configuration has the thinner cells (8 mils) which are typical of cells being considered for future large arrays.

A new development in the antireflective cell coating will also be studied. Configuration 10 will have a titanium dioxide coating instead of the standard silicon monoxide antireflective coating. This new cell coating is purported to improve the power of the cell by three to five percent and may possibly become standard on the next generation of solar cells.

The cells on Configuration 12 will be "grouted", i.e., cell adhesive, or a similar material will be applied to the bus area and around the cell. This will assure complete protection to the solar cell, including the bus bar area, from low energy protons. This configuration will be compared with Configuration 3. The latter is protected via the "zero gap" dimensioned coverslide-cell design. but has no special coating on its soldered bus bar areas.

The bar gap, i.e., exposed cell area between bus bar and coverslide edge, will be examined in Configuration 13. It is generally agreed that bar gaps will cause degradation to a greater degree than would be expected on the basis of percentage area exposed. However, the absolute magnitude of the degradation caused by this exposure remains controversial. The controlled samples on ATS-F will provide new data and reduce the amount of conjecture.

The three cell types on the flexible solar panel (Configurations 14, 15, and 16) have identical counterparts mounted on the rigid panel (Configurations 10, 9 and 8, respectively). This will permit an evaluation of the effect of radiation on the back surface of the solar cells.

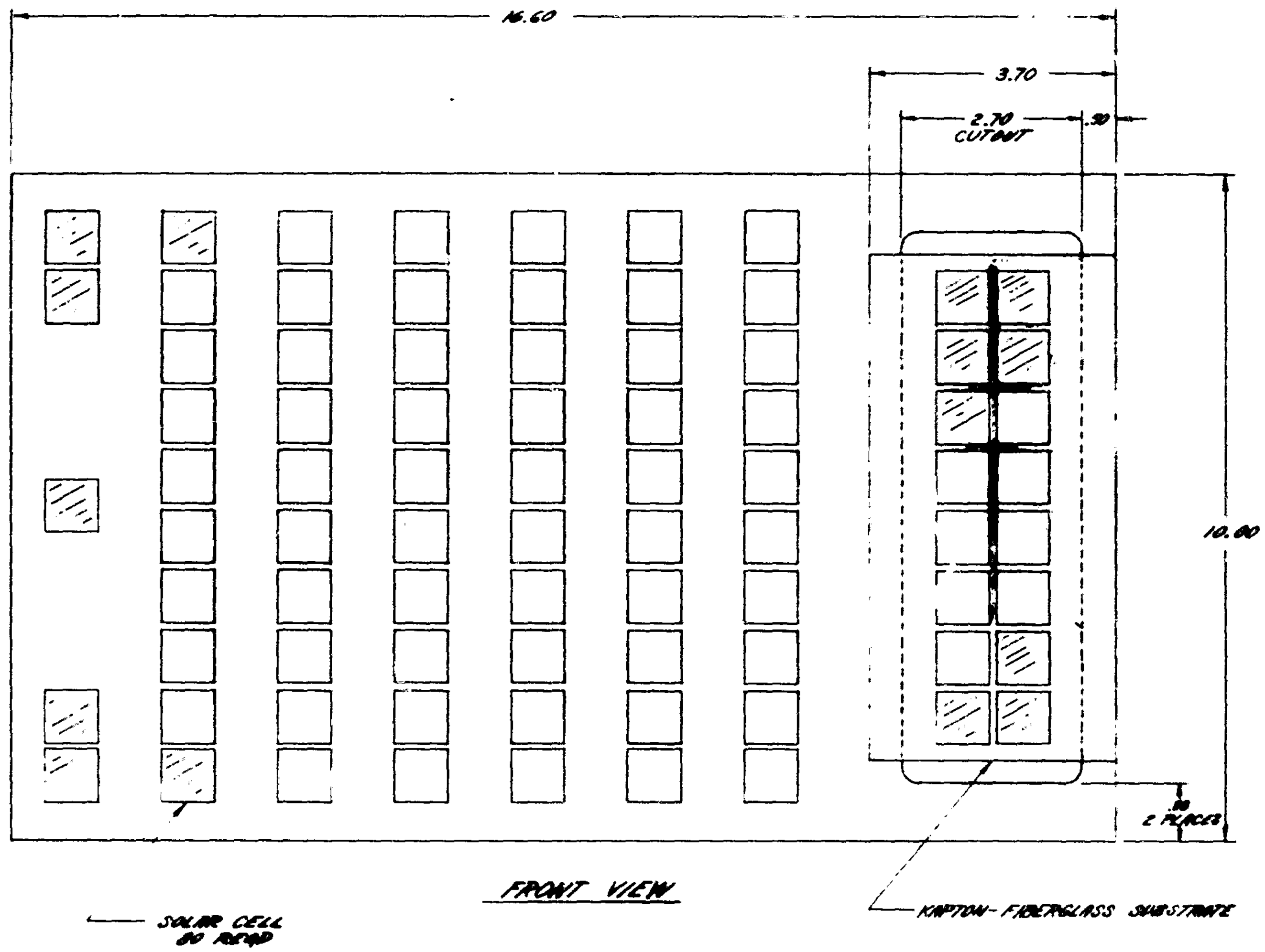
SOLAR PANEL DESCRIPTION

A small solar panel, 10 by 16.9 inches, will contain 81 solar cells, 65 solar cells mounted on the rigid substrate and 16 solar cells mounted on the flexible substrate (for symmetry, one cell on the flexible will be a dummy; see Figures 1 and 2). The solar panel will be mounted to the EME package such that the backside of the rigid portion of the solar panel will face the EME package and the flexible portion will extend beyond the EME package as shown in Figure 3. The solar cells on the flexible substrate will experience the particulate radiation environment both on the front and back surfaces of the cell. The solar cells on the rigid substrate will experience the particulate radiation environment on the front surfaces only.

CONFIGURATION	RESISTIVITY, OHM-CM	CELL THICKNESS, MILS	COVERSLIDE THICKNESS, MILS	REMARKS	LOCATION
1	10	12	3		Rigid
2	10	12	6		Rigid
3	10	12	12		Rigid
4	10	12	30		Rigid
5	10	12	3	Plain 7940 quartz coverglass, no filter or coatings.	Rigid
6	10	12	3	7940 Integral	Rigid
7	10	12	3	7070 Integral	Rigid
8	2	12	6		Rigid
9	2	8	6		Rigid
10	2	8	6	Titanium dioxide cell anti-reflective coating	Rigid
11	10	8	6		Rigid
12	10	12	12	"Grouted" cell	Rigid
13	10	12	12	15 mil bar gap	Rigid
14	10	8	6		Flexible
15	2	8	6		Flexible
16	2	12	6		Flexible

TABLE 1

ATS-F SOLAR CELL FLIGHT EXPERIMENT CONFIGURATIONS



SOLAR CELL EXPERIMENT, ATS-F

FIGURE 1

SHEET 1 OF 2

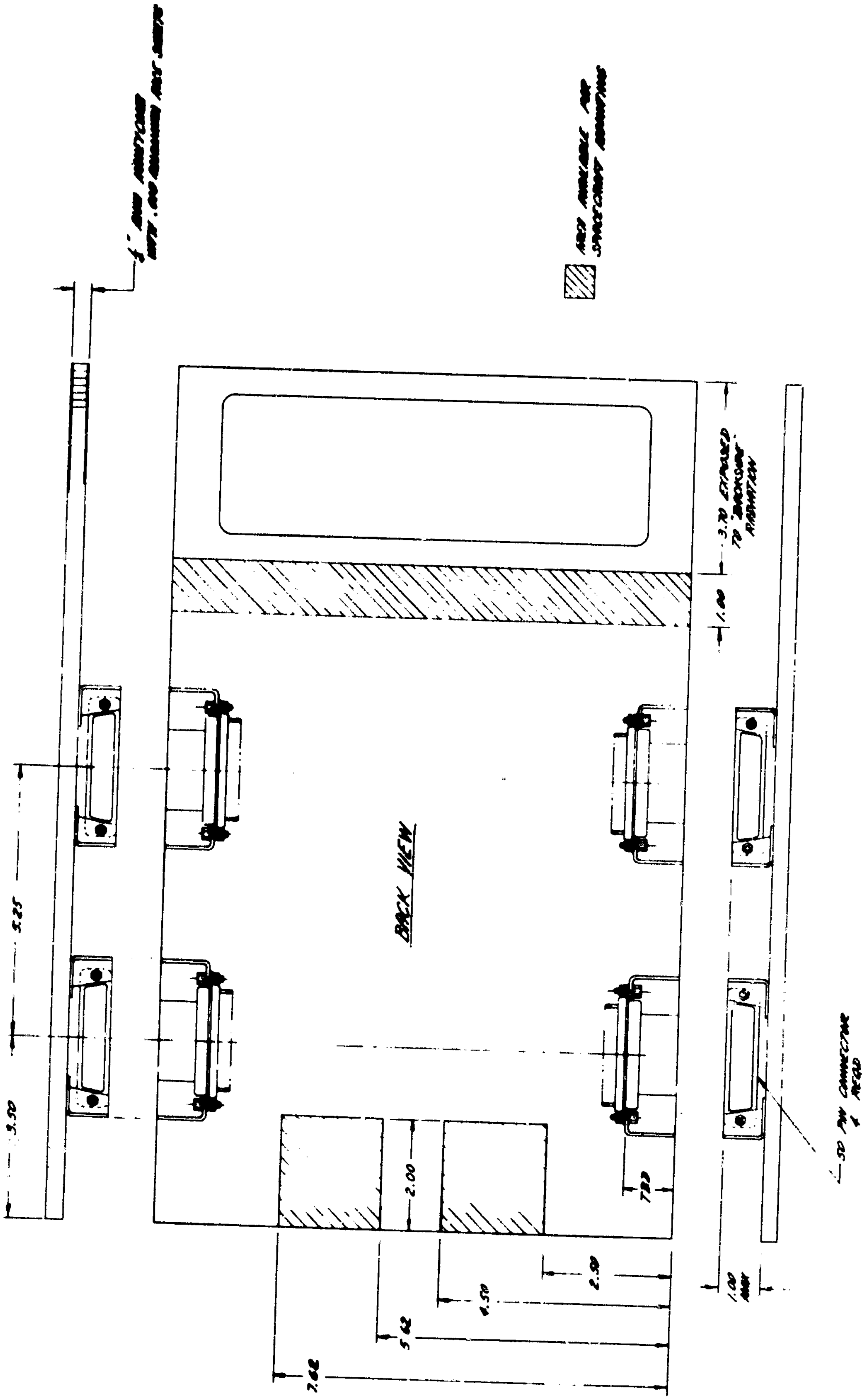


FIGURE 2 - BACK VIEW

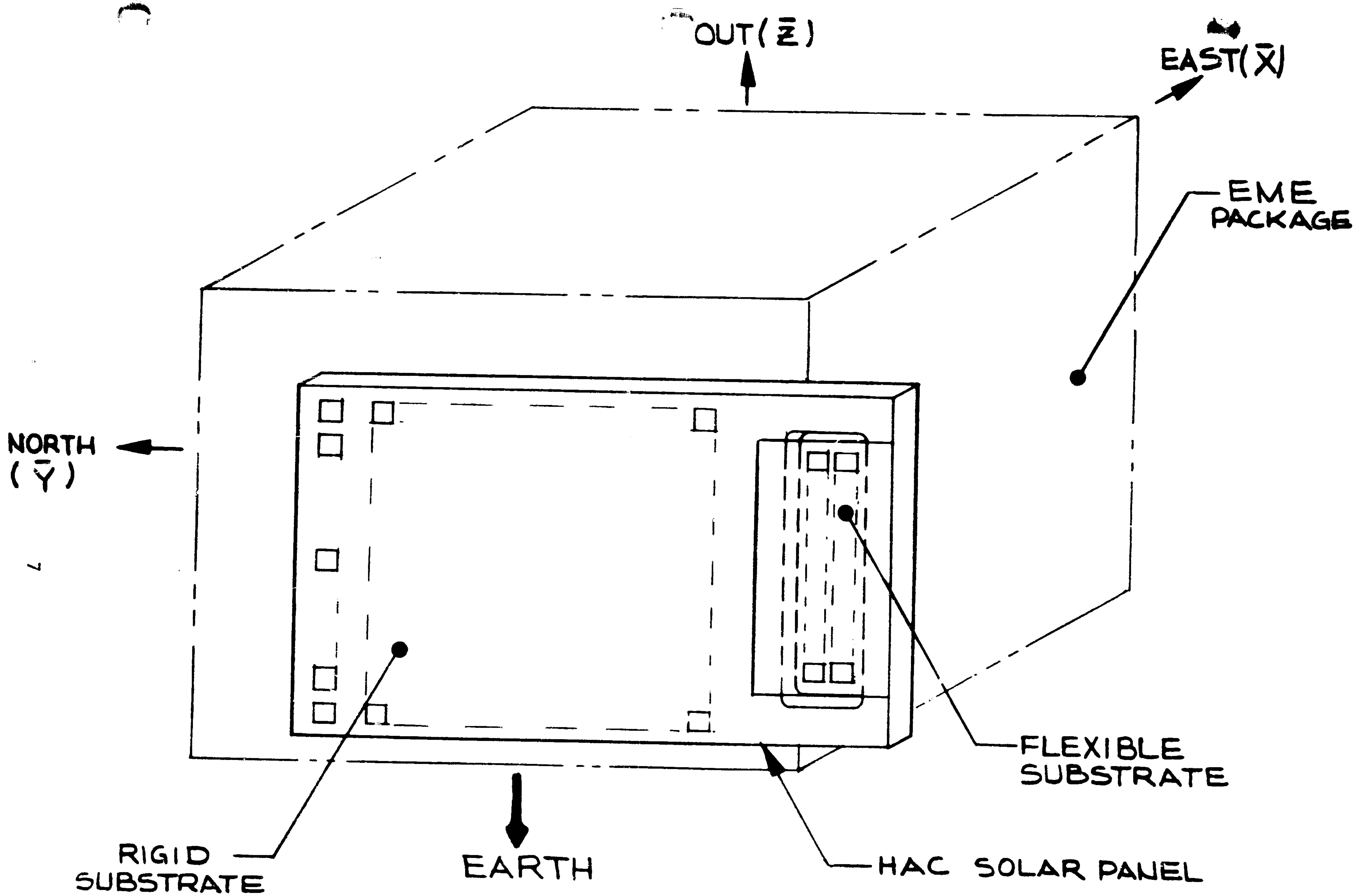


FIGURE 3 ATS-F WESTINGHOUSE EME PACKAGE

The rigid substrate will be a 0.25-inch thick aluminum honeycomb with 0.010-inch thick aluminum face sheets. An insulating paint will be applied to the aluminum face sheet to insulate the solar cells from the aluminum. The solar cells will be individually mounted to the substrate using an RTV silicon rubber adhesive. The cells on the rigid substrate will be "framed" using aluminized teflon; this mirror-like material aids in reducing the panel temperature.

A hole, 2.70 by 8.25 inches, will be cut in the rigid substrate to allow for the attachment of the flexible substrate section. The flexible substrate will be a composite laminate of 0.001-inch thick fiberglass cloth and 0.001-inch thick kapton. Cells, fiberglass and kapton will be simultaneously bonded and cured using an epoxy adhesive system. The complete substrate will be mounted, pre-tensioned and bonded to the rigid substrate using a structural epoxy adhesive. To obtain comparative data on the radiation effect on the back surface of the cell, all types on the flexible panel will be duplicated on the rigid panel.

Each group of twenty cells will be individually wired to one of four panel connectors which will be connected to one of two signal processor units. Separate lead wires will be provided for voltage and current sensing. The ground return from each cell will be connected to a common ground. Five temperature sensors will be included to sample cell temperatures.

The solar panel will mount parallel (body mounted) to the west face of the Westinghouse EME package (see Figure 3 for sketch). The flexible portion of the solar panel will extend beyond the EME package to the south. A thermal blanket, provided by Westinghouse, will extend from the EME package to the edge of the solar panel which will enclose the back surfaces of the rigid portion of the solar panel. Five thermal watts of heat will be supplied by the EME package to the solar panel; the heat supply will keep the temperature of the solar panel above -130°F.

SOLAR PANEL QUARTERLY PROGRESS

Some delays are being experienced in completing the solar panel qualification vibration test. The flexible portion of the panel behaves as would a drum head responding violently to high frequency vibration. The solar cells are unaffected but the connecting wires and copper mesh fail. Several redesigns are being considered and will be included on an engineering model which will then be vibrated. Most promising is the addition of a 60 mil thick fiberglass doubler with sixteen 0.7 inch by 0.7 inch cutouts to be placed under the flexible panel; this will provide additional support and stiffness to the design.

The design passing the vibration requirements will then be used in reworking the qualification panel. The qualification test program will follow the completion of the rework.

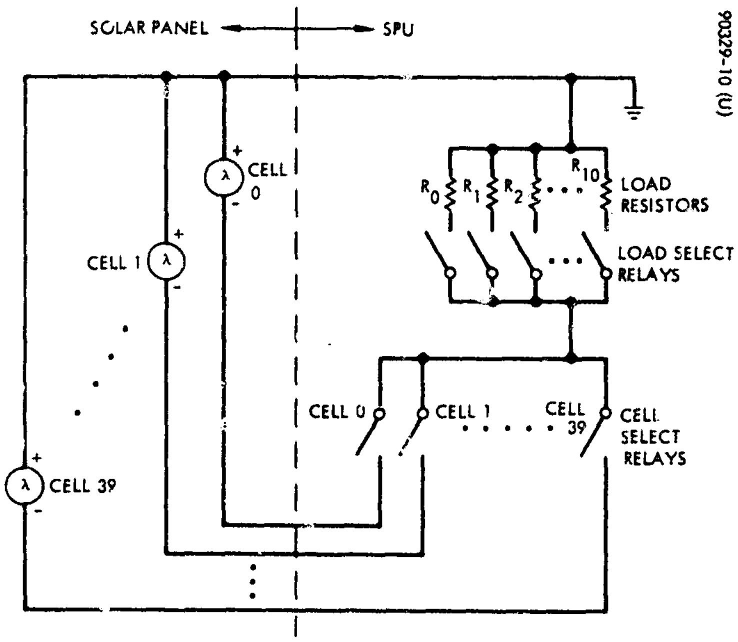


Figure 4 Solar Cell/Relay Configuration

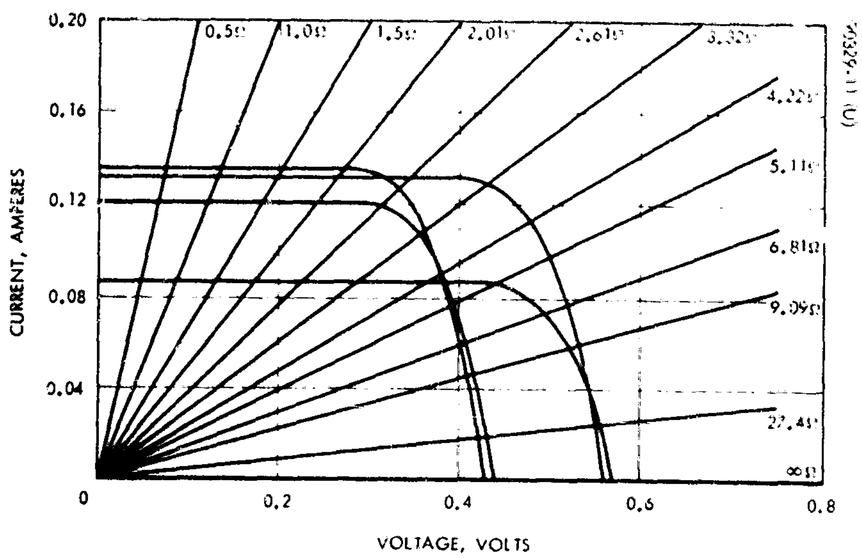


Figure 5 Solar Cell Characteristics and Load Resistors

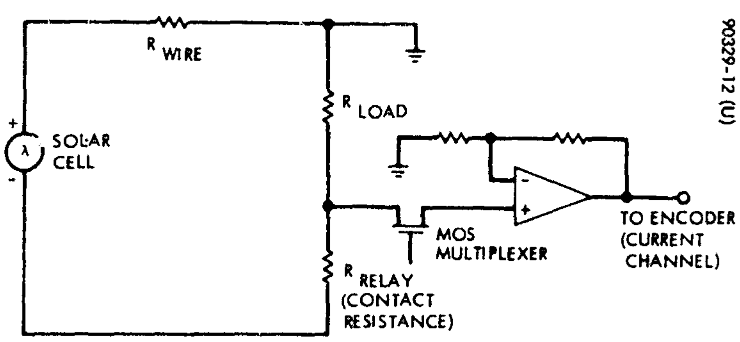


Figure 6 Current Section

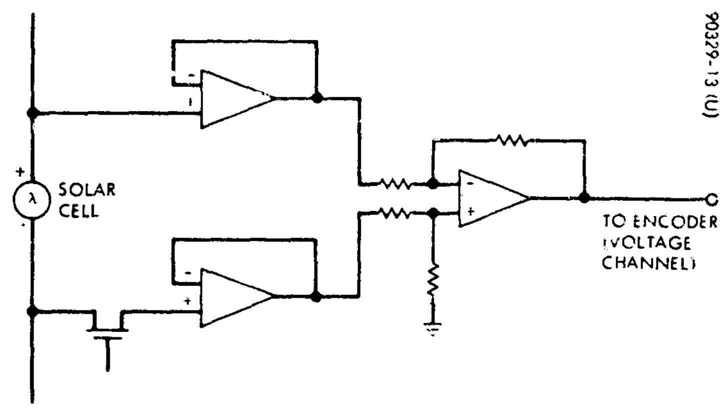


Figure 7 Voltage Section

SIGNAL PROCESSOR UNIT DESCRIPTION

The signal processing unit (SPU) is designed to interface between the solar panels and the ATS encoder. It measures the voltage-current characteristics of 40 solar cells using 12 precisely known loads, and also provides temperature information. The ATS-F spacecraft will carry two units so that the total of 80 cells may be analyzed.

The basic configuration of the experiment is shown in Figure 4. In operation, one of the 40 cells is connected to one of the 12 load resistors by means of relays. Thus, only two relays are energized within each SPU at any one time. Relays are used because of their low contact impedance.

The anticipated range of solar cell characteristics is shown in Figure 5, which includes load lines for the SPU load resistors.

In order to measure cell characteristics, one cell select relay is energized while the unit sequences through the load select relays. Each load is connected for 30 milliseconds during which each SPU output is sampled and telemetered once. The encoder then outputs a pulse which is used to increment the load relays. The process is repeated for each of the 40 solar cells.

Cell current is determined from the voltage developed across an accurately known load resistor. The SPU amplifies this voltage so that it is compatible with the encoder's +5.12 volt analog input capability (see Figure 6).

Cell voltage is measured differentially across a cell (see Figure 7). The voltage measurement lines are separate from the cell current lines so that line drops are eliminated from the readings. The voltages on the lines from a cell are buffered and the difference between them is amplified to the 0 to +5.12 volt level.

Thermistors packaged with the solar cells are used to determine temperature (see Figure 8). These elements are used with a bias network to divide down a precision -10.24 reference voltage to produce a temperature-sensitive output voltage.

Both signal processing units on the spacecraft derive their power from a single +28 volt experimenter payload regulator. Each SPU has an electronic conversion unit (ECU) which generates all necessary supply voltages from this +28 volts. A prime purpose of the ECU is to provide isolation between the power return (transformer primary) and the signal ground (secondary), thus minimizing ground current.

Figure 9 shows the interface between the solar panel and the signal processing unit. The 40 solar cells are designated in the figure as being arranged in eight pads of five cells each. It should also be noted that the voltage common (cell RTN) line and the current common line are connect together at the solar panel, but not at the signal processing unit. This is due to the requirement that no current flow in the voltage common line.

The interface between the signal processing units and the encoder is shown in Figure 10. The two signal processing units use separate clock inputs from the encoder and they use separate encoder inputs, since they will operate simultaneously.

The signal processing unit is produced by using two packaging approaches for integrated circuit chips (ICs) and small associated components and some major discrete components (see Figure 11). The IC's are packaged on a "Stitch" formed HICAM (Hi-Density Connection Assembly Method) and the major discrete components are housed in welded modules. The dual approach requires an overall design in which HICAM subassemblies and welded cordwood modules are compatible in certain dimensions for maximum volumetric efficiency and optimum weight. The use of the HICAM circumvents the need for soldered interconnections at the IC's and component level. Consequently, components contained both in cordwood welded modules and in HICAM subassemblies are not thermally stressed during assembly.

The principal parts and construction of the HICAM subassembly is shown in Figure 11. An interconnection matrix or grid is chemically etched out of 0.001" thick nickel sheet. The center portion of the grid is taped on one side with a glass cloth tape. The tape is installed prior to trimming and provides an uninterrupted insulator. The grids are then stacked and positioned in an alignment fixture with a 0.001" double sided, thermosetting adhesive strip between each of the grids to prevent shifting after alignment. The number of grids used varies among HICAM subassemblies, with a maximum of ten levels.

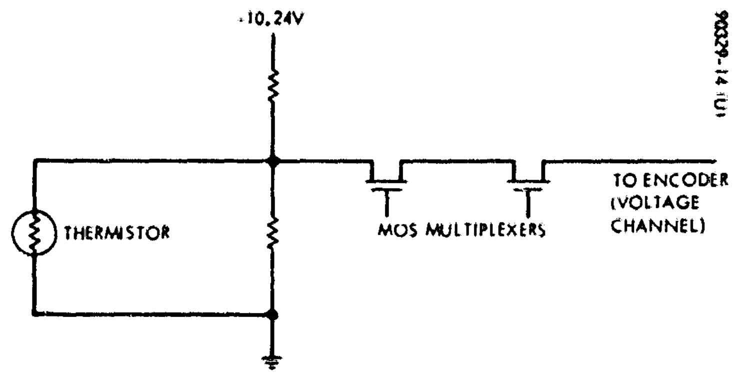


Figure 8 Temperature Section

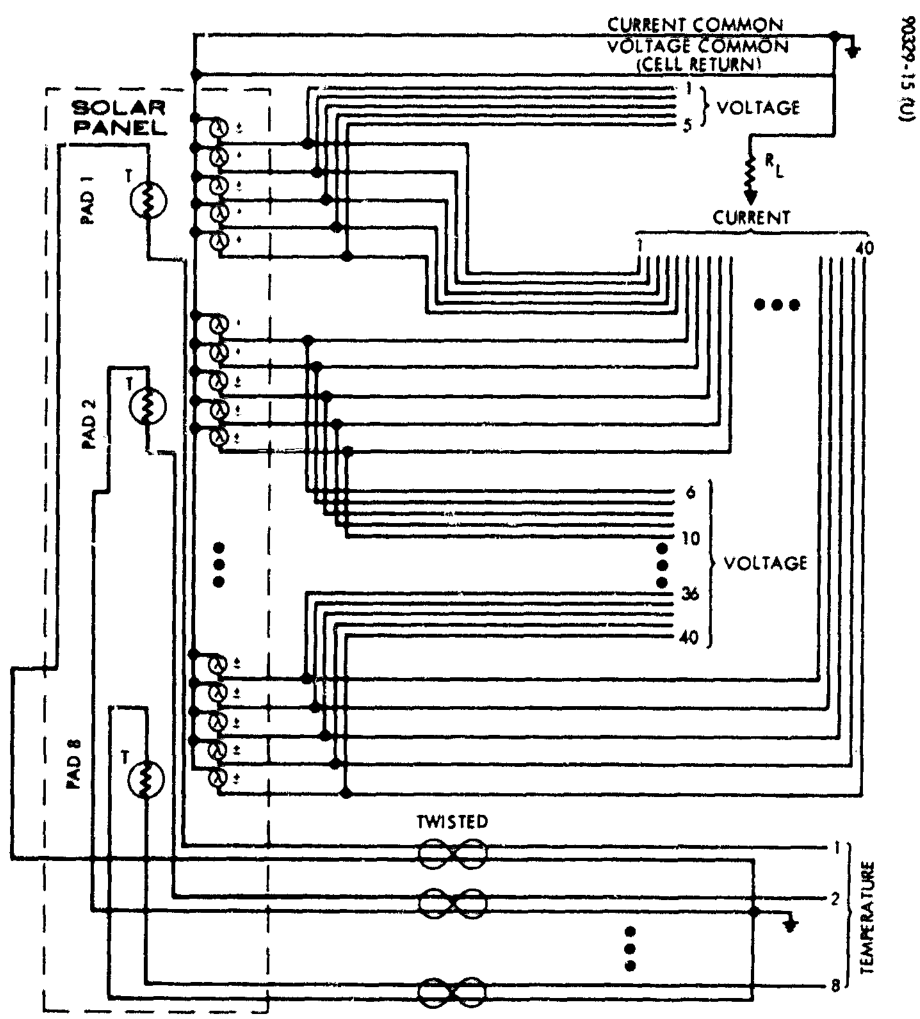


Figure 9 Solar Panel/Signal Processing Unit Interface

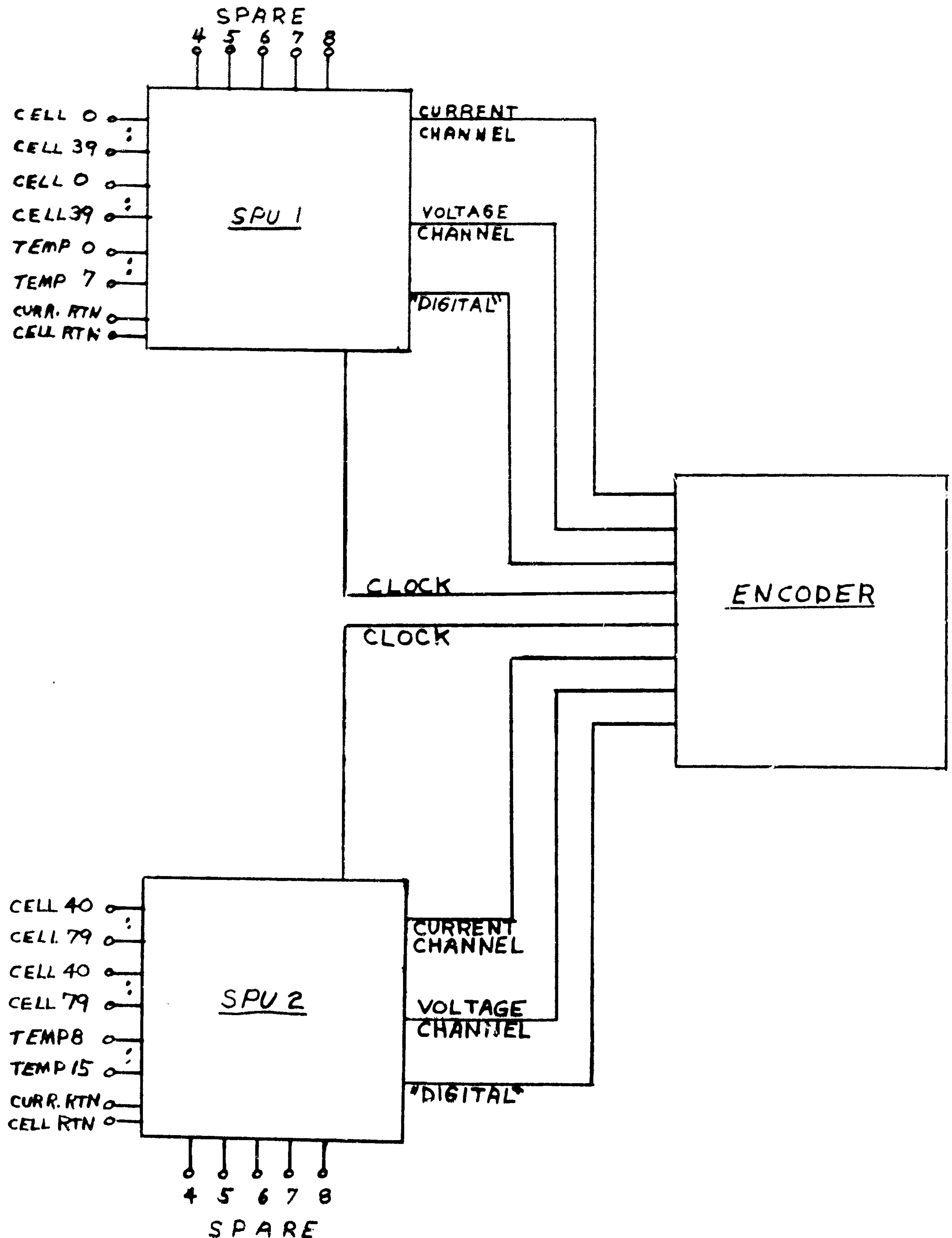


FIG. 10

SPU/ENCODER INTERFACE

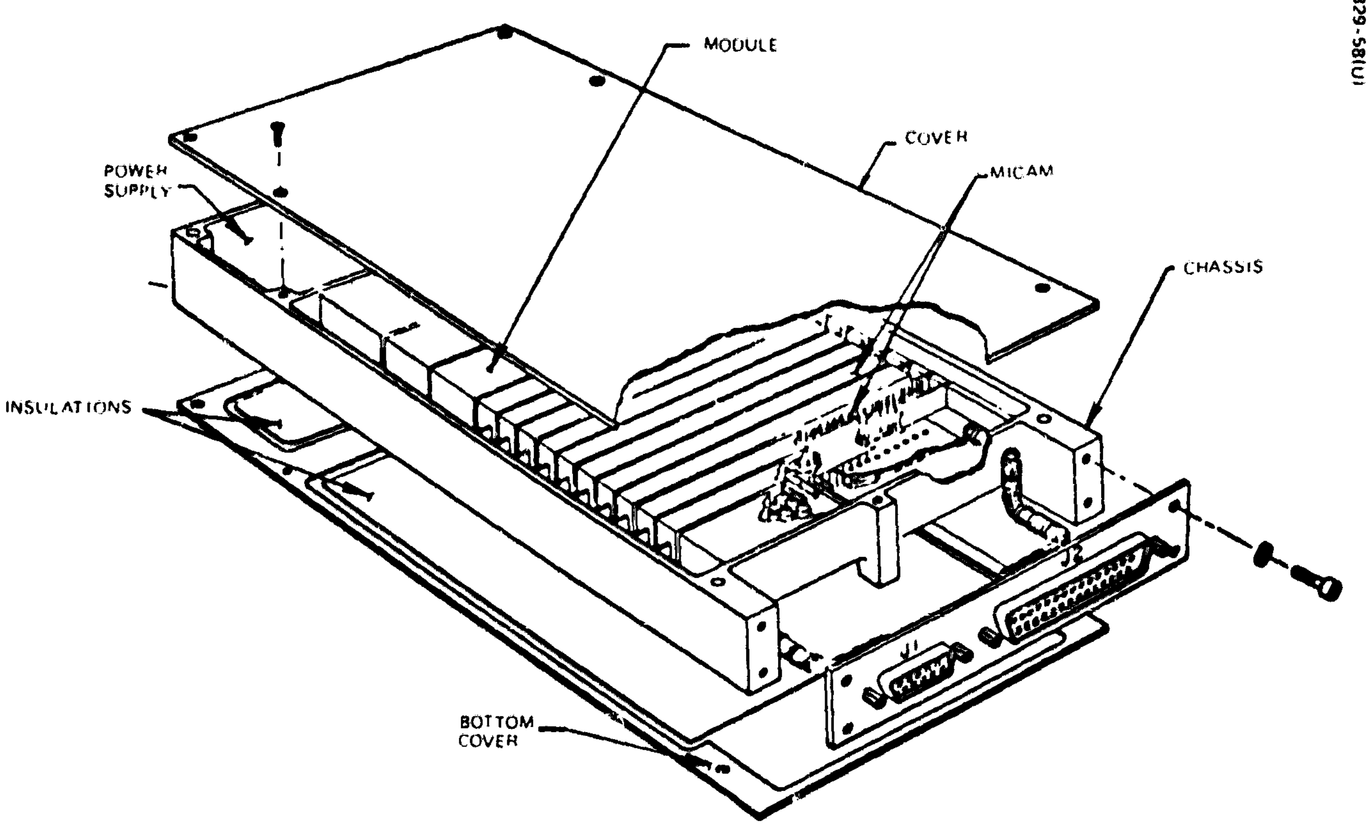


Figure 11 Signal Processor Unit Configuration

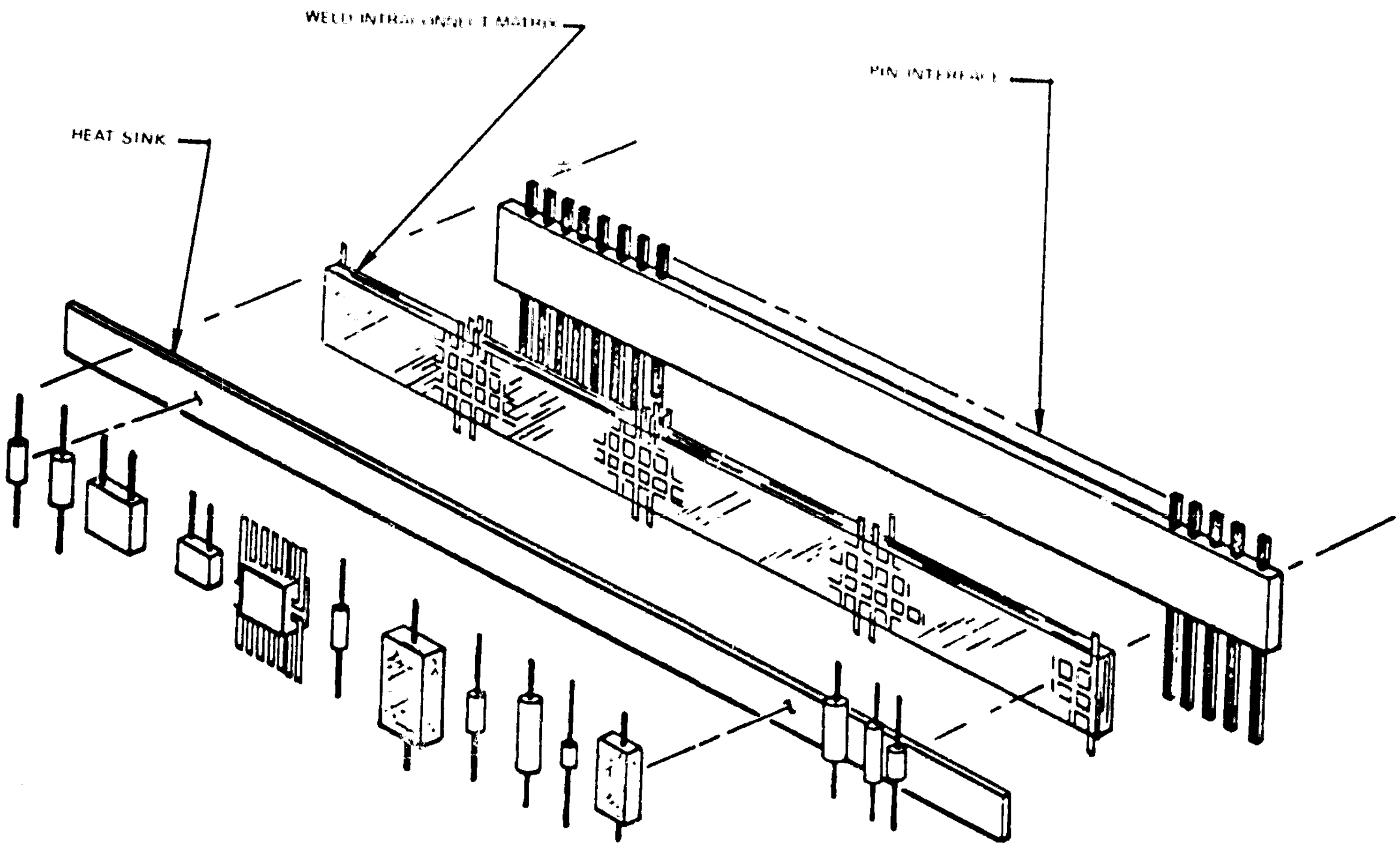


Figure 12 Micam Subassembly

SIGNAL PROCESSING UNIT (SPU) QUARTERLY PROGRESS

Rework was completed on the two flight SPU's and the units were returned to Westinghouse, the experiment integrator. Rework consisted of adding capacitors and π filters to each SPU unit as well as installing new interface cables. The cables included were shields for data lines, analog ground, and signal ground lines.

Following rework, the units were functionally tested and showed significant reduction in high frequency noise. Peak to peak noise was a maximum of 15 millivolts at frequencies as high as 4 MHz. Prior to the rework, the same test had noise figures as high as 300 millivolts.

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GROUND TEST PROGRAM

A comprehensive ground test program is required for evaluation of the state-of-the-art and advanced solar cell characteristics. The program aided the final selection of the candidate solar cells for the flight experiment. The test solar cells were irradiated with low-energy protons and electrons, simulating the synchronous environment.

All irradiations and data reduction have been completed. The results of the ground test program will be included in the final report. It had been planned to supply this information in a separate report. However, it has been decided the ground test data could be more efficiently used if it were combined with flight cell data and predictions.

Several general remarks should be made about the calibration of the solar cells used in the ground program. The solar cells vibration-current characteristics were measured using an X-25L solar simulator furnished by Heliotek. The X-25L simulator was calibrated and maintained at an illumination intensity equivalent to near earth-space sunlight using a Balloon Flight Standard Cell. The temperature of the solar cells during measurements was maintained at 25°C using a water-cooled brass cell holder. Three Hughes standard control cells were also used throughout the V-I measurements. Short-circuit current, open-circuit voltage, and current at 0.445 volt of the Hughes control cells were measured during the cell calibrations. Short-circuit current provides control on the illumination of the X-25L; open-circuit voltage provides control on the cell temperature; and current at 0.445 volt provides a general control. One Hughes control cell was measured and checked before and after each set of ten test cells. If any of the three parameters exceed the set limits, adjustments were made and test cells remeasured.

A computer program has been written to reduce and be an aid to data analysis. The program calculates the mean, standard deviations and 95 percent confidence limits of the unnormalized and normalized cell parameters (short-circuit current, open-circuit voltage, maximum power current, maximum power voltage and maximum power).

PRIMARY OBJECTIVES

The ground test program included investigation of the following items:

1) Cells with controlled bar gap areas (see Figure 12 for definition) and their resulting behavior after low-energy proton irradiation (masked and entire cells).

2) The significance of irradiation on contact materials, with and without Z tabs (interconnects).

3) The thin solar cell performance following electron spectrum irradiations.

4) Rear contact resistance changes as a result of low-energy proton irradiations.

5) The effect of irradiating the rear surface of solar cells with different base resistivities.

6) The performance degradation of solar cells with integral covers as a result of low-energy proton and electron spectrum irradiations.

7) Evaluating the typical coverslide thickness under electron spectrum irradiations.

8) The effect of combining front and backside electron spectrum irradiations.

9) The effect of combining low-energy proton and electron irradiations.

LOW ENERGY PROTONS

An investigation of the effects of low energy protons was conducted (fluence levels simulated the synchronous orbit trapped particle environment). Four solar cell parameters were examined.

1) Small exposed cell areas (bar gaps).

2) Zero gap covered cells (no exposed active area) with and without interconnects attached.

3) Different ohmic contact materials.

4) Cell backside contacts.

Test Apparatus

The Van de Graaff particle accelerator at NASA-Ames was used as the source of the low-energy proton environment. Figure 13 shows the test facility. The basic energy range for this accelerator is from 100 kev to 2 mev. The maximum target area is 24 by 24 inches and is obtained by scanning the beam. With this large target area, it was possible to place all samples in the accelerator chamber at the same time. Attached to a shield on the side away from the proton beam (i.e., shielded from the protons) were five control cells. The voltage-current characteristics of these five control cells were measured before and after each irradiation to ensure that only protons were affecting the test cells.

Test Procedures

The solar cells were irradiated with a low-energy proton spectrum representative of synchronous orbit. This simulation of the synchronous low-energy proton environment was based on the published AP5 proton maps, as defined by J. H. King, using the McIlwain coordinates with an L value of 6.6 and B/Bo = 1. The low-energy proton spectrum used to irradiate the test samples consisted of the following energies: 0.2, 0.3, 0.4, 0.6, 0.8, 1.0, and 1.5 Mev. The irradiations were conducted in vacuum. The test samples were irradiated with flux levels simulating 0.5, 1.0, and 7.0 years in synchronous orbit.

The integral proton spectrum used to irradiate the test samples is displayed in Figure 15 and is superimposed on the unidirectional integral synchronous proton flux. Table 2 shows the fluence levels as a function of radiation level and represents a simulated cumulative time of one-half, one, and seven years in synchronous orbit.

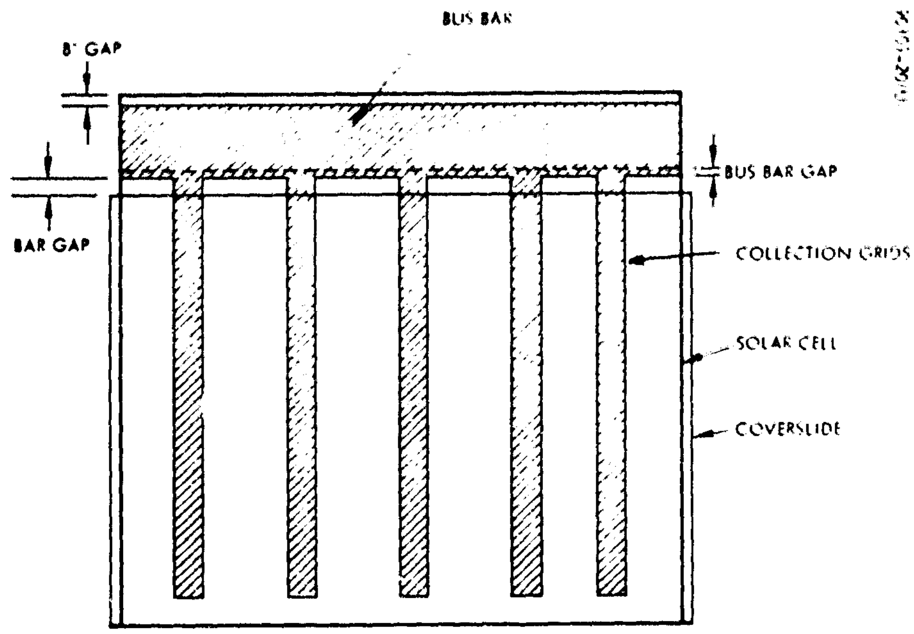

Figure 13 Low-Energy Proton Test Terminology Chart

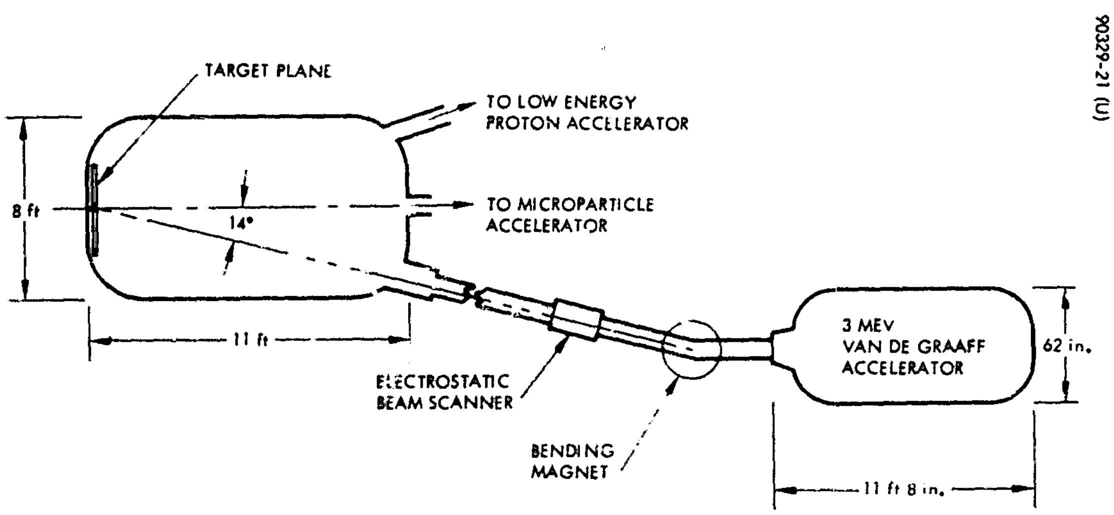

Figure 14 NASA-Ames Van de Graaff Accelerator and Target Chamber

TABLE 2

FLUENCE LEVELS AS FUNCTION OF PROTON ENERGY

REPRESENTING SYNCHRONOUS ORBIT IRRADIATIONS

PROTON ENERGY, mev	FIRST IRRADIATION Fluence, $Protons/cm^2$	SECOND IRRADIATION Fluence, $Protons/cm^2$	THIRD IRRADIATION Fluence, $Protons/cm^2$
0.2	1.9×10^{13}	1.8×10^{13}	2.2×10^{14}
0.3	3.5×10^{12}	3.5×10^{12}	4.2×10^{13}
0.4	1.4×10^{12}	1.3×10^{12}	1.7×10^{13}
0.6	9.0×10^{11}	9.0×10^{11}	1.1×10^{13}
0.8	9.0×10^{11}	9.0×10^{11}	1.1×10^{13}
1.0	1.4×10^{10}	1.4×10^{10}	1.7×10^{11}
1.5	2.7×10^{9}	2.7×10^{9}	3.4×10^{10}
Integral Fluence ($\geq$ 0.2 mev)	2.6×10^{13} (0.5 - year level)	5.0×10^{13} (1.0 - year level)	3.5×10^{14} (7.0 - year level)

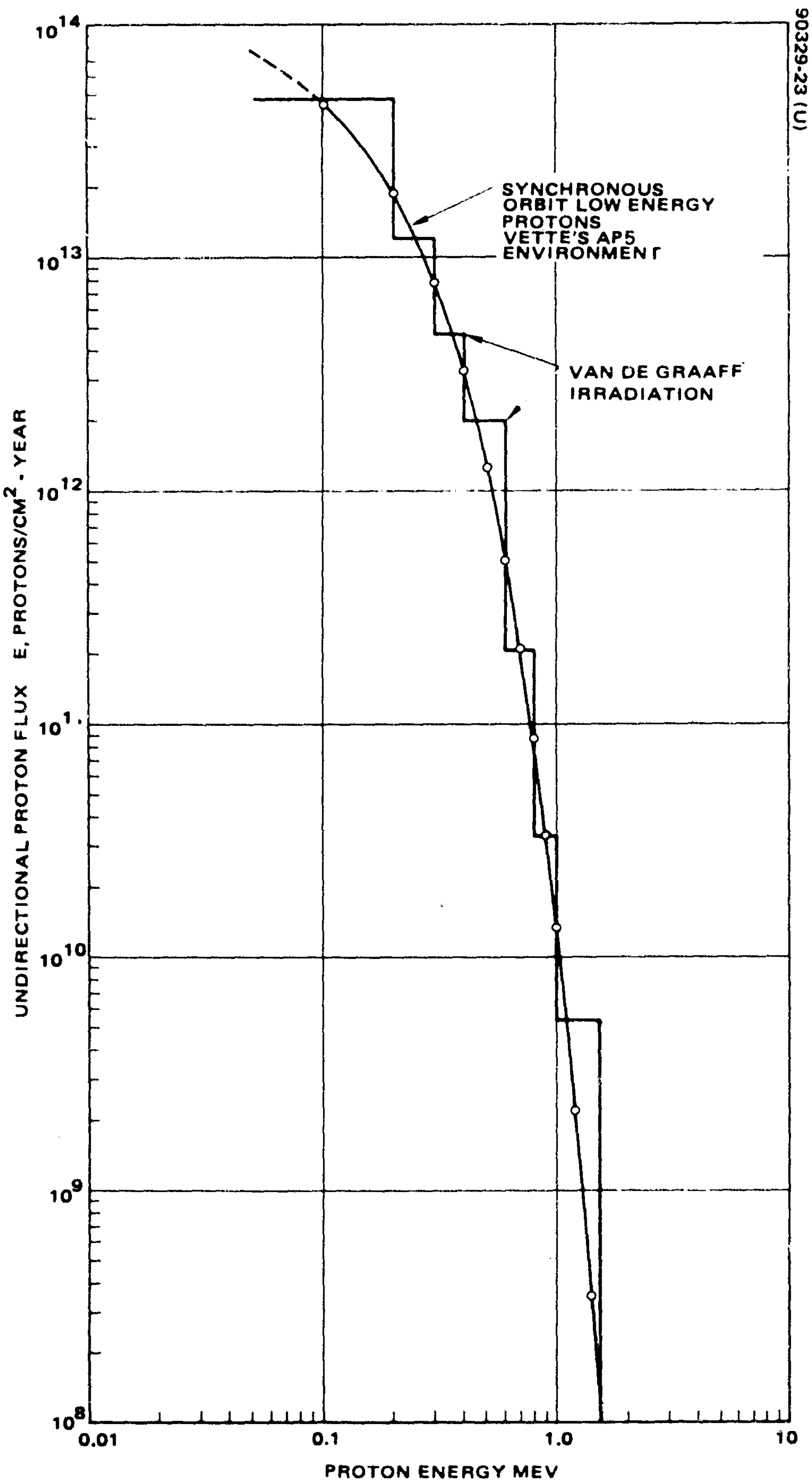

Figure 15 Spectral Content of Synchronous Proton Irradiations

ELECTRONS

The investigation of the effect of Van Allen belt synchronous orbit electrons on solar cell performance was conducted in six parts: cell thickness, base resistivity, coverglass thickness, backside irradiation, combination of front and backside irradiations and combination with low energy proton irradiations were the parameters examined.

Test Apparatus

The Dynamitron particle accelerator at JPL (Figure 16) was used as the source of the electron environment. In the electron mode, the accelerator has an operating range of 10^{-10} amperes to 3 milliamperes at energies from 200 kev to [illegible] mev.

An ion chamber was placed next to the end of the accelerator and a Faraday cup was placed in the plane of the target area. Using these two detectors, the fluence rate was measured and the target area was mapped. The target area was consistent within 5 percent. A solid-state detector was used to measure the energy fluence relationships at the target area.

Test Procedure

The solar cells were irradiated with the JPL Dynamitron accelerator using an electron spectrum representative of synchronous orbit. The synchronous electron environment was based on J. I. Vette's proposed AE3 environment for electrons at synchronous altitude.

The omnidirectional aspect of the environment was simulated by mounting the cells on a rotating cylindrical cell holder. The cell holder was large enough to hold all the samples. The electron beam at the target area encompassed the entire cell holder; therefore, all samples experienced the same environment during irradiations.

The advantage of a rotating cylindrical cell holder for the simulation of the omnidirectional aspect of the real environment versus the cell mounted in a plane is that the angel dependence is not lost. That is, only one degree of freedom is lost in converting from the spherical geometry of space to the cylindrical geometry of this experiment.

A relatively unique manner of simulating the electron energy spectrum was accomplished. Employing the JPL accelerator, a beam of electrons, which would be monoenergetic in vacuum, was passed through a volume of air to effectively reduce and spread the particle energies. The electron energy of the accelerator (monoenergetic at the source) was maintained at 1.05 mev. In order to match the space spectrum, an additional 26 mil aluminum shield was placed in front of the electron beam. The cells were then irradiated with and without the shield to obtain the proper electron spectrum. By integrating the resulting energy spectrums with and without the shield and adjusting the integral fluence with and without the shield a simulation of the synchronous integral electron environment was obtained. As was the case with the proton irradiations, the test samples were irradiated at three electron radiation levels simulating 0.5, 1.0 and 5.0 years in synchronous orbit. The resulting integrated spectrum is shown in Figure 17, where it is compared to Vette AE3 environment.

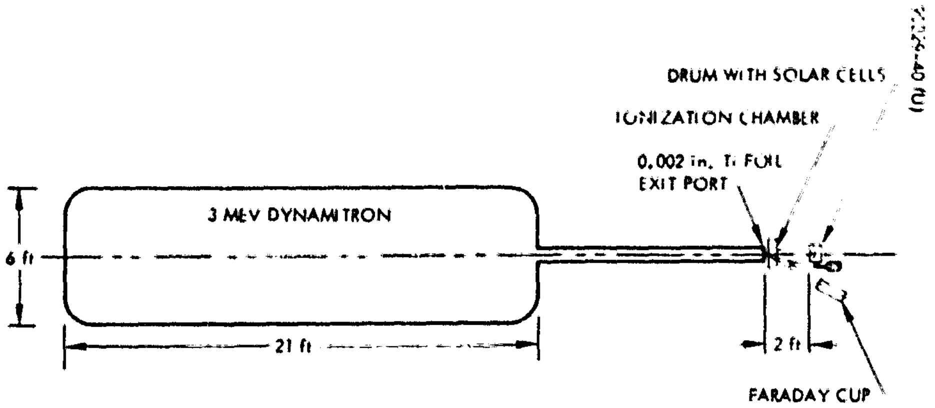

Figure 16 JPL Dynamitron and Setup for Electron Irradiation of Solar Cells in Air

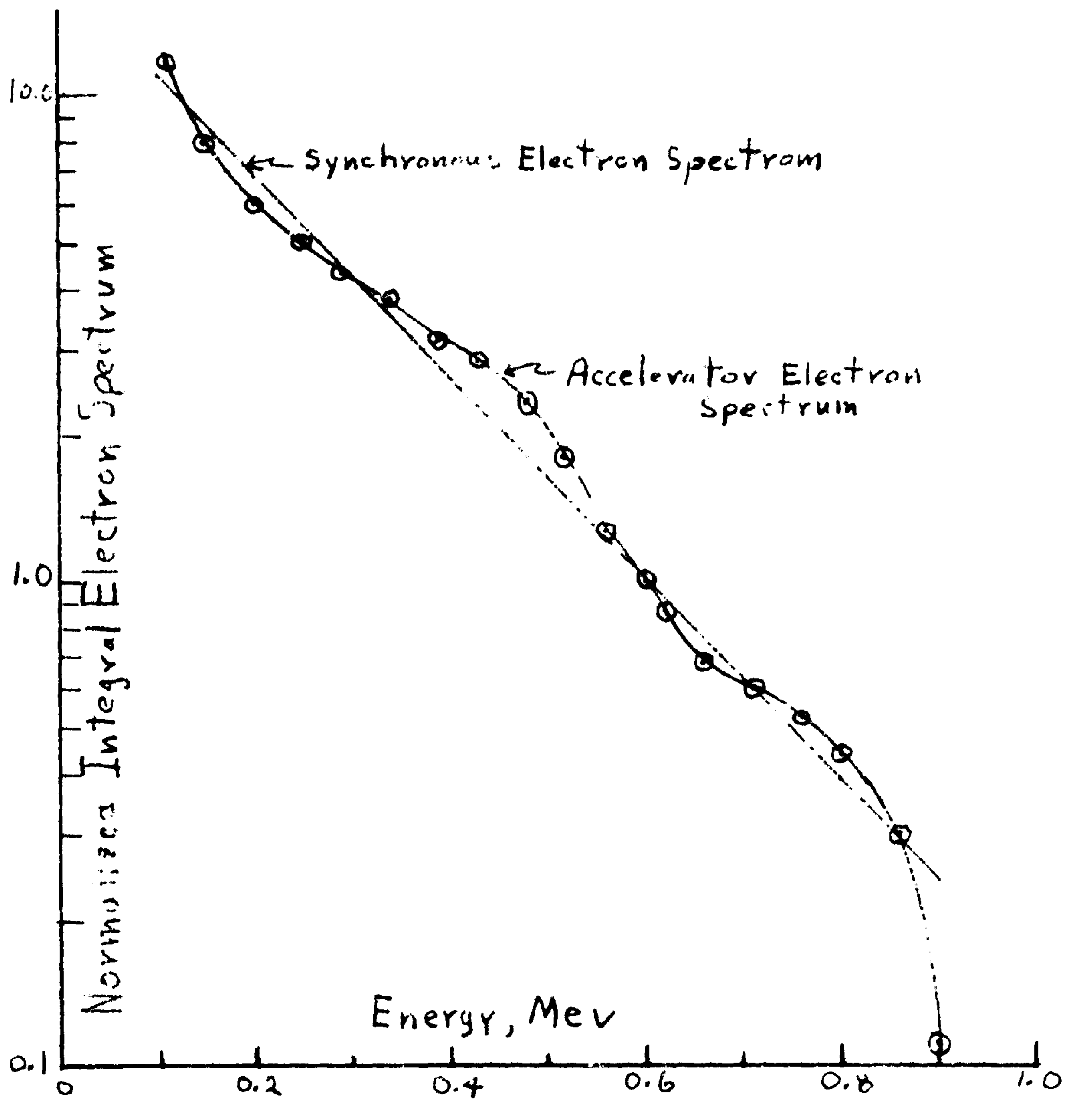

Figure 17 Synchronous Integral Electron Spectrum Comparison

NEW TECHNOLOGY

This report does not contain items of new technology developed by Hughes Aircraft Company under this contract.

PROGRAM FOR NEXT QUARTER

Program Management

A final report will be prepared.

Solar Panels

During the next quarter, the rework of the flexible substrate portion of both the qualification and flight solar panels will be completed. The qualification and acceptance testing of the panels will be performed. Delivery of the panels to NASA is also scheduled.