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THE SOLAR ARRAY SYNTHESIS COMPUTER PROGRAM

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September 1969

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ABSTRACT

Solar-cell arrays provide the primary energy source for most earth-orbiting satellites. The solar cell utilizes the radiative energy from the sun in direct photovoltaic conversion to provide electrical power to the spacecraft. The computer program described here will account for all factors - including isolation diode voltage losses, charged particle irradiation, temperature, solar incidence angle and other solar cell degradation factors - affecting the power output of solar arrays, and thereby greatly reduce the lengthy and laborious hand calculations now necessary in designing an array or predicting its performance.

The program will determine the total power output of solar arrays consisting of up to 25 electrically-parallel panels; each panel may have its own series-parallel solar cell arrangement, temperature verses time profile and sun angle verses time profile. The output of the program is a series of current-voltage (I-V) points representing the total solar array I-V characteristic at up to 20 times during an orbit.

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THE SOLAR ARRAY SYNTHESIS COMPUTER PROGRAM

I. INTRODUCTION

The accurate determination of a solar array's power output in orbit is essential in the adequate design of a spacecraft power system. The lengthy and laborious hand calculations now associated with this determination can be greatly reduced through the use of the Solar Array Synthesis Computer Program. This program will compute and print out solar array output I-V (current-voltage) characteristics for arrays consisting of up to twenty-five (25) solar cell panels. Each panel may have its own series - parallel solar cell arrangement, temperature verses time and solar incidence angle verses time profiles. Also, the program will account for isolation diode voltage losses, charged particle irradiation degradation and other solar cell degradation factors. Calculations may be performed for cells of either 1 or 10 ohm-cm nominal base resistivity.

An individual solar cell I-V characteristic is entered into the computer data deck as a series of current and voltage points at nominal solar intensity and room temperature. After calculating the equivalent 1-Mev electron flux from the given charged particle spectrum, the program will degrade the solar cell characteristic to account for the equivalent 1-Mev flux. The cell I-V curve is next shifted to account for user-specified current and voltage degradation factors. The fully-degraded solar cell I-V characteristic is then extrapolated into a family of solar cell I-V curves at nominal intensity for 15 temperatures (covering the temperature range of interest to the user) through the use of specified current and voltage temperature coefficients and appropriate changes to the I-V curve shape. Each panel's contribution to the total solar array I-V curve is determined separately depending upon the panel's solar cell arrangement, temperature and sun angle; all solar cells on any one panel must be operating at the same temperature and solar incidence angle.

Summing the individual panel output currents at a voltage as voltage is increased from zero to the open-circuit value of the highest-voltage panel, in one-volt increments, yields the total solar array I-V characteristics. Up to 20 such solar array I-V curves can be obtained during a single program execution, corresponding to 20 equal time increments during an orbit, or 20 combinations of solar panel temperature and illumination incidence angle as defined by the program user in the input data.

The program consists of five parts:

- MAIN - reads input data, prints output data, calls the subroutines as required, computes and stores individual panel I-V curves for up to

twenty-five panels and computes the total resulting solar array I-V curve in one volt increments.

- PHI - computes a damage - equivalent, normally - incident (deni) 1-Mev electron flux from tables of omnidirectional electron, proton, solar flare proton and solar flare alpha particle fluxes, accounting for the protection afforded by the selected values of coverglass and back-shielding thicknesses.

- DEGRAD - degrades a room temperature solar cell I-V curve for the equivalent 1-Mev electron flux computed by Subroutine PHI or any other user-specified value of equivalent 1-Mev electron flux.

- STASH - degrades a solar cell I-V curve for current and voltage degradation factors and series resistance effects and computes and stores the degraded cell I-V curve over the specified temperature range.

- STINT - stores in tables, and then supplies on command, the values of variables which are functions of one, two or three arguments. The name stands for Standard Table INTerpolation, and is an adaption of the STINT routine which is a part of the IBM SHARE library.

The program user may elect to perform solar cell calculations only, or solar cell and solar array calculations. Any number of runs may be chained together if desired. The program, originally written in the FORTRAN II computer language compatible with the IBM 7094 computer, has been converted to the FORTRAN IV language for use on the IBM 360 computer. The information contained in this report pertains equally to both versions.

II. PROGRAM DESCRIPTION

This section provides a description of each of the program subroutines. Figure 1 presents a basic block diagram of the solar array synthesis program and summarizes the important functions of each subroutine.

A. MAIN - Computer Program Control

The primary function of the MAIN routine is to perform all data input and parameter initialization, and call the other subroutines as required. In addition, MAIN performs all of the solar array calculations. Up to 20 solar array I-V curves can be determined during one computer run, corresponding to 20 equal time increments during the sunlight-illuminated portion of an orbit or any 20 specified combinations of solar panel sun angle and temperature.

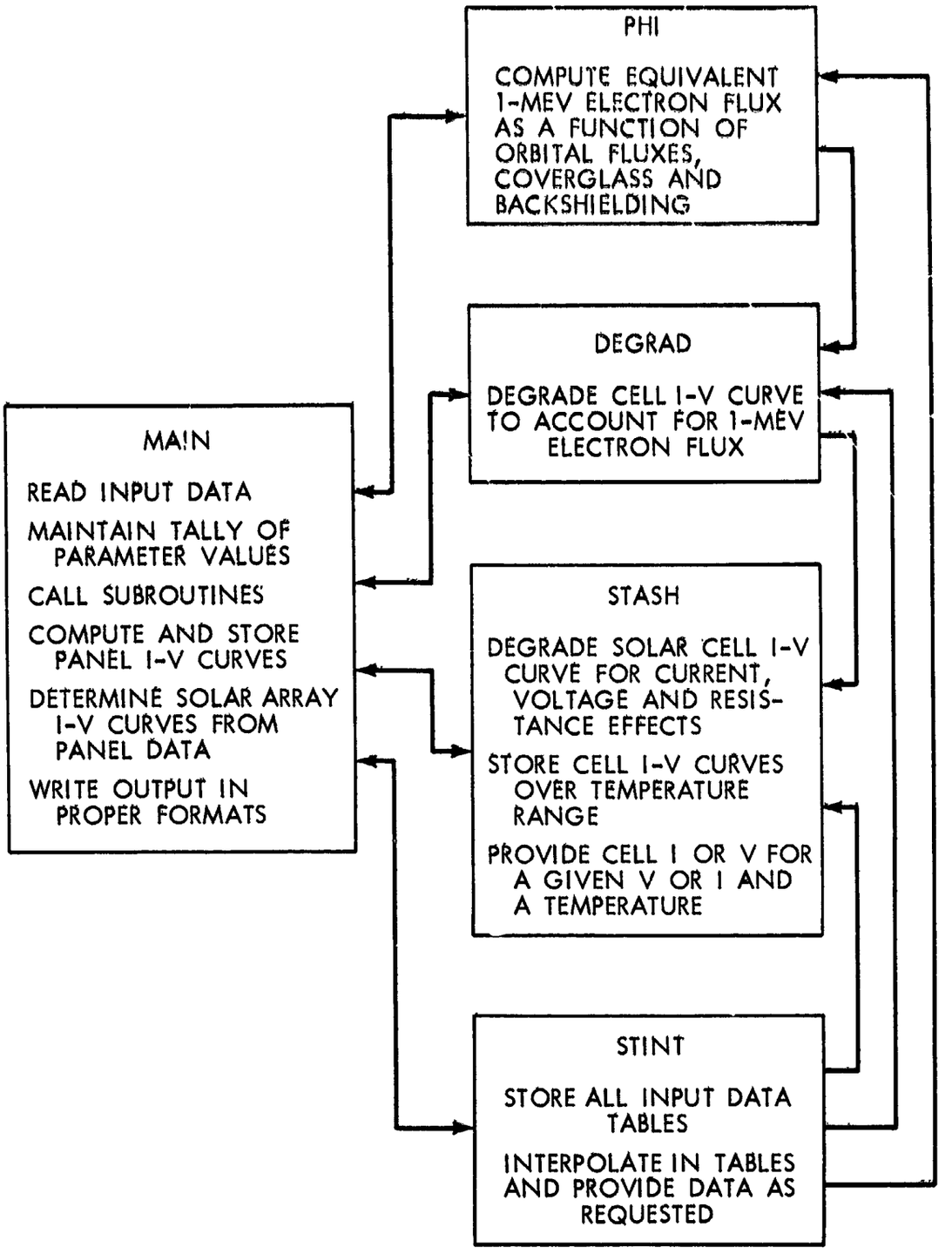

Figure 1. Subroutine Functions in Solar Array Synthesis Computer Program

The contribution to the total solar array I-V curve of each of up to 25 parallel panels is calculated individually. After first determining the panel's operating temperature and solar incidence angle, a representative solar cell curve is constructed. A total panel I-V curve is determined by multipling the representative cell's current values by the number of parallel strings on the panel, and the voltage points by the panel's number of series solar cells. (Each parallel string of a given panel must have the same number of series cells, although separate panels may have different series - parallel combinations.) If the program user has specified a value of array blocking diode loss, this drop is incorporated into the calculation of the panel I-V curve. Summation of the individual panel curves yields a total solar array I-V characteristic at each time increment.

B. Subroutine PHI - Calculation of 1-Mev Electron Flux

Subroutine PHI converts the known charged particle spectrum of the four types of particles which damage solar cells most: trapped orbital electrons, trapped orbital protons, solar-flare protons and solar-flare alpha particles, to a damage-equivalent, normally-incident (deni) 1-Mev electron flux. Solar cell irradiation degradation is usually defined in terms of this low-energy flux because the damage equivalency of 1-Mev electrons for each type and energy range of space particle has been defined.[1] Once calculated, the 1-Mev equivalent flux for each type of particle is summed to determine the total 1-Mev flux the cell experiences.

A flux table, prepared for each type of particle, contains the particle's flux population through specific energy ranges for a particular time in orbit. Tables 1 through 4 list the energy ranges for each type of particle and gives the population of each at one year in a given example orbit. The electron environment is broken into 11 ranges; the other particle environments are divided into 18 ranges. The program will operate properly only when the particle populations are divided into the energy ranges specified in tables 1 through 4.

The program calculates the equivalent 1-Mev electron flux for each type of particle by applying a damage factor (KD) to the population of each energy range; damage factors depend on the effective coverglass and backshielding densities (gm/cm^2) protecting the solar cell. Tables 5 and 6 list damage factors for orbital electrons and protons, based on the data reported by Brown, Gabbe and Rosenzweig.[2] Although previously trapped orbital protons were distinguished from solar-flare protons-based primarily on the relative uncertainty associated with the solar-flare proton model-both proton classifications will use the same damage factor table. Damage factors for alpha particles, from the work of Smith and Blue,[3] are based on the relationship:

$$3.8\ \varphi_p(E) = \varphi_A(4E)$$

Table 1
Electron Flux Format

Energy Range Number	ΔE (Mev)	Ne (Electrons/cm^2)
1	0.0-0.25	1.06E15
2	0.25-0.50	8.58E14
3	0.50-0.75	2.84E14
4	0.75-1.0	9.12E13
5	1.0-2.0	3.87E12
6	2.0-3.0	1.49E11
7	3.0-4.0	1.42E9
8	4.0-5.0	1.08E7
9	5.0-6.0	1.13E5
10	6.0-7.0	6.57E4
11	>7.0	3.65E3

Table 2
Proton Flux Format

Energy Range Number	ΔE (Mev)	Np (Protons/cm^2)
1	0.0-1.0	8.47E13
2	1.0-2.0	1.23E11
3	2.0-3.0	1.50E10
4	3.0-4.0	7.99E9
5	4.0-5.0	4.49E9
6	5.0-6.0	2.50E9
7	6.0-7.0	2.00E9
8	7.0-8.0	1.10E9
9	8.0-9.0	4.35E8
10	9.0-10.0	4.49E8
11	10.0-11.0	3.98E8

Table 2 (Continued)

Energy Range Number	Δ E (Mev)	Np (Protons/cm^2)
12	11.0-12.0	3.98E8
13	12.0-13.0	3.98E8
14	13.0-14.0	1.50E8
15	14.0-15.0	1.14E8
16	15.0-30.0	8.98E8
17	30.0-100.0	8.47E8
18	>100.0	1.40E8

Table 3
Solar-Flare Proton Flux Format

Energy Range Number	Δ E (Mev)	Nfp (Protons/cm^2)
1	0.0-1.0	0.0
2	1.0-2.0	6.06E10
3	2.0-3.0	1.50E10
4	3.0-4.0	7.99E9
5	4.0-5.0	4.49E9
6	5.0-6.0	2.48E9
7	6.0-7.0	1.97E9
8	7.0-8.0	1.09E9
9	8.0-9.0	6.97E8
10	9.0-10.0	4.49E8
11	10.0-11.0	3.98E8
12	11.0-12.0	3.98E8
13	12.0-13.0	3.98E8
14	13.0-14.0	2.99E8
15	14.0-15.0	2.48E8

Table 3 (Continued)

Energy Range Number	Δ E (Mev)	Nfp (Protons/cm^2)
16	15.0-30.0	1.79E9
17	30.0-100.0	1.68E9
18	>100.0	1.97E9

Table 4
Solar-Flare Alpha Particle Flux Format

Energy Range Number	Δ E (Mev)	Nfα (Alpha-Particles/cm^2)
1	16-18	3.98E7
2	18-20	2.99E7
3	20-22	2.99E7
4	22-25	2.99E7
5	25-30	3.98E7
6	30-32	1.97E7
7	32-35	1.97E7
8	35-40	1.97E7
9	40-45	1.97E7
10	45-47	9.86E6
11	47-52	1.17E7
12	52-57	1.28E7
13	57-60	4.96E6
14	60-80	3.20E8
15	80-100	1.97E7
16	100-200	2.23E7
17	200-400	4.49E5
18	>400	9.86E5

Table 5
Damage Factors for Electrons (KDE)

Energy Range Number	Shielding Number						
	0.0	1.0	1.5	3.0	6.0	9.0	200.0
1	0.01	0.0	0.0	0.0	0.0	0.0	0.0
2	0.06	0.03	0.02	0.0	0.0	0.0	0.0
3	0.18	0.13	0.08	0.03	0.0	0.0	0.0
4	0.38	0.30	0.20	0.10	0.02	0.0	0.0
5	1.3	1.15	1.02	0.75	0.47	0.25	0.0
6	2.9	2.70	2.50	2.05	1.55	1.10	0.0
7	4.35	4.15	3.92	3.38	2.85	2.15	0.0
8	5.5	5.30	5.15	4.60	4.10	3.30	0.0
9	6.5	6.15	6.10	5.70	5.30	4.60	0.0
10	7.4	7.30	7.30	6.80	6.50	5.85	0.0
11	7.8	7.80	7.80	7.70	7.50	7.0	0.0

Table 6
Damage Factors for Protons (KDP)

Energy Range Number	Shielding Number						
	0.5	1.0	1.5	3.0	6.0	9.0	200.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6000.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6 (Continued)

Energy Range Number	Shielding Number						
	0.5	1.0	1.5	3.0	6.0	9.0	200.0
4	5400.0	0.0	0.0	0.0	0.0	0.0	0.0
5	4500.0	3000.0	0.0	0.0	0.0	0.0	0.0
6	3900.0	3700.0	2000.0	0.0	0.0	0.0	0.0
7	3500.0	3500.0	3100.0	0.0	0.0	0.0	0.0
8	3100.0	3100.0	3100.0	200.0	0.0	0.0	0.0
9	2800.0	2800.0	2800.0	1400.0	0.0	0.0	0.0
10	2700.0	2700.0	2700.0	2000.0	0.0	0.0	0.0
11	2600.0	2600.0	2600.0	2100.0	0.0	0.0	0.0
12	2500.0	2500.0	2500.0	2100.0	100.0	0.0	0.0
13	2500.0	2500.0	2500.0	2100.0	1000.0	0.0	0.0
14	2500.0	2500.0	2500.0	2000.0	1400.0		0.0
15	2500.0	2500.0	2500.0	2000.0	1500.0	100.0	0.0
16	2500.0	2500.0	2500.0	2000.0	1800.0	1500.0	0.0
17	2300.0	2300.0	2300.0	2000.0	2000.0	2000.0	0.0
18	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	0.0

This relationship states that an alpha particle of four times the energy of a proton does 3.8 times the damage of the proton. Table 7 lists damage factors for alpha particles. The program user must specify an equivalent thickness of backshielding and coverglass for each computation; Table 8 lists the stored shielding densities, and equivalent thicknesses of fused silica coverglass and aluminum

Table 7
Damage Factors for Alpha Particles (KDA)

Energy Range Number	Shielding Number						
	0.0	1.0	1.5	3.0	6.0	9.0	200.0
1	20000.0	10000.0	0.0	0.0	0.0	0.0	0.0
2	15000.0	13000.0	0.0	0.0	0.0	0.0	0.0
3	14500.0	14000.0	7000.0	0.0	0.0	0.0	0.0
4	13700.0	13700.0	11000.0	0.0	0.0	0.0	0.0
5	12500.0	12500.0	12000.0	0.0	0.0	0.0	0.0
6	11500.0	11500.0	11500.0	2500.0	0.0	0.0	0.0
7	11000.0	11000.0	11000.0	5200.0	0.0	0.0	0.0
8	10400.0	10400.0	10400.0	7200.0	0.0	0.0	0.0
9	9800.0	9800.0	9800.0	7900.0	0.0	0.0	0.0
10	9500.0	9500.0	9500.0	8000.0	1700.0	0.0	0.0
11	9500.0	9500.0	9500.0	7800.0	3650.0	0.0	0.0
12	9500.0	9500.0	9500.0	7700.0	5200.0	0.0	0.0
13	9500.0	9500.0	9500.0	7600.0	5700.0	1600.0	0.0
14	9400.0	9400.0	9400.0	7600.0	6300.0	4000.0	0.0
15	9200.0	9200.0	9200.0	7600.0	7000.0	6400.0	0.0
16	8600.0	8600.0	8600.0	7700.0	7400.0	7100.0	0.0
17	7000.0	7000.0	7000.0	7000.0	7000.0	7000.0	0.0
18	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	0.0

Table 8
Shielding Numbers

Shielding Density (gm/cm^2)	0.016	0.033	0.05	0.1	0.2	0.3	*
Equivalent mils of fused silica coverglass	3.0	6.0	9.0	18.0	36.0	54.0	—
Equivalent mils of Aluminum	2.5	5.0	7.5	15.0	30.0	45.0	1000.0*
Shielding Number for Computer Lookup	0.5	1.0	1.5	3.0	6.0	9.0	200.0

*Simulates infinite backshielding

backshielding. The user may specify any desired thickness of coverglass or backshielding within the range of stored data. The program will automatically make a linear interpolation between the damager factor values associated with the two closest thicknesses to determine the damage factor to be used.

Once the charged particle population of each type of particle has been entered into the computer, and the coverglass and backshielding thicknesses have been selected, the computer can calculate the total equivalent 1-Mev electron flux using the relationship:

$$\varphi_T = \varphi_e + \varphi_p + \varphi_{fp} + \varphi_{f\alpha} \quad \text{(reference 1)}$$

where

φ_T = total 1-Mev equivalent flux
φ_e = electron 1-Mev equivalent flux
φ_p = proton 1-Mev equivalent flux
φ_{fp} = solar-flare proton 1-Mev equivalent flux
$\varphi_{f\alpha}$ = solar-flare alpha particle 1-Mev equivalent flux

The contribution of each particle to the total flux is calculated separately by a summation process. For example, φ_p is calculated by multiplying the population of each of the 18 proton energy ranges by the appropriate damage factors for backshielding and coverglass, then summing each of these products. The

following expression demonstrates this summation process:

$$\varphi_p = \sum_{\Delta E = 1}^{18} \left[KDP \times NP \,|_{CG} + KDP \times NP \,|_{BS} \right]$$

where

KDP = proton damage factor for a given energy range
NP = number of protons in a particular energy range

The equivalent flux for each of the other types of particles is calculated similarly. The value of φ_T is stored by the computer until called for by subroutine DEGRAD.

C. Subroutine DEGRAD - Calculation of Solar Cell I-V Curve Irradiation Degradation

Subroutine DEGRAD degrades a single solar cell I-V characteristic to compensate for damage caused by an equivalent 1-Mev flux. The input to this subroutine is either the output of PHI or a user specified 1-Mev flux; in the latter case subroutine PHI is not called and the computer immediately enters subroutine DEGRAD to degrade the I-V curve for the given flux.

The undegraded solar cell I-V curve is entered into the computer as a series of voltage and current points at room temperature and nominal solar intensity (140 mw/cm^2). The computer interpolates the orginal points to arrive at 100 current and voltage pairs (Vi and Ii) at 10-mv increments. These interpolated points will then be shifted to account for the charged-particle irradiation degradation.

The effect of a charged particle flux on the solar cell is a decrease in solar cell output current and voltage and a change in the I-V curve shape. Flight and laboratory experiments have shown that a solar cell will incur a "softening" of the I-V curve due to junction damage if low energy protons are allowed to reach the silicon where the coverglass does not completely protect the exposed cell surface. However, the computer program assumes an adequate shielding design and therefore accounts for the effect of bulk damage only (decrease of minority carrier lifetime in the base material). The I-V curve shape change due to the bulk damage is a "squaring" of the curve shape. This change is implemented by a series resistance correction technique in the computer program. A very lucid graphical example of the curve shape change can be found in the Cherry and Statler report on U.S. and European solar cells (Reference 4). This reference includes I-V curves for Heliotek, Centralab and Texas Instruments 10-ohm-cm cells and Heliotek 2-ohm-cm cells, at 1-Mev electron flux levels from 0 to 10^{16} e/cm^2. When the 10^{16} I-V curve is traced on a transparent paper overlay and

this curve is now translated to the 0 flux curve, the sharper line of the irradiated I-V curve is quite obvious for all of the U.S. cells.

Implementation of this effect in the computer is shown in Figure 2.

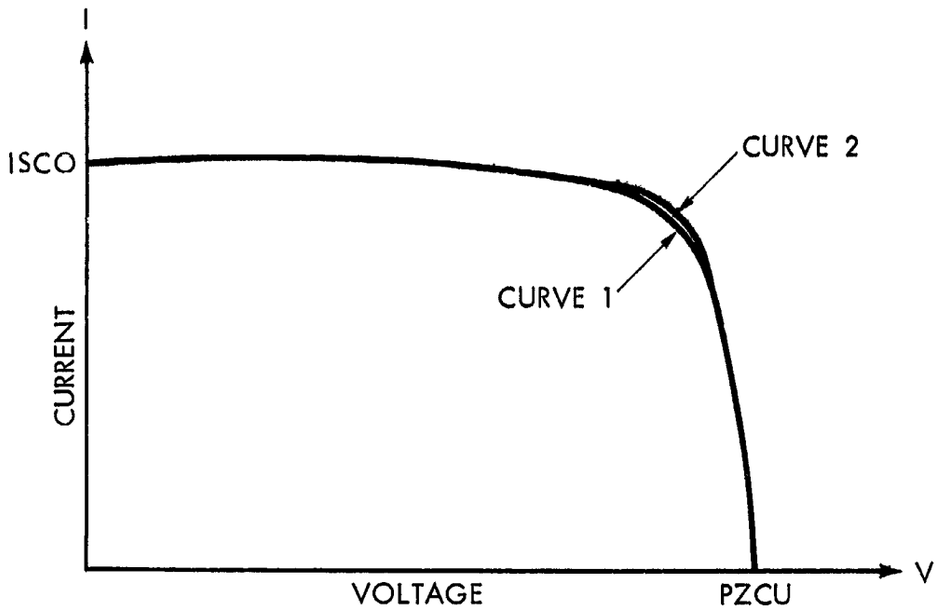

Figure 2. Curve Shape Correction

A curve shape correction, dependent on the equivalent 1-Mev flux, effectively sharpens the knee of the curve by adding a negative "radiation resistance" (RR) correction to each voltage point of the curve:

$$Vi_{corrected} = Vi_{initial} + Ii \times RR \text{ (reference 1)}$$

RR is defined as "volts at short circuit current (VISC) divided by the initial, undegraded value of short circuit current (ISCO)." Values of VISC, dependent upon flux level and solar cell base resistivity, are entered as a portion of the user specified input data (STINT table number 10: "NMVTBL CURVE SHAPE VOLTS VS PHI"). The proper value of VISC will be determined by a linear interpolation between the values associated with the flux levels closest to actual value of φ_T . Figure 2 shows the effect of the curve shape correction. Curve 1 is the original I-V curve and curve 2 shows the sharpening of the knee caused by the charged-particle irradiation.

Next the program shifts the total I-V curve parallel to the current axis an amount Δ I to account for the reduction in short circuit current caused by the

equivalent flux. The current increment is calculated as ISCO(1-RI), where RI is defined as the relative short-circuit current degradation factor. Equations for RI, dependent on cell base resistivity and flux level, are contained in the program. Curve 3 of Figure 3 is determined by subtracting Δ I from each current point of curve 2: Ii = Ii-Δ I. The point PZCD is not the actual degraded open-circuit voltage, but merely a temporary value of the "point of zero current" of the cell.

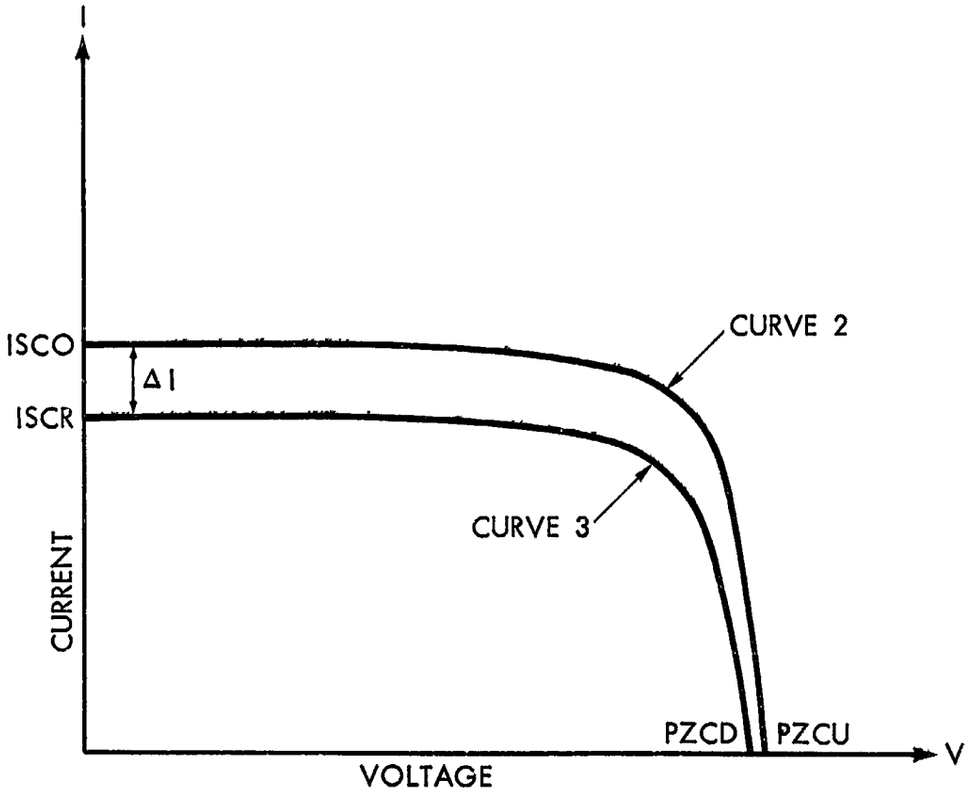

Figure 3. Short Circuit Current Correction

A final characteristic correction is made to account for the reduction of open-circuit voltage in the solar cell caused by the equivalent flux. The relative open-circuit voltage degradation factor, RV, is calculated through the use of stored equations. (Unlike the previous degradation parameters, RV depends only on the equivalent flux and not on the solar cell base resistivity.) The degraded open-circuit voltage (VOCR) is calculated as (PZCU x RV), where PZCU is the initial undegraded value of cell open-circuit voltage. The curve is then shifted parallel to the voltage axis an amount Δ V - defined as (PZCD-VOCR) - by subtracting Δ V from each voltage point: Vi = Vi-Δ V. Curve 4 of Figure 4 shows the fully degraded solar cell I-V curve.

Figure 5 shows typical solar cell I-V curves for various flux levels. A small computer program employing the techniques of PHI and DEGRADE has been developed and is described in Reference 5.

D. Subroutine STASH - Solar Cell Degradation and Temperature Effects

The purpose of subroutine STASH is to account for all factors, with the exception of charged particle irradiation degradation, which effect the solar cell's I-V characteristic. External series resistance effect, illumination intensity change, voltage measurement error and temperature effect are all included. The input to this subroutine, curve 1 of Figure 6, is either the output of DEGRAD or, if beginning-of-life calculations are being performed, the program's original input solar cell I-V curve. In the latter case, subroutines PHI and DEGRAD are bypassed and the computer immediately enters subroutine STASH to account for the user-specified current and voltage degradation factors and temperature effects. All design uncertainties, or factors for a conservative design, should be included when the degradation factors and temperature coefficients are selected.

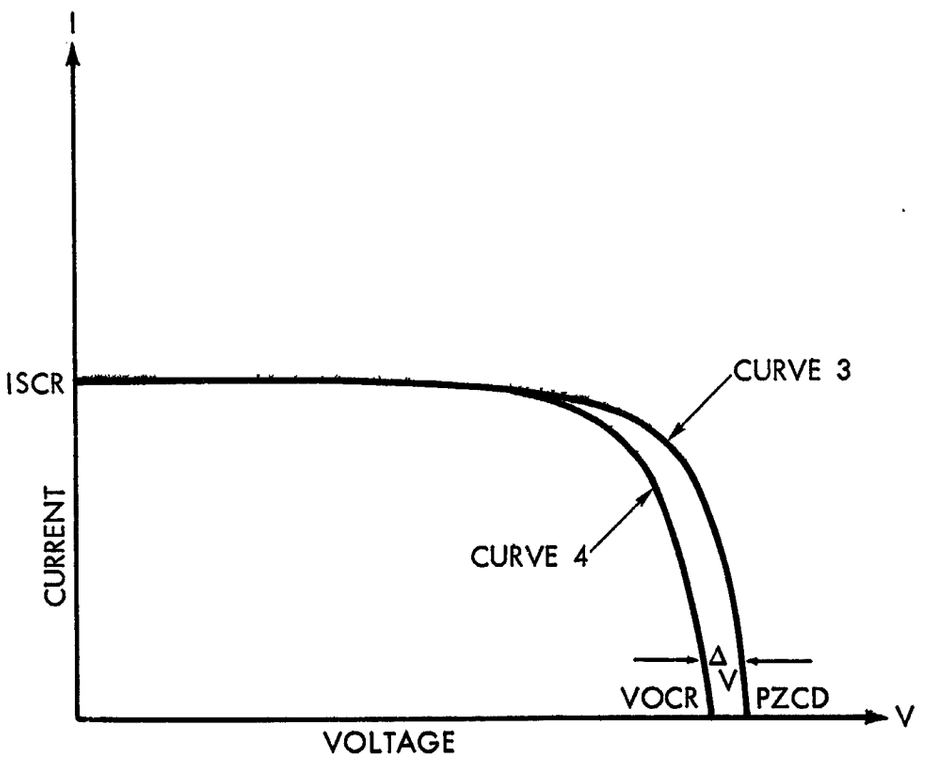

Figure 4. Open Circuit Voltage Correction

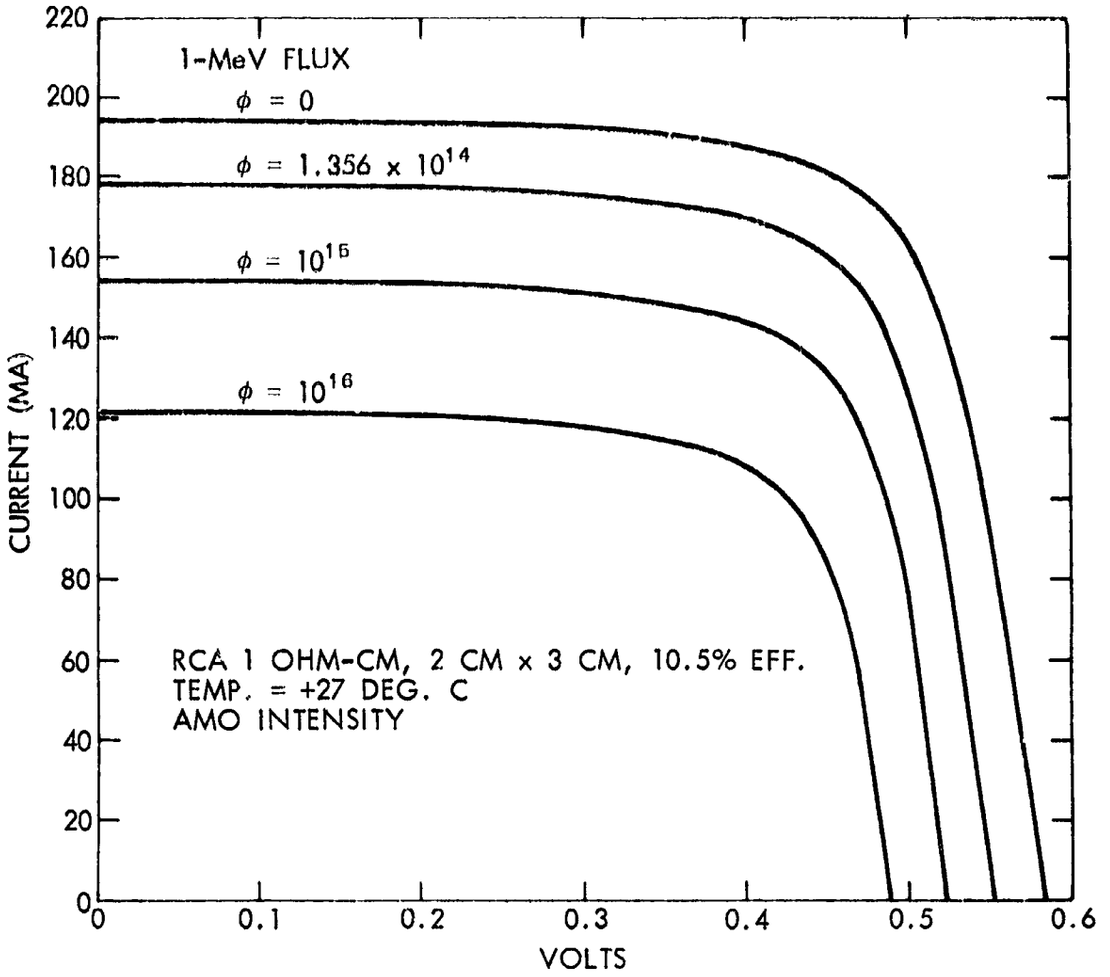

Figure 5. Solar Cell I-V Curves at Various Flux Levels

The I-V characteristic is first shifted parallel to the current axis an amount DELI to account for the current degradation factors DI1 through DI4; each factor is defined as a percentage of short circuit current remaining after degradation. (For example, if it is assumed that DI1 causes a 10% loss in short circuit current, DI1 would have a value of 90.0.) DELI is defined as ISC1(1-γ), where γ is merely the product of the four current degradation factors. Although the four parameters usually refer to standard cell error, solar intensity variation, ultraviolet degradation and current measurement error, respectively, any four factors which effect the solar cell's short circuit current output may be used. The current-shifted I-V curve is translated parallel to the voltage axis until V_2 is intercepted, which accounts for the change in open-circuit voltage caused by the relative decrease in short circuit current. Curve 2 of Figure 6 shows the current-degraded I-V characteristic.

A voltage degradation factor which effects all voltages on the I-V curve equally is usually defined as a percentage of the open circuit voltage of the reference I-V curve. Such a factor may be a voltage measurement error. The I-V curve is corrected to account for this factor by translating the entire curve parallel to the voltage axis an amount DELV : $DELV = \frac{\text{percentage degradation}}{100} \times V_1$. Curve 3 of Figure 7 shows the voltage degraded I-V curve; VOC is the degraded value of open circuit voltage.

A final correction is made to the cell's I-V characteristic to account for an effective increase in the external series resistance. This increase, which is usually caused by either a series wiring loss or thermal cycling degradation, is defined as a percentage loss of voltage at the maximum power point of the solar cell I-V curve. There is, in addition, a corresponding voltage loss to all other points on the I-V curve which is proportional to the current at each point. Figure 8 shows the I-V characteristic before and after the resistance change; V_{pmo} is the original maximum power point voltage, while V_{pmr} is the degraded value.

After applying the degradation factors, subroutine STASH uses the current and voltage temperature coefficients to expand the fully degraded I-V curve into a family of curves at fifteen temperatures. Maximum power, maximum power point voltage and current, open circuit voltage and short circuit current values are calculated at each temperature.

A detailed technical discussion of the techniques employed in this subroutine is contained in Reference 6.

E. Subroutine STINT - Data Storage and Retrieval

Subroutine STINT merely stores in tables, and then supplies on demand, the values of variables which are functions of one, two or three arguments. The first use of STINT loads the tabular data into the computer. Subsequent STINT calls will ask for a linear interpolation to be performed which corresponds to the supplied argument values.

As an example, STINT table No. 12 of Appendix B gives a typical solar array temperature verses time profile for a Nimbus orbit. If the program user has requested that a solar array I-V curve be generated at 21 minutes into the sunlight portion of the orbit, MAIN will call STINT to determine the array temperature at this time in orbit. By interpolating between the array temperatures corresponding to the two closest time references - in this case 20.0 and 25.0 minutes - STINT calculates an array temperature of 19.0 degrees; this value is returned to MAIN.

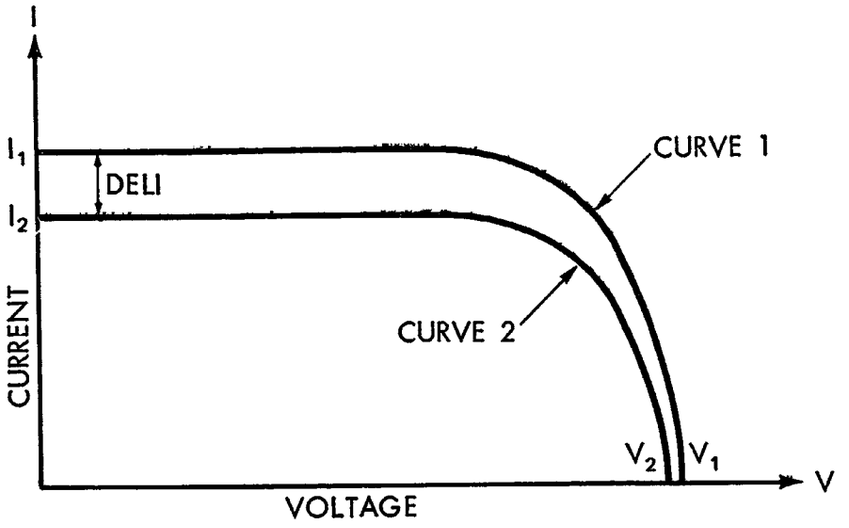

Figure 6. Short Circuit Current Degradation Effects

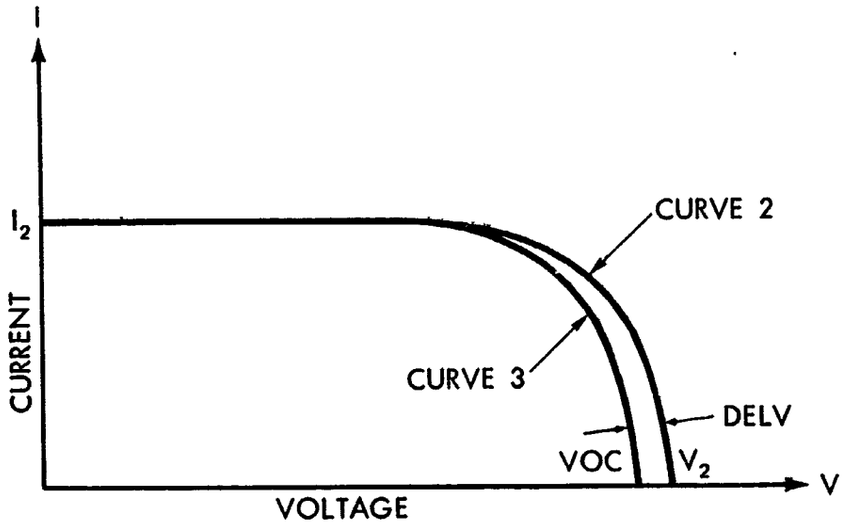

Figure 7. Open Circuit Voltage Degradation Effects

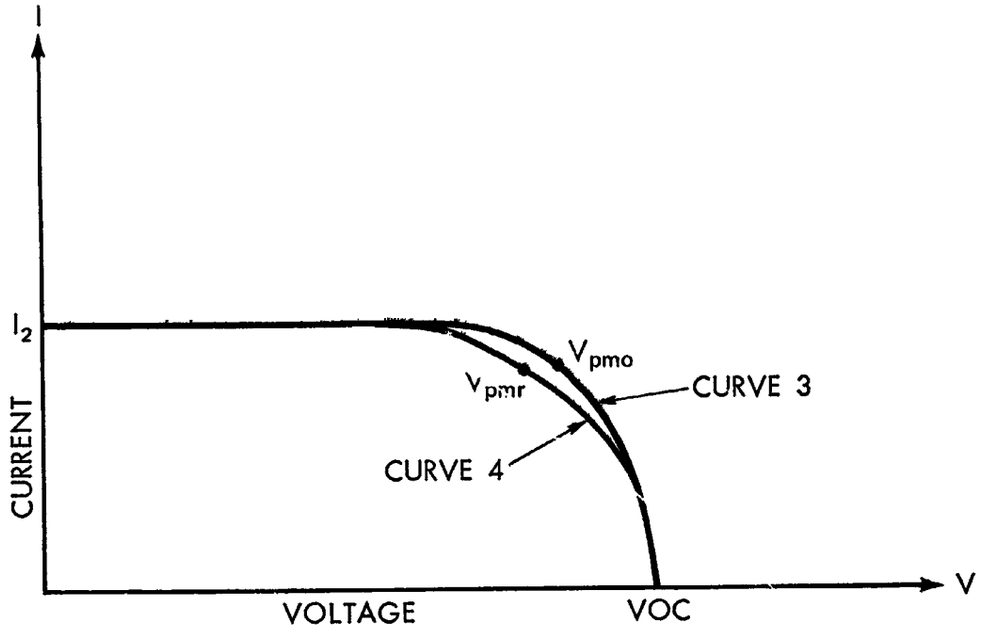

Figure 8. External Series Resistance Correction

One and two argument functions may be stored in single tables - Tables 1 and 7 are examples of one and two argument functions, respectively. Three argument functions must be stored in consecutive two argument tables; the number of two argument tables will be equal to the number of $argument_3$ values.

Subroutine STINT is called by means of a statement with the following format:

CALL STINT (ARG1, ARG2, ARG3, FCT, KEY, NGRIPE, MINTBL, MAXTBL)

The first three dummy variables are the three arguments; zeroes must be subsituted for unused arguments. FCT is the variable value to be calculated, and KEY tells the computer what kind of operation is to be performed. A value of -1 indicates the table-loading mode, while a +1 calls for a linear interpolation to be performed. NGRIPE is an error flag. MINTBL and MAXTBL are the number of the STINT tables used; both tables are the same if the variable is a function of two arguments. MINTBL is set equal to the table number which contains the lowest value of $argument_3$ values and MAXTBL is set to the table which contains the highest $argument_3$ values if the variable is a function of three arguments.

III. PROGRAM USAGE

The following describes the mechanics of using the program in "non-programmer" language. Appendix A contains a program deck listing, while Appendix B illustrates a typical data deck set-up written in the FORTRAN IV computer language.

The assembly of the complete program as it is submitted to the computer is shown in Figure 9. This assembly basically consists of two parts — a program deck and a data deck. The program deck is always used and is placed first in the assembly. It contains the MAIN routine and all of the subroutines used in the program (STINT, PHI, DEGRAD and STASH) and does not require any card changes to perform its function.

The data deck contains all the numerical information the program requires for computation and defines the user-selected options for each run. Consequently, the data deck must be prepared specifically for each run, or series of chained runs, to be made. Cards and tables in the data deck must be positioned in the order shown in the program assembly in Figure 9. The data deck description and format are presented below in the proper assembly sequence.

Asterisk Data Card. The first card in the data deck is labeled:

Column 1	*
Columns 7 - 10	DATA

Date and List Option Card

Column 1-2	Number of month
Column 3-4	Number of day
Column 5-6	Number of year
Column 9	0 - Input data (STINT) tables not printed out
Column 9	1 - Input data (STINT) tables printed out in exponential format

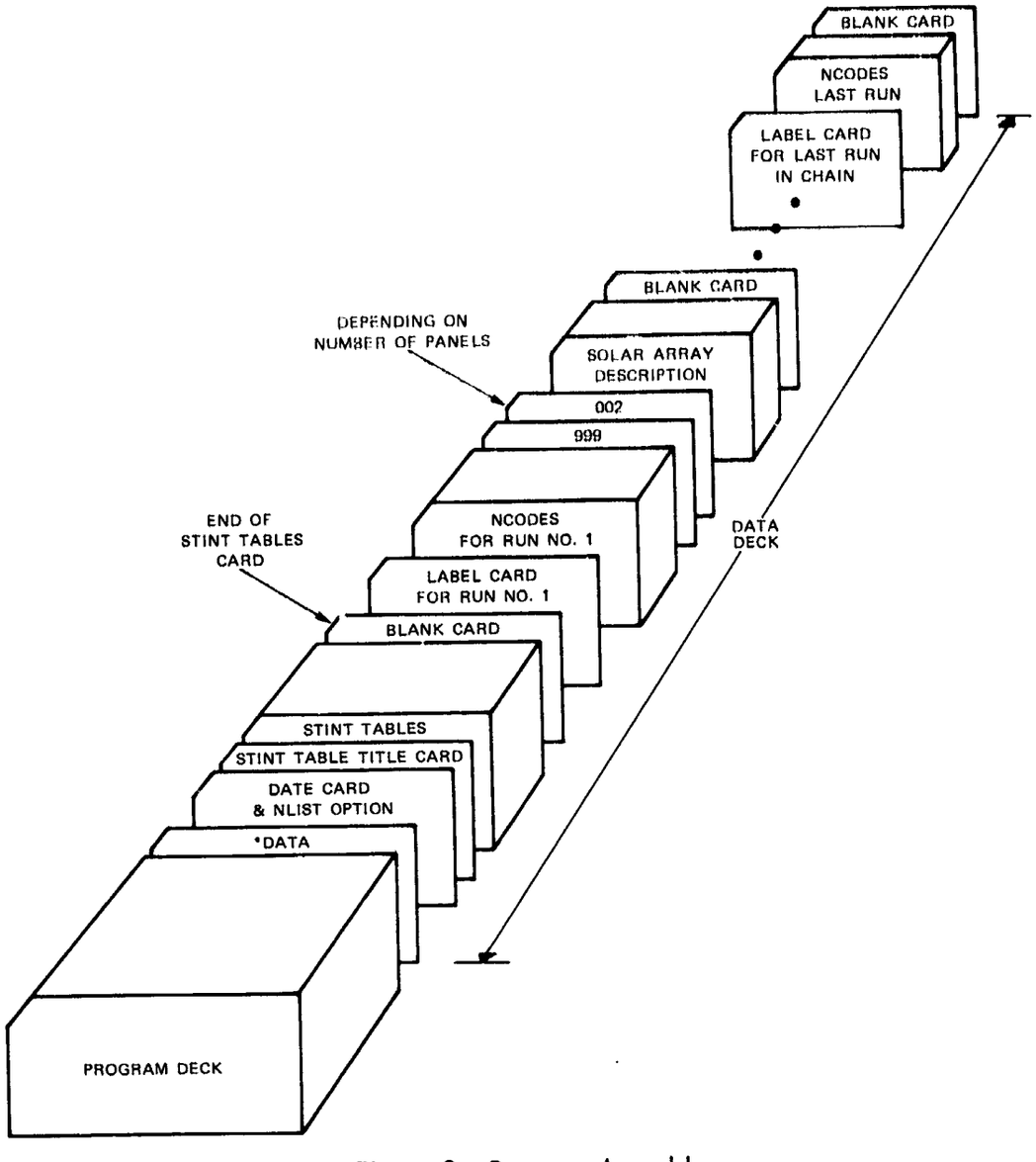

Figure 9. Program Assembly

STINT Table Title Card

Column 1	Blank
Column 2-72	Any Alpha-Numeric information

The STINT tables are stacked one behind the other in the data deck in ascending numerical order. The ten tables listed below must always be present in the data deck, in the order shown.

Table #	Table Name
1	Solar Cell I-V Curve
2	Relative Solar Array Current vs. Incidence Angle
3	Orbital Electrons 1 yr. 600 N.M. (or suitable substitute)
4	Orbital Protons 1 yr. 600 N.M. (or suitable substitute)
5	Solar Flare Protons 1 yr. 600 N.M. (or suitable substitute)
6	Solar Flare Alpha Particles 1 yr. 600 N.M. (or suitable substitute)
7	Damage Factors for Electrons
8	Damage Factors for Protons
9	Damage Factors for Alpha Particles
10	NMVTBL Curve Shape Volts vs. PHI

The maximum number of STINT tables that the program will accept is 60; the 10 above tables plus, starting with Table No. 11, a sun angle vs. time table and a temperature vs. time table for each of the 25 panels comprising the solar array. If fewer than the maximum number (25) of panels is specified, fewer STINT tables are required. More than one panel may use the same angle or temperature table stored in STINT.

The first card of each STINT table is a header card, which must be prepared in the following format:

Columns 1-8	:	Any alpha-numeric characters can be used for a date.
Columns 9-12	:	Table number. Cannot be zero. Fixed point and right-justified.
Columns 13-14	:	Number of $argument_1$ values. Cannot be zero. Fixed point and right-justified.
Columns 15-16	:	Number of $argument_2$ values. Cannot be zero, is 1 for a function of one argument. Fixed point and right-justified.
Columns 17-19	:	Not used.

Columns 20-70 : Any alpha-numeric characters desired. Usually used for table title.

Columns 71-72 : 00

After the header card, each card in the table uses 10 fields of 7 columns each for the argument values and the function values. The first card contains the first nine $argument_1$ values in fields 2 through 10. In the following cards, field 1 contains an $argument_2$ value, and fields 2 through 10 contain corresponding function values. After all the $argument_2$ values have been spanned, the whole series of an $argument_1$ card followed by $argument_2$ cards can repeat until all the function values are used. If there is an $argument_3$ value for the table, it goes into field 1 of the $argument_1$ card. Columns 71 and 72 on each card must contain a sequence number, starting with 01 for the first card. Figure 10 shows a typical STINT table coding sheet for a single argument (current as a function of voltage) STINT table. Figure 11 shows a two-argument STINT table format.

After the last STINT table in the data deck, there is a card labeled END OF STINT TABLES, starting in Col. 21. Cols. 9-12 and 71-72 must be left blank on this card. This card is referred to as the blank card following the STINT tables in Figure 9.

Run Label Card

Following the END OF STINT TABLES card is a card containing any desired alpha-numeric information in columns 2-72, which usually describes the first run to be made.

NCODE

Following the Run Label Card are the 24 NCODE cards. The card number, or NCODE, is right justified against Col. 3. The numerical value of the NCODE variable is left-justified against Col. 5 and must have a decimal point. Figure 10 shows the NCODE names, the NCODE numbers, the NCODE values and a brief description of each NCODE for a sample computer run. Only the NCODE number and its numerical value are punched on the NCODE cards; the other data in Figure 12 are for information only. All 24 of the NCODES are initially loaded into memory, thus a single run or the first of a series of chained runs must contain all the NCODES in the data deck. The NCODE descriptions in Figure 12 are described below:

a. TD is the total orbit suntime in minutes.

b. DELTAT is the time increment in the orbit between solar array calculations, starting with 0 minutes (beginning of orbit suntime), and

FORTRAN TABLES FORMAT

PUNCH 1 CARD AS FOLLOWS

COLS 1-8 0 4 -0 6 -6 8 (TBL DATE) COLS 9-12 0 0 0 1 (TBL NO) COLS 13-14 2 7 (ARG 1's) COLS 15-16 0 1 (ARG 2's) COLS 20-70 (TITLE) COLS 71-72 0 0 (SEQ. NO)

FIELD 1 ±INTEGER ±EXP	FIELD 2 ±INTEGER ±EXP	FIELD 3 ±INTEGER ±EXP	FIELD 4 ±INTEGER ±EXP	FIELD 5 ±INTEGER ±EXP	FIELD 6 ±INTEGER ±EXP	FIELD 7 ±INTEGER ±EXP	FIELD 8 ±INTEGER ±EXP	FIELD 9 ±INTEGER ±EXP	FIELD 10 ±INTEGER ±EXP	SEQ. NO.	PROGRAM DECK NO.
1 2 3 4 5 6 7	8 9 10 11 12 13 14	15 16 17 18 19 20 21	22 23 24 25 26 27 28	29 30 31 32 33 34 35	36 37 38 39 40 41	42 43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66 67	68 69 70 71 72	73 79 80
	0.0	0.225	0.275	0.295	0.315	0.335	0.350	0.365	0.380	01	
	0.1257	0.1245	0.1241	0.1240	0.1237	0.1231	0.1229	0.1222	0.1213	02	
	0.390	0.400	0.410	0.420	0.430	0.440	0.450	0.460	0.470	03	
	0.1204	0.1194	0.1180	0.1167	0.1149	0.1129	0.1101	0.1066	0.1025	04	
	0.480	0.490	0.500	0.510	0.520	0.551	0.577	0.603	1.0	05	
	0.0974	0.0917	0.0850	0.0765	0.0655	0.030	0.0	-0.030	-0.030	06	

Figure 10. Sample Coding Sheet Showing Format for a Single Argument STINT TABLE

FORTRAN TABLES FORMAT

PUNCH 1 CARD AS FOLLOWS

COLS 1-8 0,4,-,0,6,-,6,8 (TBL DATE) COLS 9-12 0,0,0,7 (TBL NO) COLS 13-14 1,1 (ARG 1's) COLS 15-16 0,6 (ARG 2's) COLS 20-70 (TITLE) COLS 71-72 0,0 (SEQ NO)

FIELD 1 ±INTEGER ±EXP	FIELD 2 ±INTEGER ±EXP	FIELD 3 ±INTEGER ±EXP	FIELD 4 ±INTEGER ±EXP	FIELD 5 ±INTEGER ±EXP	FIELD 6 ±INTEGER ±EXP	FIELD 7 ±INTEGER ±EXP	FIELD 8 ±INTEGER ±EXP	FIELD 9 ±INTEGER ±EXP	FIELD 10 ±INTEGER ±EXP	SEQ NO	PROGRAM DECK NO
1 2 3 4 5 6 7	8 9 10 11 12 13 14	15 16 17 18 19 20 21	22 23 24 25 26 27 28	29 30 31 32 33 34 35	36 37 38 39 40 41 42	43 44 45 46 47 48 49	50 51 52 53 54 55 56	57 58 59 60 61 62 63	64 65 66 67 68 69 70	71 72	78 79 80
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	01	
1.0	0.0	0.03	0.13	0.3	1.15	2.7	4.15	5.3	6.15	02	
1.5	0.0	0.02	0.08	0.20	1.02	2.5	3.92	5.15	6.1	03	
3.0	0.0	0.0	0.03	0.10	0.75	2.05	3.38	4.6	5.7	04	
6.0	0.0	0.0	0.0	0.02	0.47	1.55	2.85	4.1	5.3	05	
9.0	0.0	0.0	0.0	0.0	0.25	1.1	2.15	3.3	4.6	06	
200.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	07	
	10.0	11.0								08	
1.0	7.3	7.8								09	
1.5	7.3	7.8								10	
3.0	6.8	7.7								11	
6.0	6.5	7.5								12	
9.0	5.85	7.0								13	
200.0	0.0	0.0								14	

Figure 11. Sample Coding Sheet Showing Format for a Two-Argument STINT TABLE

NCODE NAME	NCODE NO.	TYPICAL VALUE		RUN COMMENTS OR VARIABLE DESCRIPTION
TD	1	85.0		ORBIT SUNTIME DURATION (MINUTES)
DELTAT	2	5.0		TIME BETWEEN CALCULATIONS (MINUTES)
SIGISC	3	0.00014		ISC TEMP. COEF.(AMPS/DEG.C)
SIGVOC	4	0.0024		VOC TEMP. COEF.(VOLTS/DEG.C)
DI1	5	90.0		ISC DEGRADATION FACTOR (PERCENT)
DI2	6	100.0		ISC DEGRADATION FACTOR (PERCENT)
DI3	7	100.0		ISC DEGRADATION FACTOR (PERCENT)
DI4	8	100.0		ISC DEGRADATION FACTOR (PERCENT)
DV1	9	95.0		VPM DEGRADATION FACTOR (PERCENT)
DV2	10	100.0		VPM DEGRADATION FACTOR (PERCENT)
AVPMO	11	0.460		VPM OF UNDEGRADED CELL (VOLTS)
AIPMO	12	0.113		IPM OF UNDEGRADED CELL (AMPS)
AVOCO	13	0.577		VOC OF UNDEGRADED CELL (VOLTS)
THETA	14	95.0		VOC DEGRADATION FACTOR (PERCENT)
TNOT	15	30.0		SOLAR CELL REFERENCE TEMP. (DEG.C)
ADIODE	16	1.0		ARRAY BLOCKING DIODE DROP (VOLTS)
DELTT	17	10.0		TEMP. INCREMENT FOR STASH STORAGE (DEG.C)
ADDT	18	45.0		HIGHEST STASH TEMP. MINUS TNOT (DEG.C)
FLUX	19	-1.0		DENI 1-MEV ELECTRON FLUX (ELEC/SQ.CM.)
CG	20	6.0		COVER GLASS THICKNESS (MILS)
BS	21	15.0		BACKSHIELDING THICKNESS (MILS. OF ALUM.)
BOHMS	22	1.0		SOLAR CELL BASE RESISTIVITY (OHM-CM)
NDGRAD	23	1.0		INITIALIZE STASH (1.0 OR 0.0)
NEND	24	2.0		END OF RUNS KEY (1.0,2.0,3.0 OR 4.0)
	1 2 3	4 5 6 7 8 9 10 11 12 13	14 15 16	17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64

Figure 12. Format and Description of NCODES

calculating up to a maximum of 20 solar array I-V curves for each run. If the value of DELTAT is made larger than the value of TD (NCODE 1), only one solar array curve (at 0 minutes) will be computed.

c. SIGISC is the solar cell short circuit current temperature coefficient.

d. SIGVOC is the solar cell open-circuit voltage temperature coefficient and is punched on the card as a positive number; the program later gives it the proper negative sign.

e. DI 1 is the first short circuit current degradation factor; it usually refers to a standard cell error.

f. DI 2 is the second short circuit current degradation factor; it usually refers to a solar illumination intensity variation.

g. DI 3 is the third short circuit current degradation factor; it usually refers to ultraviolet degradation.

h. DI 4 is the fourth short circuit current degradation factor; it usually refers to a current measurement error.

i. DV 1 is the first maximum power point voltage degradation factor; it usually refers to an external series wiring loss.

j. DV 2 is the second maximum power point degradation factor; it usually refers to a thermal cycling degradation loss.

k. AVPMO is the maximum power point voltage of the input, undegraded solar cell.

l. AIPMO is the maximum power point current of the input, undegraded solar cell.

m. AVOCO is the open circuit voltage of the input, undegraded solar cell.

n. THETA is the open circuit voltage degradation factor; it usually refers to a voltage measurement error.

o. TNOT is the input solar cell reference temperature (Deg. C).

p. ADIODE is the array blocking diode voltage drop, specified by user. A value of 0.0 is punched if no blocking diode drop is desired in the output solar array curves.

q. DELTT is the temperature increment (Deg. C) between solar cell I-V curve calculations in STASH.

r. ADDT is the temperature increment (Deg. C) to be added to TNOT to determine the highest STASH temperature.

s. FLUX is punched as 0.0 if no charged particle irradiation damage is to be considered, in which case Subroutines PHI and DEGRAD do not compute. If FLUX has a value of 1-Mev equivalent flux (Example: 2.6×10^{14} is punched as 260000000000000.0 on the card) subroutine PHI is bypassed and subroutine DEGRAD will degrade the solar cell for the specified 1-Mev flux. If FLUX is given a value of -1.0, subroutine PHI will compute a value of 1-Mev flux from tables of omnidirectional particle fluxes that the user must supply in table locations 3, 4, 5, and 6. This computed 1-Mev flux will then be automatically sent to subroutine DEGRAD for the appropriate solar cell corrections.

t. CG is the solar cell coverglass thickness in mils of fused silica.

u. BS is the equivalent solar cell backshielding thickness in mils of aluminum.

v. BOHMS is the solar cell base resistivity (ohm-cm).

w. NDGRAD must be set to 1.0 in the first run. This causes the machine to automatically degrade the solar cell and expand it for temperature in subroutine STASH as specified by the degradation and temperature parameters in the NCODES. When chaining additional runs, if the solar cell degradations are not changed, NDGRAD should be set to 0.0 in the second run. By setting NDGRAD to 0.0, needless repetitive computations in the solar cell subroutines are eliminated.

x. NEND must be set to either 1.0, 2.0, 3.0, or 4.0 for each run, and determines which of the following options is selected:

NEND = 1.0 Do solar cell calculations only (PHI, DEGRAD and STASH) and stop.

NEND = 2.0 Do solar cell calculations and read new set of run instructions.

NEND = 3.0 Do solar cell and solar array calculations and stop.

NEND = 4.0 Do solar cell and solar array calculations and read new set of run instructions.

If no solar array calculations are to be made (NEND = 1.0 or 2.0), a blank card must follow NCODE 24. This tells the computer to stop reading in data and to start computing. If no additional (chained) run is to be made, this blank card is the last card in the data deck.

Array Signal Card

If NCODE 24 has been punched with a 3.0 or a 4.0, immediately following the NCODE 24 card must be a card containing 999 in columns 1-3. This card tells the computer that solar array information is to follow.

NPANEL Card

Following the Array Signal Card is the NPANEL card, which contains the number (NPANEL) of solar panels in the array (maximum number of panels is 25). This number must appear right-justified in columns 1-3; no decimal point is required.

Panel Description Cards

Following the NPANEL card is a panel description card for each solar panel in the array, up to a maximum of 25 panels. The number of these panel description cards must agree with the value of NPANEL. Each card contains four fields of ten columns each, in floating point format (requires decimal point).

Columns	Variable	Typical Value
1-10	No. of Series Solar Cells per String	100.0
11-20	No. of Parallel Strings per Panel	10.0
21-30	Panel Incidence Angle vs. Time Table Location in STINT	11.0
31-40	Panel Temperature vs. Time Table Location in STINT	12.0

Following the Panel Description Cards is a blank card. This tells the computer to stop reading in data and to start computing. If it is desired to chain an additional run, a new Run Label Card and only those NCODES and Panel Description Cards that contain changed or new information should be placed after the blank card. As many runs as are desired can be chained in this manner, ensuring that each new run starts with a Run Label Card and ends with a blank card. Refer again to Figure 9 for the proper sequence of card positions for chained runs.

IV. PROGRAM OUTPUT

The information that the computer prints out after a run consists of the following items:

1. Stint Table Listing Option: There is an option in the program to list all the STINT tables. This is done by taking the date card at the beginning of the data package and either punching a one (1) or a zero (0) in column 9. Punching a one (1) will produce a listing of the STINT tables. A zero (0) will not produce a listing of the STINT tables.

2. Input Data Page:

   a. Run number and date

   b. Run comments (as specified on input cards)

   c. Listing of NCODE numbers, names and values

   d. Solar array description: panel number, number of series solar cells, number of parallel solar cell strings, number of STINT table which contains the solar illumination incidence angle, number of STINT table which contains the array temperature-time profile

3. Subroutine PHI:

   a. The computed electron flux

   b. The computed proton flux

   c. The computed solar flare proton flux

   d. The computed solar flare alpha particle flux

   e. The computed total flux

   The fluxes are in equivalent 1-Mev electrons/cm^2

4. Subroutine DEGRAD

   a. The solar cell I-V curve (irradiation degraded)

   b. Short circuit current

c. Current at the maximum power point

d. Voltage at the maximum power point

e. Open circuit voltage

5. Subroutine STASH: Values of temperature for which the degraded solar cell I-V curve has been prepared are listed in a row across the page. Values of maximum-power voltage and current, open circuit voltage and short-circuit current appear in columns under each temperature. Values of every other calculated current and voltage pair comprising the I-V curve and stored in the computer memory, are listed in columns under each temperature (in 20 mv increments).

6. Solar Array Data:

a. Value of blocking diode voltage drop.

b. Time in orbit sunlight (up to 20 time increments starting with 0.0 min.).

c. Solar array voltage in one-volt steps from 0 volts to open-circuit voltage.

d. Total solar array current at each voltage above for each time increment; a maximum of 20 solar array I-V curves can be produced per computer run.

V. SUMMARY

A computer program has been described which accounts for all factors that affect the power output of a solar cell. Charged particle irradiation degradation, external series resistance, illumination intensity variation and temperature effects are taken into account. Using the fully degraded solar cell characteristic as a basis, the program will determine the total I-V curve of solar arrays consisting of up to 25 separate panels. Each panel may have its own series-parallel solar cell arrangement, temperature versus time profile and solar incidence angle versus time profile.

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GLOSSARY

- DELI - decrease in short circuit current caused by current degradation factors; used in STASH.
- DELV - decrease in open circuit voltage caused by the voltage degradation factor; used in STASH.
- Ii - any particular current value of input I-V curve.
- ISCO - initial, undegraded value of short curcuit current.
- I_1 - radiation degraded value of short circuit current; used in STASH.
- I_2 - degraded value of short circuit current; used in STASH.
- KD - arbitrary damage factor

- KDA - alpha particle damage factor; used in PHI.
- KDE - electron damage factor; used in PHI.
- KDP - proton damage factor; used in PHI.
- Ne - number of electrons in a given energy range; used in PHI.
- $N_{f\alpha}$ - number of solar-flare alpha particles in a given energy range; used in PHI.
- N_{fp} - number of solar-flare protons in a given energy range; used in PHI.
- Np - number of protons in a given energy range; used in PHI.
- PZCD - degraded point of zero current; a temporary parameter used in DEGRAD.
- PZCU - undegraded point of zero current; the initial value of open-circuit voltage used in DEGRAD.
- RI - relative short circuit current degradation factor; used in DEGRAD.
- RR - radiation resistance, defined as VISC/ISCO; used in DEGRAD.
- RV - relative open circuit voltage degradation factor; used in DEGRAD.
- Vi - any particular voltage point on input I-V curve.
- VISC - volts at short circuit current; used in DEGRAD.
- VOCR - degraded value of open circuit voltage; used in DEGRAD.
- VOC - degraded value of open circuit voltage; used in STASH.
- V_{pmo} - initial value of maximum power point voltage; used in STASH.
- V_{pmr} - the degraded value of maximum power point voltage; used in STASH.
- V_1 - radiation degraded value of open circuit voltage; used in STASH.
- V_2 - degraded value of open circuit voltage; used in STASH.

- ΔI - decrease in short circuit current caused by the equivalent flux, defined as ISCO-ISCR; used in DEGRAD.
- φ_e - electron 1-Mev equivalent flux.
- φ_f - solar-flare alpha particle 1-Mev equivalent flux.
- φ_{fp} - solar-flare proton 1-Mev equivalent flux.
- φ_p - proton 1-Mev equivalent flux.
- φ_T - total 1-Mev equivalent flux.

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Appendix A

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C**** SOLAR ARRAY SYNTHESIS PROGRAM DEVELOPED FOR NASA (GSFC) BY RCA-AED01 00010
C****          PROGRAMMERS R.RASMUSSEN, P.J.HYLAND, JUNE 1968          01 00020
      DIMENSION NDATE(3)                                               01 00030
      DIMENSION T(20)                                                  01 00040
      DIMENSION XIA(20,100)                                            01 00050
      DIMENSION XC(25),XS(25),NANGLE(25),NTEMPS(25)                    01 00060
C**** READ DATE                                                        01 00070
      IA=5                                                             01 00080
      IB=6                                                             01 00090
      READ  (IA,7000)NDATE(1),NDATE(2),NDATE(3),NLIST                  01 00100
      CALL SLITE (0)                                                   01 00110
      NRUN=1                                                           01 00120
      DO 6001 I=1,25                                                   01 00130
      XC(I)=0.0                                                        01 00140
      XS(I)=0.0                                                        01 00150
      NANGLE(I)=0                                                      01 00160
 6001 NTEMPS(I)=0                                                      01 00170
      TD=0.0                                                           01 00180
      DELTAT=1000.0                                                    01 00190
      SIGISC=0.0                                                       01 00200
      SIGVOC=0.0                                                       01 00210
      DI1=100.0                                                        01 00220
      DI2=100.0                                                        01 00230
      DI3=100.0                                                        01 00240
      DI4=100.0                                                        01 00250
      DV1=100.0                                                        01 00260
      DV2=100.0                                                        01 00270
      AVPMO=0.0                                                        01 00280
      AIPMO=0.0                                                        01 00290
      AVOCO=0.0                                                        01 00300
      THETA=100.0                                                      01 00310
      TNOT=0.0                                                         01 00320
      ADIODE=0.0                                                       01 00330
      DELTT=0.0                                                        01 00340
      ADDT=0.0                                                         01 00350
      FLUX=0.0                                                         01 00360
      CG=0.0                                                           01 00370
      BS=0.0                                                           01 00380
      BOHMS=0.0                                                        01 00390
      NDGRAD=0                                                         01 00400
      NEND=0                                                           01 00410
      NCELLT=1                                                         01 00420
      NKOST=2                                                          01 00430
      NELECT=3                                                         01 00440
      NPROTT=4                                                         01 00450
      NFLARE=5                                                         01 00460
      NALPHA=6                                                         01 00470
      NKDE=7                                                           01 00480
      NKDP=8                                                           01 00490
      NKDA=9                                                           01 00500
      NMVTBL=10                                                        01 00510
      NKDFL=8                                                          01 00520
      KEY=NLIST-1                                                      01 00530
C**** READ TABLES COMMENT CARD                                         01 00540
  100 READ  (IA,7001)                                                  01 00550
C**** LOAD STINT TABLES                                                01 00560
      CALL STINT (0.0,0.0,0.0,0.0,KEY,NGRIPE,0,0)                      01 00570
      IF (NGRIPE) 101,101,102                                          01 00580
  102 WRITE (IB,7001)                                                  01 00590
      WRITE (IB,7002)                                                  01 00600
      PRINT 7002                                                       01 00610
      CALL EXIT                                                        01 00620
C**** READ RUN COMMENTS CARD                                           01 00630
  101 READ  (IA,7003)                                                  01 00640
C**** PRINT HEADER CARD                                                01 00650
      WRITE (IB,7004)NRUN,(NDATE(J),J=1,3)                             01 00660
```

```
      WRITE (IB,7001)                                                   01 00670
      WRITE (IB,7005)                                                   01 00680
      WRITE (IB,7003)                                                   01 00690
      WRITE (IB,7006)                                                   01 00700
C**** READ INPUT DATA,NCODES                                            01 00710
  103 READ  (IA,7007)NCODE,PARAM                                        01 00720
      IF (NCODE-999) 1103,106,1103                                      01 00730
 1103 IF (NCODE) 105,105,5000                                           01 00740
  106 READ  (IA,7007)NPANEL                                             01 00750
      DO 6000 K=1,NPANEL                                                01 00760
      READ  (IA,6600)P1,P2,P3,P4                                        01 00770
 6600 FORMAT(10F10.5)                                                   01 00780
      XC(K)=P1                                                          01 00790
      XS(K)=P2                                                          01 00800
      NANGLE(K)=P3+.01                                                  01 00810
      NTEMPS(K)=P4+.01                                                  01 00820
 6000 WRITE (IB,6601)K,XC(K),XS(K),NANGLE(K),NTEMPS(K)                  01 00830
 6601 FORMAT (7H0PANEL  I3/ 16H SERIES CELLS = F5.1,20H PARALLEL STRINGS01 00840
     1 = F6.2,15H ANGLE TABLE = I2,14H TEMP TABLE = I2)                 01 00850
      WRITE (IB,6602)                                                   01 00860
 6602 FORMAT (1H0)                                                      01 00870
      GO TO 103                                                         01 00880
 5000 GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,        01 00890
     121,22,23,24,25),NCODE                                             01 00900
    1 TD=PARAM                                                          01 00910
      WRITE (IB,201)NCODE,TD                                            01 00920
      GO TO 103                                                         01 00930
    2 DELTAT=PARAM                                                      01 00940
      WRITE (IB,202)NCODE,DELTAT                                        01 00950
      GO TO 103                                                         01 00960
    3 SIGISC=PARAM                                                      01 00970
      WRITE (IB,203)NCODE,SIGISC                                        01 00980
      GO TO 103                                                         01 00990
    4 SIGVOC=PARAM                                                      01 01000
      WRITE (IB,204)NCODE,SIGVOC                                        01 01010
      GO TO 103                                                         01 01020
    5 DI1=PARAM                                                         01 01030
      WRITE (IB,205)NCODE,DI1                                           01 01040
      GO TO 103                                                         01 01050
    6 DI2=PARAM                                                         01 01060
      WRITE (IB,206)NCODE,DI2                                           01 01070
      GO TO 103                                                         01 01080
    7 DI3=PARAM                                                         01 01090
      WRITE (IB,207)NCODE,DI3                                           01 01100
      GO TO 103                                                         01 01110
    8 DI4=PARAM                                                         01 01120
      WRITE (IB,208)NCODE,DI4                                           01 01130
      GO TO 103                                                         01 01140
    9 DV1=PARAM                                                         01 01150
      WRITE (IB,209)NCODE,DV1                                           01 01160
      GO TO 103                                                         01 01170
   10 DV2=PARAM                                                         01 01180
      WRITE (IB,210)NCODE,DV2                                           01 01190
      GO TO 103                                                         01 01200
   11 AVPMO=PARAM                                                       01 01210
      WRITE (IB,211)NCODE,AVPMO                                         01 01220
      GO TO 103                                                         01 01230
   12 AIPMO=PARAM                                                       01 01240
      WRITE (IB,212)NCODE,AIPMO                                         01 01250
      GO TO 103                                                         01 01260
   13 AVOCO=PARAM                                                       01 01270
      WRITE (IB,213)NCODE,AVOCO                                         01 01280
      VOCOI=AVOCO                                                       01 01290
      GO TO 103                                                         01 01300
   14 THETA=PARAM                                                       01 01310
      WRITE (IB,214)NCODE,THETA                                         01 01320
```

```
      THETA=THETA/100.0                                                 01 01330
      GO TO 103                                                         01 01340
   15 TNOT=PARAM                                                        01 01350
      WRITE (IB,215)NCODE,TNOT                                          01 01360
      GO TO 103                                                         01 01370
   16 ADIODE=PARAM                                                      01 01380
      WRITE (IB,216)NCODE,ADIODE                                        01 01390
      GO TO 103                                                         01 01400
   17 DELTT=PARAM                                                       01 01410
      WRITE (IB,217)NCODE,DELTT                                         01 01420
      GO TO 103                                                         01 01430
   18 ADDT=PARAM                                                        01 01440
      WRITE (IB,218)NCODE,ADDT                                          01 01450
      GO TO 103                                                         01 01460
   19 FLUX=PARAM                                                        01 01470
      WRITE (IB,219)NCODE,FLUX                                          01 01480
      GO TO 103                                                         01 01490
   20 CG=PARAM                                                          01 01500
      WRITE (IB,220)NCODE,CG                                            01 01510
      GO TO 103                                                         01 01520
   21 BS=PARAM                                                          01 01530
      WRITE (IB,221)NCODE,BS                                            01 01540
      GO TO 103                                                         01 01550
   22 BOHMS=PARAM                                                       01 01560
      WRITE (IB,222)NCODE,BOHMS                                         01 01570
      GO TO 103                                                         01 01580
   23 NDGRAD=PARAM+.01                                                  01 01590
      WRITE (IB,223)NCODE,NDGRAD                                        01 01600
      GO TO 103                                                         01 01610
   24 NEND=PARAM+.01                                                    01 01620
      WRITE (IB,224)NCODE,NEND                                          01 01630
      GO TO 103                                                         01 01640
   25 CONTINUE                                                          01 01650
      GO TO 103                                                         01 01660
C**** END DATA LOADER                                                   01 01670
C**** HOUSEKEEPING FOLLOWS                                              01 01680
  105  IF (NDGRAD) 70,501,70                                            01 01690
   70 DISC=(DI1/100.)*(DI2/100.)*(DI3/100.)*(DI4/100.)                  01 01700
      DV  =(DV1/100.)*(DV2/100.)                                        01 01710
      IF(BOHMS-5.0)81,81,82                                             01 01720
   81 DENFAC=0.065                                                      01 01730
      GO TO 83                                                          01 01740
   82 DENFAC=0.0                                                        01 01750
   83 PHITOT=FLUX                                                       01 01760
      IF(FLUX)71,73,72                                                  01 01770
   71 CALL PHI (CG,BS,NKDE,NKDP,NKDFL,NELECT,NPROTT,NFLARE,             01 01780
     1NALPHA,NKDA,PHITOT)                                               01 01790
      FLUX=PHITOT                                                       01 01800
   72 CALL DEGRAD (PHITOT,BOHMS,NCELLT,NMVTBL)                          01 01810
      CALL SLITE (1)                                                    01 01820
C**** INITIAL ENTRY INTO SUBROUTINE STASH,INITIALIZATION                01 01830
   73 CALL STASH (DISC,THETA,AVPMO,AIPMO,TNOT,-1,NGRIPE,NCELLT,VOCOI,   01 01840
     1ADDT,DELTT)                                                       01 01850
C
C**** SECOND ENTRY INTO SUBROUTINE STASH,INITIALIZATION                 01 01860
      CALL STASH (DV,DISC,SIGISC,SIGVOC,TNOT,0,NGRIPE,NCELLT,DENFAC,ADDT01 01870
     1,DELTT)                                                           01 01880
      IF(NGRIPE)74,76,74                                                01 01890
   74 WRITE (IB,7009)                                                   01 01900
      CALL EXIT                                                         01 01910
   76 GO TO (80,30,501,501),NEND                                        01 01920
   30 NRUN=NRUN+1                                                       01 01930
      GO TO 101                                                         01 01940
   80 CONTINUE                                                          01 01950
      CALL EXIT                                                         01 01960
```

```
  201 FORMAT (I7,50H TD,ORBIT SUNTIME DURATION (MINUTES)                01 01970
     1F12.4)                                                            01 01980
  202 FORMAT (I7,50H DELTAT,TIME BETWEEN CALCULATIONS (MINUTES)         01 01990
     1F12.4)                                                            01 02000
  203 FORMAT (I7,50H SIGISC,ISC TEMP. COEF.(AMPS/DEG.C)                 01 02010
     1F12.6)                                                            01 02020
  204 FORMAT (I7,50H SIGVOC,VOC TEMP. COEF.(VOLTS/DEG.C)                01 02030
     1F12.6)                                                            01 02040
  205 FORMAT (I7,50H DI1,ISC DEGRADATION FACTOR (PERCENT)               01 02050
     1F12.4)                                                            01 02060
  206 FORMAT (I7,50H DI2,ISC DEGRADATION FACTOR (PERCENT)               01 02070
     1F12.4)                                                            01 02080
  207 FORMAT (I7,50H DI3,ISC DEGRADATION FACTOR (PERCENT)               01 02090
     1F12.4)                                                            01 02100
  208 FORMAT (I7,50H DI4,ISC DEGRADATION FACTOR (PERCENT)               01 02110
     1F12.4)                                                            01 02120
  209 FORMAT (I7,50H DV1,VPM DEGRADATION FACTOR (PERCENT)               01 02130
     1F12.4)                                                            01 02140
  210 FORMAT (I7,50H DV2,VPM DEGRADATION FACTOR (PERCENT)               01 02150
     1F12.4)                                                            01 02160
  211 FORMAT (I7,50H AVPMO,VPM OF UNDEGRADED CELL (VOLTS)               01 02170
     1F12.4)                                                            01 02180
  212 FORMAT (I7,50H AIPMO,IPM OF UNDEGRADED CELL (VOLTS)               01 02190
     1F12.4)                                                            01 02200
  213 FORMAT (I7,50H AVOCO,VOC OF UNDEGRADED CELL (VOLTS)               01 02210
     1F12.4)                                                            01 02220
  214 FORMAT (I7,50H THETA,VOC DEGRADATION FACTOR (PERCENT)             01 02230
     1F12.4)                                                            01 02240
  215 FORMAT (I7,50H TNOT,SOLAR CELL REFERENCE TEMP.(DEG.C)             01 02250
     1F12.4)                                                            01 02260
  216 FORMAT (I7,50H ADIODE,ARRAY BLOCKING DIODE DROP (VOLTS)           01 02270
     1F12.4)                                                            01 02280
  217 FORMAT (I7,50H DELTT, TEMP. INCREMENT FOR STASH STORAGE (DEG.C)   01 02290
     1F12.4)                                                            01 02300
  218 FORMAT (I7,50H ADDT, HIGHEST STASH TEMP. MINUS TNOT (DEG.C)       01 02310
     1F12.4)                                                            01 02320
  219 FORMAT (I7,50H FLUX,DENI 1-MEV ELECTRON FLUX (ELEC/SQ.CM.)        01 02330
     1E12.4)                                                            01 02340
  220 FORMAT (I7,50H CG,COVER GLASS THICKNESS (MILS)                    01 02350
     1F12.4)                                                            01 02360
  221 FORMAT (I7,50H BS,BACKSHIELDING THICKNESS (MILS. OF ALUM.)        01 02370
     1F12.4)                                                            01 02380
  222 FORMAT (I7,50H BOHMS,SOLAR CELL BASE RESISTIVITY (OHM-CM)         01 02390
     1F12.4)                                                            01 02400
  223 FORMAT (I7,50H NDGRAD,INITIALIZE STASH (1.0 OR 0.0)               01 02410
     1I8)                                                               01 02420
  224 FORMAT (I7,50H NEND,END OF RUNS KEY (1.0,2.0,3.0 OR 4.0)          01 02430
     1I8)                                                               01 02440
  225 FORMAT (I7,50H NLIST,STINT TABLE LISTING OPTION (1.0 OR 0.0)      01 02450
     1I8)                                                               01 02460
C**** FORMATS                                                           01 02470
 7000 FORMAT (3I2,2X,I1)                                                01 02480
 7001 FORMAT (72H                                                       01 02490
     1                )                                                 01 02500
 7002 FORMAT (34H  UNABLE TO READ TABLES, ABORT RUN)                    01 02510
 7003 FORMAT (72H                                                       01 02520
     1                )                                                 01 02530
 7004 FORMAT (12H1    RUN NO.I3,18H  ON THIS DATE OF I2,1H-I2,1H-I2,75H 01 02540
     1            SOLAR ARRAY SYNTHESIS PROGRAM                         01 02550
     2        /20H0    TABLE COMMENTS.)                                 01 02560
 7005 FORMAT (18H0    RUN COMMENTS.)                                    01 02570
 7006 FORMAT (30H0    NEW OR CHANGED PARAMETERS/1H0)                    01 02580
 7007 FORMAT (I3,1X,F20.0)                                              01 02590
 7008 FORMAT (35H0   ERROR IN TABLE LOOKUP, NGRIPE =I1)                 01 02600
 7009 FORMAT (25H STASH DID NOT INITIALIZE)                             01 02610
C**** START SOLAR ARRAY COMPUTATIONS                                    01 02620
```

```
  501 DO 503 INCR=1,20
      DO 503 JVOLT=1,100
      XIA(INCR,JVOLT) = 0.0
  503 CONTINUE
      T(1) = 0.0
      INCR = 1
      GO TO 599
  502 T(INCR+1) = T(INCR) + DELTAT
      IF (TD - T(INCR+1)) 700,505,505
  505 INCR = INCR + 1
      IF (20 - INCR) 700,599,599
C**** K IS PANEL NUMBER                                                 01 02740
  599 K=1                                                               01 02750
  600 CALL STINT (T(INCR),0.0,0.0,PANANG,1,NGRIPE,NANGLE(K),NANGLE(K))  01 02760
      IF (NGRIPE)690,601,690                                            01 02770
  690 NGRIPE=1                                                          01 02780
      GO TO 1000                                                        01 02790
  601 CALL STINT (T(INCR),0.0,0.0,PTEMP,1,NGRIPE,NTEMPS(K),NTEMPS(K))   01 02800
      IF (NGRIPE)691,602,691                                            01 02810
  691 NGRIPE=2                                                          01 02820
      GO TO 1000                                                        01 02830
  602 CALL STINT(PANANG,0.0,0.0,EFFECT,1,NGRIPE,2,2)                    01 02840
      IF (NGRIPE)692,603,692                                            01 02850
  692 NGRIPE=3                                                          01 02860
      GO TO 1000                                                        01 02870
  603 JVOLT=1                                                           01 02880
      IF (EFFECT) 607,607,604                                           01 02890
  604 AVOLT=FLOAT (JVOLT)-1.0+ADIODE                                    01 02900
      ARG1=AVOLT/XC(K)                                                  01 02910
      IF(JVOLT-1)610,610,611                                            01 02920
C**** GET VALUE OF FULL INTENSITY ISC FROM STASH                        01 02930
  610 CALL STASH(TLU,0.0,0.0,PTEMP,0.0,1,0.0,0.0,0.0,0.0,DELTT)         01 02940
      DELI=TLU*(1.0-EFFECT)                                             01 02950
      PHIL=1.0/EFFECT                                                   01 02960
      DELVOC=(0.026*(273.0+PTEMP)/300.0)*ALOG  (PHIL)                   01 02970
C**** GET VALUE OF FULL INTENSITY VOC FROM STASH                        01 02980
      CALL STASH(OCV,0.0,0.0,PTEMP,0.0,989,0.0,0.0,0.0,0.0,DELTT)       01 02990
C**** GET VALUE OF VOLTAGE AT CURRENT DELI FROM STASH                   01 03000
      CALL STASH(VAI,0.0,DELI,PTEMP,0.0,988,0.0,0.0,0.0,0.0,DELTT)      01 03010
      DELTAV=OCV-VAI-DELVOC                                             01 03020
  611 IF(ARG1-DELTAV)606,605,605                                        01 03030
  605 ARG1=ARG1-DELTAV                                                  01 03040
  606 CALL STASH(CELLI,0.0,ARG1,PTEMP,0.0,1,0.0,0.0,0.0,0.0,DELTT)      01 03050
      PANELI=XS(K)*(CELLI-DELI)                                         01 03060
      IF(PANELI)607,607,609                                             01 03070
  607 PANELI=0.0                                                        01 03080
  608 K=K+1                                                             01 03090
      IF(NPANEL-K)502,600,600                                           01 03100
  609 XIA(INCR,JVOLT)=XIA(INCR,JVOLT)+PANELI                            01 03110
      JVOLT=JVOLT+1                                                     01 03120
      IF(100-JVOLT)608,604,604                                          01 03130
 1000 WRITE (IB,7008)NGRIPE                                             01 03140
      CALL EXIT                                                         01 03150
  700 WRITE (IB,9000)ADIODE                                             01 03160
      T(INCR+1)=0.0                                                     01 03170
      IBEG=1                                                            01 03180
      IEND=10                                                           01 03190
      DO 400 K=1,2                                                      01 03200
      AVOLT=0.0                                                         01 03210
      WRITE (IB,9001)(T(INCR),INCR=IBEG,IEND)                           01 03220
  401 DO 410 J=1,100                                                    01 03230
      WRITE (IB,9002)AVOLT,(XIA(INCR,J),INCR=IBEG,IEND)                 01 03240
      AVOLT=AVOLT+1.0                                                   01 03250
  402 DO 420 L=IBEG,IEND                                                01 03260
      IF (XIA(L,J)-0.0)410,420,410                                      01 03270
  420 CONTINUE                                                          01 03280
```

```
      GO TO 430                                                         01 03290
  410 CONTINUE                                                          01 03300
  430 IBEG=11                                                           01 03310
      IEND=20                                                           01 03320
      WRITE (IB,9003)                                                   01 03330
  400 CONTINUE                                                          01 03340
      NRUN=NRUN+1                                                       01 03350
      GO TO (80,80,80,101),NEND                                         01 03360
 9000 FORMAT (60H1                          SOLAR ARRAY I-V CURVES WI01 03370
     1TH  (F4.2,28H) VOLTS BLOCKING DIODE DROP    )                     01 03380
 9001 FORMAT (/17H TIME IN SUNLIGHT/11H  (MINUTES)10F10.2,//51X,16HCURRE01 03390
     1NT(AMPERES)/2X,5HVOLTS)                                           01 03400
 9002 FORMAT (F5.1,6X,10F10.2)                                          01 03410
 9003 FORMAT (1H1)                                                      01 03420
      END                                                               01 03430
      SUBROUTINE STINT (ARG1,ARG2,ARG3,FCT,KEY,NGRIPE,MINTBL,MAXTBL)    02 00020
      DIMENSION NUMPTS(61),L1(60),L2(60),L3(60),STG(3600),DUMMY(10)     02 00030
      DIMENSION NAME (14)                                               02 00040
      EQUIVALENCE (NAT,L3(1))                                           02 00050
C**** SIZE OF STG IS CALCULATED BY SUM OF ((1+N(ARG1))*(1+N(ARG2)))     02 00060
      IA=5                                                              02 00070
      IB=6                                                              02 00080
      NGRIPE=0                                                          02 00090
      IF (KEY) 1,1,70                                                   02 00100
  646 FORMAT(1X,10E11.4,I2)                                             02 00110
    1 NG=1                                                              02 00120
      NORMAL=1                                                          02 00130
      WRITE (IB,1357)                                                   02 00140
 1357 FORMAT (34H0  TABLE        DATE        CONTENTS)                  02 00150
      GO TO 55                                                          02 00160
 2000 NG=2                                                              02 00170
      NORMAL=2                                                          02 00180
      WRITE (IB,1257)                                                   02 00190
 1257 FORMAT (1H1)                                                      02 00200
 3000 RETURN                                                            02 00210
  775 NGRIPE=1                                                          02 00220
      RETURN                                                            02 00230
  776 NGRIPE=2                                                          02 00240
      WRITE (IB,9000)ARG1,ARG2,ARG3,MINTBL,MAXTBL                       02 00250
      RETURN                                                            02 00260
 9000 FORMAT (20H0 ERROR IN TLU,ARG1=E12.5,6H ARG2=E12.5,6H ARG3=E12.5, 02 00270
     18H MINTBL=I4,8H MAXTBL=I4)                                        02 00280
C     BEGINNING OF STINT                                                02 00290
   55 NUMTBL=1                                                          02 00300
      NUMPTS(1)=0                                                       02 00310
  102 READ  (IA,57)DA1,DA2,DA3,K,L1(NUMTBL),L2(NUMTBL),NAME,   ISEQ     02 00320
   57 FORMAT (A2,A3,A3,I4,2I2,13A4,A2,I2)                               02 00330
      WRITE (IB,1157)K,DA1,DA2,DA3,NAME                                 02 00340
 1157 FORMAT (/I8,5X,A2,A3,A3,5X,13A4,A2)                               02 00350
  104 IF(ISEQ) 69,58,69                                                 02 00360
   58 IF (K)  99,99,1159                                                02 00370
 1159 IF (K-60) 59,59,1103                                              02 00380
   59 L8=L1(NUMTBL)                                                     02 00390
      N1=(L8-1)/9+1                                                     02 00400
      DO 68 IS=1,N1                                                     02 00410
      NAT=(IS-1)*9+1                                                    02 00420
      IF (IS-N1) 60,61,60                                               02 00430
   60 L4=NAT+8                                                          02 00440
      GO TO 62                                                          02 00450
   61 L4=L8                                                             02 00460
   62 L5=NUMPTS(NUMTBL)+1                                               02 00470
      L6=L5+NAT                                                         02 00480
      L7=L5+L4                                                          02 00490
      JJ=0                                                              02 00500
      L9=L2(NUMTBL)                                                     02 00510
      LM=L5+L8                                                          02 00520
```

```
      LN=LM+L9                                                          02 00530
  105 READ  (IA,64)(DUMMY(K),K=1,10),ISEQ                               02 00540
   64 FORMAT (10E7.0,I2)                                                02 00550
      IF (KEY) 107,11,11                                                02 00560
   11 WRITE (IB,646)(DUMMY(K),K=1,10),ISEQ                              02 00570
  107 STG(L5)=DUMMY(1)                                                  02 00580
      K=2                                                               02 00590
      DO 65 J=L6,L7                                                     02 00600
      STG(J)=DUMMY(K)                                                   02 00610
   65 K=K+1                                                             02 00620
      IF (ISEQ-((IS-1)*(L9+1)+JJ+1)) 69,66,69                           02 00630
   66 L6=LN+NAT                                                         02 00640
      L7=LN+L4                                                          02 00650
      L5=LM+1+JJ                                                        02 00660
      IF (JJ-L9) 67,68,69                                               02 00670
   67 JJ=JJ+1                                                           02 00680
      LN=LN+L8                                                          02 00690
      GO TO 105                                                         02 00700
   68 CONTINUE                                                          02 00710
  109 LEE=NUMPTS(NUMTBL)+(L8+1)*(L9+1)                                  02 00720
      IF (LEE-3600) 1100,1100,1101                                      02 00730
 1100 IF (NUMTBL-60) 1102,108,1103                                      02 00740
 1102 NUMPTS(NUMTBL+1)=LEE                                              02 00750
  108 NUMTBL=NUMTBL+1                                                   02 00760
      GO TO 102                                                         02 00770
 1101 WRITE (IB,1111)LEE                                                02 00780
      GO TO 775                                                         02 00790
 1103 WRITE (IB,1113)NUMTBL                                             02 00800
      GO TO 775                                                         02 00810
 1111 FORMAT (17H TOO MANY POINTS  I8)                                  02 00820
 1113 FORMAT (17H TOO MANY TABLES  I8)                                  02 00830
   69 GO TO (775,776,776),NG                                            02 00840
   70 IF (MINTBL-MAXTBL) 71,100,69                                      02 00850
   71 DO 73 NAT=MINTBL,MAXTBL                                           02 00860
      L4=NUMPTS(NAT)+1                                                  02 00870
      IF (ARG3-STG(L4)) 72,74,73                                        02 00880
   72 IF(NAT-MINTBL)69,69,75                                            02 00890
   73 CONTINUE                                                          02 00900
      GO TO 69                                                          02 00910
   75 L5=1                                                              02 00920
      L6=2                                                              02 00930
      L7=L4                                                             02 00940
  101 DO 97 L8=L5,L6                                                    02 00950
      L4=NUMPTS(NAT)+1                                                  02 00960
      L9=L1(NAT)                                                        02 00970
      LM=L9+L4                                                          02 00980
      DO 77 LN=1,L9                                                     02 00990
      JJ=L4+LN                                                          02 01000
 2626 IF (ARG1-STG(JJ)) 76,78,77                                        02 01010
   76 IF (LN-1) 69,69,79                                                02 01020
   77 CONTINUE                                                          02 01030
      GO TO 69                                                          02 01040
   78 N1=-1                                                             02 01050
      GO TO 80                                                          02 01060
   79 N1=+1                                                             02 01070
   80 K=L2(NAT)                                                         02 01080
      DO 82 I=1,K                                                       02 01090
      IDATE=LM+I                                                        02 01100
      IF (ARG2-STG(IDATE)) 81,83,82                                     02 01110
   81 IF (I-1) 69,69,84                                                 02 01120
   82 CONTINUE                                                          02 01130
      GO TO 69                                                          02 01140
   83 IS=-1                                                             02 01150
      GO TO 85                                                          02 01160
   84 IS=+1                                                             02 01170
   85 ISEQ=LM+L2(NAT)+LN+(I-1)*L9                                       02 01180
```

```
      J=ISEQ-L9                                                         02 01190
      K8=LM+(I-1)                                                       02 01200
      K9=L4+LN-1                                                        02 01210
      IF (N1+IS) 86,88,91                                               02 01220
   86 IF (STG(ISEQ)-999.E20) 87,69,69                                   02 01230
   87 FCT=STG(ISEQ)                                                     02 01240
      GO TO 95                                                          02 01250
   88 IF (N1) 89,69,93                                                  02 01260
   89 IF (AMAX1 (STG(ISEQ),STG(J))-999.E20) 90,69,69                    02 01270
   90 FCT=STG(ISEQ)-(STG(IDATE)-ARG2)*(STG(ISEQ)-STG(J))/(STG(IDATE)    02 01280
     1-STG(K8))                                                         02 01290
      GO TO 95                                                          02 01300
   91 IF (AMAX1 (STG(ISEQ),STG(J),STG(ISEQ-1),STG(J-1))-999.E20) 92,    02 01310
     1 69,69                                                            02 01320
   92 FCT=((STG(IDATE)-ARG2)*((STG(JJ)-ARG1)*STG(J-1)-(STG(K9)-ARG1)    02 01330
     1*STG(J))-(STG(K8)-ARG2)*((STG(JJ)-ARG1)*STG(ISEQ-1)-(STG(K9)-     02 01340
     2ARG1)*STG(ISEQ)))/((STG(IDATE)-STG(K8))*(STG(JJ)-STG(K9)))        02 01350
      GO TO 95                                                          02 01360
   93 IF (AMAX1 (STG(ISEQ),STG(ISEQ-1))-999.E20) 94,69,69               02 01370
   94 FCT=STG(ISEQ)-(STG(JJ)-ARG1)*(STG(ISEQ)-STG(ISEQ-1))/(STG(JJ)-    02 01380
     1STG(K9))                                                          02 01390
   95 GO TO (96,98,99),L8                                               02 01400
   96 DUMMY(1)=FCT                                                      02 01410
   97 NAT=NAT-1                                                         02 01420
   98 FCT=DUMMY(1)-(STG(L7)-ARG3)*(DUMMY(1)-FCT)/(STG(L7)-STG(L4))      02 01430
   99 GO TO (2000,3000),NORMAL                                          02 01440
  100 NAT=MINTBL                                                        02 01450
   74 L5=3                                                              02 01460
      L6=3                                                              02 01470
      GO TO 101                                                         02 01480
C     END STINT  TABLE LOOK-UP                                          02 01490
      END                                                               02 01500

      SUBROUTINE PHI (CG,BS,NKDE,NKDP,NKDFL,NELECT,NPROTT,NFLARE,       03 00020
     1NALPHA,NKDA,PHITOT)                                               03 00030
      IA=5                                                              03 00040
      IB=6                                                              03 00050
      GLASS=CG/6.0                                                      03 00060
      SCBACK=BS/5.0                                                     03 00070
      PHIELE = 0.0                                                      03 00080
      PHIPRO = 0.0                                                      03 00090
      PHIFLR = 0.0                                                      03 00100
      PHIALP = 0.0                                                      03 00110
      PHITOT = 0.0                                                      03 00120
C**** COMPUTE ELECTRON FLUX                                             03 00130
      DO 1 I = 1,11                                                     03 00140
      DUM = FLOAT (I)                                                   03 00150
      CALL STINT (DUM,GLASS,0.0,XKDE,1,NGRIPE,NKDE,NKDE)                03 00160
      CALL STINT (DUM,SCBACK,0.0,YKDE,1,NGRIPE,NKDE,NKDE)               03 00170
      CALL STINT (DUM,0.0,0.0,XNE,1,NGRIPE,NELECT,NELECT)               03 00180
      PHIELE = PHIELE + XNE*XKDE + XNE*YKDE                             03 00190
      IF (NGRIPE) 10,1,10                                               03 00200
   10 NGRIPE = 5555                                                     03 00210
      GO TO 11                                                          03 00220
    1 CONTINUE                                                          03 00230
C**** COMPUTE PROTON FLUX                                               03 00240
      DO 2 I = 1,18                                                     03 00250
      DUM = FLOAT (I)                                                   03 00260
      CALL STINT (DUM,GLASS,0.0,XKDP,1,NGRIPE,NKDP,NKDP)                03 00270
      CALL STINT (DUM,SCBACK,0.0,YKDP,1,NGRIPE,NKDP,NKDP)               03 00280
      CALL STINT (DUM,0.0,0.0,XNP,1,NGRIPE,NPROTT,NPROTT)               03 00290
      PHIPRO = PHIPRO + XNP*XKDP + XNP*YKDP                             03 00300
      IF (NGRIPE) 20,2,20                                               03 00310
   20 NGRIPE = 6666                                                     03 00320
      GO TO 11                                                          03 00330
    2 CONTINUE                                                          03 00340
```

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C**** COMPUTE SOLAR FLARE PROTON FLUX                                   03 00350
      DO 3 I = 1,18                                                     03 00360
      DUM = FLOAT (I)                                                   03 00370
      CALL STINT (DUM,GLASS,0.0,XKDL,1,NGRIPE,NKDFL,NKDFL)              03 00380
      CALL STINT (DUM,SCBACK,0.0,YKDL,1,NGRIPE,NKDFL,NKDFL)             03 00390
      CALL STINT (DUM,0.0,0.0,XNF,1,NGRIPE,NFLARE,NFLARE)               03 00400
      PHIFLR = PHIFLR + XNF*XKDL + XNF*YKDL                             03 00410
      IF (NGRIPE) 30,3,30                                               03 00420
   30 NGRIPE = 7777                                                     03 00430
      GO TO 11                                                          03 00440
    3 CONTINUE                                                          03 00450
C**** COMPUTE SOLAR FLARE ALPHA PARTICLE FLUX                           03 00460
      DO 4  I = 1,18                                                    03 00470
      DUM = FLOAT (I)                                                   03 00480
      CALL STINT (DUM,GLASS,0.0,XKDA,1,NGRIPE,NKDA,NKDA)                03 00490
      CALL STINT (DUM,SCBACK,0.0,YKDA,1,NGRIPE,NKDA,NKDA)               03 00500
      CALL STINT (DUM,0.0,0.0,XNA,1,NGRIPE,NALPHA,NALPHA)               03 00510
      PHIALP = PHIALP + XNA*XKDA + XNA*YKDA                             03 00520
      IF (NGRIPE) 40,4,40                                               03 00530
   40 NGRIPE = 8888                                                     03 00540
      GO TO 11                                                          03 00550
    4 CONTINUE                                                          03 00560
C**** COMPUTE TOTAL FLUX                                                03 00570
      PHITOT = PHIELE + PHIPRO + PHIFLR + PHIALP                        03 00580
      WRITE (IB,100)                                                    03 00590
  100 FORMAT (58H1 SUMMATIONS OF ELECTRON,PROTON, AND SOLAR FLARE PARTIC03 00600
     1LES//89H   ELECTRONS      PROTONS      SOLAR FLARE PROTONS      SOLA03 00610
     2R FLARE ALPHA PARTICLES   TOTAL//)                                03 00620
      WRITE (IB,101)PHIELE,PHIPRO,PHIFLR,PHIALP,PHITOT                  03 00630
  101 FORMAT (1X,E12.4,2X,E12.4,E12.4,13X,E12.4,19X,E12.4)              03 00640
      WRITE (IB,102)                                                    03 00650
  102 FORMAT (54H0 NOTE, THESE FLUXES ARE IN EQUIVALENT 1 MEV ELECTRONS)03 00660
      RETURN                                                            03 00670
   11 WRITE (IP,103)NGRIPE                                              03 00680
      CALL EXIT                                                         03 00690
  103 FORMAT (15H0 ERROR IN TLU 15)                                     03 00700
      END                                                               03 00710
      SUBROUTINE DEGRAD (PHITOT,BOHMS,NCELLT,NMVTBL)                    04 00020
      DIMENSION VVEC(101),XIVEC(101)                                    04 00030
      COMMON VVEC,XIVEC                                                 04 00040
      IA=5                                                              04 00050
      IB=6                                                              04 00060
      VVEC(1) = 0.0                                                     04 00070
      XIVEC(1) = 0.0                                                    04 00080
      DO 1 I = 2,101                                                    04 00090
      XIVEC(I) = 0.0                                                    04 00100
    1 VVEC(I) = VVEC(I-1) + 0.01                                        04 00110
      DO 3 I = 1,101                                                    04 00120
      CALL STINT (VVEC(I),0.0,0.0,XIVEC(I),1,NGRIPE,NCELLT,NCELLT)      04 00130
      IF (NGRIPE)  2,3,2                                                04 00140
    2 WRITE (IB,100)                                                    04 00150
  100 FORMAT (48H0 ERROR IN DEGRADATION ROUTINE TLU OF CELL CURVE)      04 00160
      CALL EXIT                                                         04 00170
    3 CONTINUE                                                          04 00180
C**** TLU OF MILLIVOLTS AT ISC VS. TOTAL FLUX AND BASE RESTIVITY        04 00190
      CALL STINT (PHITOT,BOHMS,0.0,XMV,1,NGRIPE,NMVTBL,NMVTBL)          04 00200
      IF (NGRIPE) 4,5,4                                                 04 00210
    4 NGRIPE = NMVTBL                                                   04 00220
      WRITE (IB,101)NGRIPE                                              04 00230
  101 FORMAT (25H0 ERROR IN TLU, TABLE NO.15)                           04 00240
C**** COMPUTE RR                                                        04 00250
    5 XISCO = XIVEC(1)                                                  04 00260
      RR = XMV/XISCO                                                    04 00270
C**** CHANGE VVEC                                                       04 00280
      DO 6 I = 1,101                                                    04 00290
      VVEC(I) = VVEC(I) + XIVEC(I)*RR                                   04 00300
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    6 CONTINUE                                                          04 00310
C**** FIND VOCO                                                         04 00320
      DO 7 I = 2,101                                                    04 00330
      N= I                                                              04 00340
      IF (XIVEC(I)) 8,8,7                                               04 00350
    7 CONTINUE                                                          04 00360
    8 SLOPE = (XIVEC(N-1)-XIVEC(N-2))/(VVEC(N-1)-VVEC(N-2))             04 00370
      DO 9 J = N,101                                                    04 00380
    9 XIVEC(J) = XIVEC(N-1)+(VVEC(J)-VVEC(N-1))*SLOPE                   04 00390
      VOCO = VVEC(N-1) + XIVEC(N-1)*(VVEC(N)-VVEC(N-1))/(XIVEC(N-1)     04 00400
     1  -XIVEC(N))                                                      04 00410
C**** COMPUTE RI FOR TOTAL  PHI                                         04 00420
      IF (BOHMS - 1.0) 10,10,13                                         04 00430
   10 IF (PHITOT - 1.0E15) 11,12,12                                     04 00440
   11 IF (PHITOT - 4.0E12) 17,17,18                                     04 00450
   12 RI = 3.3 - 0.167*0.4342944819*ALOG  (PHITOT)                      04 00460
      GO TO 16                                                          04 00470
   13 IF (PHITOT - 1.0E15) 14,15,15                                     04 00480
   14 IF (PHITOT - 5.0E12) 17,17,19                                     04 00490
   15 RI = 2.806 - 0.1325*0.4342944819*ALOG  (PHITOT)                   04 00500
      GO TO 16                                                          04 00510
   17 RI = 1.0                                                          04 00520
      GO TO 16                                                          04 00530
   18 RI = 1.0 - 7.13/((10.0)** 8.31)*((PHITOT-4.0E12)**0.451)          04 00540
      GO TO 16                                                          04 00550
   19 RI = 1.0 - 2.78/((10.0)** 7.34)*((PHITOT-5.0E12)**0.41)           04 00560
C**** COMPUTE DELTAI                                                    04 00570
   16 DELTAI = XISCO*(1.0 - RI)                                         04 00580
C**** CHANGE XIVEC                                                      04 00590
      DO 20  I = 1,101                                                  04 00600
      XIVEC(I) = XIVEC(I) - DELTAI                                      04 00610
   20 CONTINUE                                                          04 00620
C**** FIND PZC, POINT OF ZERO CURRENT                                   04 00630
      DO 21  I = 2,101                                                  04 00640
      N = I                                                             04 00650
      IF (XIVEC(I))22,22,21                                             04 00660
   21 CONTINUE                                                          04 00670
   22 SLOPE = (XIVEC(N-1)-XIVEC(N-2))/(VVEC(N-1)-VVEC(N-2))             04 00680
      DO 23 J = N,101                                                   04 00690
   23 XIVEC(J) = XIVEC(N-1)+(VVEC(J)-VVEC(N-1))*SLOPE                   04 00700
      PZC = VVEC(N-1)+XIVEC(N-1)*(VVEC(N)-VVEC(N-1))/(XIVEC(N-1)        04 00710
     1  -XIVEC(N))                                                      04 00720
C**** COMPUTE RV FOR TOTAL PHI                                          04 00730
      IF (PHITOT - 1.0E14) 25,24,24                                     04 00740
   24 RV = 1.779 - 0.0588*0.4342944819*ALOG  (PHITOT)                   04 00750
      GO TO 26                                                          04 00760
   25 IF (PHITOT - 3.0E12) 27,27,28                                     04 00770
   27 RV = 1.0                                                          04 00780
      GO TO 26                                                          04 00790
   28 RV = 1.0 - 0.0222*((0.4342944819*ALOG  (PHITOT/3.0E12))**1.67)    04 00800
C**** COMPUTE VOCR                                                      04 00810
   26 VOCR = VOCO*RV                                                    04 00820
      DELTAV = PZC - VOCR                                               04 00830
C**** FINAL UPDATE OF VOLTAGES IN ARRAY                                 04 00840
      DO 30  I = 1,101                                                  04 00850
      VVEC(I) = VVEC(I) - DELTAV                                        04 00860
   30 CONTINUE                                                          04 00870
C**** COMPUTE ISCR,IPMR,VPMR                                            04 00880
   31 DO 33  I = 1,101                                                  04 00890
      IF (VVEC (I)) 33,32,32                                            04 00900
   32 XISCR = XIVEC(I)                                                  04 00910
      GO TO 34                                                          04 00920
   33 CONTINUE                                                          04 00930
   34 N = 1                                                             04 00940
      PWR = -1000000.0                                                  04 00950
   40 PWRT = VVEC(N)*XIVEC(N)                                           04 00960
```

```
      IF (PWRT-PWR) 42,44,41                                            04 00970
   41 N = N+1                                                           04 00980
      PWR = PWRT                                                        04 00990
      GO TO 40                                                          04 01000
   44 VPMR = VVEC(N)                                                    04 01010
      XIPMR = XIVEC(N)                                                  04 01020
      GO TO 45                                                          04 01030
   42 SLOPE = (XIVEC(N-1)-XIVEC(N))/(VVEC(N)-VVEC(N-1))                 04 01040
   43 VPMR = VVEC(N-1) + 0.00015                                        04 01050
      XIPMR = XIVEC(N-1) - SLOPE*(VPMR - VVEC(N-1))                     04 01060
      PWRT = VPMR*XIPMR                                                 04 01070
      IF (PWRT-PWR) 45,45,48                                            04 01080
   48 PWR = PWRT                                                        04 01090
      GO TO 43                                                          04 01100
   45 WRITE (IB,102)                                                    04 01110
  102 FORMAT (43H1 SOLAR CELL I-V CURVE IRRADIATION-DEGRADED)           04 01120
      WRITE (IB,103)XISCR,XIPMR,VPMR,VOCR                               04 01130
  103 FORMAT (36H0   SHORT-CIRCUIT CURRENT (AMPS)  = F10.6/36H0   CURREN04 01140
     1T AT MAX PWR PT (AMPS)  = F10.6/36H0   VOLTAGE AT MAX PWR PT (VOLT04 01150
     2S) = F10.6/36H0   OPEN-CIRCUIT VOLTAGE (VOLTS)  = F10.6//)        04 01160
      WRITE (IB,105)                                                    04 01170
  105 FORMAT (20H0 DEGRADED I-V CURVE//17H  VOLTS      AMPS//)          04 01180
      DO 46  I = 1,101,2                                                04 01190
      WRITE (IB,106)VVEC(I),XIVEC(I)                                    04 01200
  106 FORMAT (2F12.6)                                                   04 01210
   46 CONTINUE                                                          04 01220
      RETURN                                                            04 01230
      END                                                               04 01240
      SUBROUTINE STASH (SIGISC,SIGVOC,DISC,DV,TNOT,KEY,NGRIPE,NCELLT,   05 00020
     1VOCOI,ADDT,DELTT)                                                 05 00030
      DIMENSION VVEC(101),XIVEC(101),TEMP(15),VMAP(15,101),XIMAP(15,101)05 00040
      DIMENSION VOCT(15),XISCT(15),VMP(15),XIMP(15)                     05 00050
      DIMENSION PWRSTG(15)                                              05 00060
      COMMON VVEC,XIVEC                                                 05 00070
C     DECIDE IF INITIALIZATION OR COMPUTATION                           05 00080
      IA=5                                                              05 00090
      IB=6                                                              05 00100
      NGRIPE=0                                                          05 00110
      IF(KEY)2000,3000,1000                                             05 00120
C     INITIALIZATION - OBTAIN I AND V INPUT VECTORS                     05 00130
C     ************************************************************      05 00140
C     IN FIRST ENTRY                                                    05 00150
C     SIGISC IS DISC                                                    05 00160
C     SIGVOC IS THETA                                                   05 00170
C     DISC IS AVPMO                                                     05 00180
C     DV IS AIPMO                                                       05 00190
C     TNOT IS THOT                                                      05 00200
C     KEY IS -1                                                         05 00210
C     NGRIPE IS NGRIPE                                                  05 00220
C     NCELLT IS NCELLT                                                  05 00230
C     VOCOI IS VOCOI                                                    05 00240
C     ADDT IS ADDT                                                      05 00250
C     DELTT IS DELTT                                                    05 00260
 2000 CALL SLITET (1, K001FX)                                           05 00270
      GO TO (2005,5000), K001FX                                         05 00280
 5000 VVEC(1)=0.0                                                       05 00290
      XIVEC(1)=0.0                                                      05 00300
      DO 2001 I=2,101                                                   05 00310
      XIVEC(I)=0.0                                                      05 00320
 2001 VVEC(I) = VVEC(I-1) + 0.010                                       05 00330
      DO 2002 I = 1,100                                                 05 00340
      CALL STINT (VVEC(I),0.0,0.0,XIVEC(I),1,NGRIPE,NCELLT,NCELLT)      05 00350
      IF(NGRIPE)2002,2002,2003                                          05 00360
 2002 CONTINUE                                                          05 00370
      GO TO 2005                                                        05 00380
 2003 IF (XIVEC(I-1))2005,2005,12003                                    05 00390
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12003 RETURN                                                          05 00400
C     EXTRAPOLATE INPUT CURVE                                         05 00410
C     LOCATE FIRST ZERO ELEMENT IN XIVEC                              05 00420
 2005 DO 2107 I = 2,101                                               05 00430
      N=I                                                             05 00440
      IF(XIVEC(I))2106,2106,2107                                      05 00450
 2107 CONTINUE                                                        05 00460
 2106 SLOPE=(XIVEC(N-1)-XIVEC(N-2))/(VVEC(N-1)-VVEC(N-2))             05 00470
C     LOCATE POINT OF ZERO CURRENT FOR UNDEGRADED CURVE               05 00480
      PZCU = VVEC(I) - XIVEC(I)/SLOPE                                 05 00490
      DO 2108 J = N,101                                               05 00500
 2108 XIVEC(J)=XIVEC(N-1)+(VVEC(J)-VVEC(N-1))*SLOPE                   05 00510
C     DO CURRENT DEGRADATION WITH GAMMA,TNOT,THETA                    05 00520
      XISC = XIVEC(1)                                                 05 00530
      GAMMA=SIGISC                                                    05 00540
      DELTAI=(1.0-GAMMA)*XISC                                         05 00550
      RECIP=1.0/GAMMA                                                 05 00560
      THETA=SIGVOC                                                    05 00570


      DELTAV=(TNOT+273.16)*0.8614E-04*ALOG  (RECIP)                   05 00580
      DELTAV = DELTAV + (1.0 - THETA)*VOCOI                           05 00590
      DO 2600 I = 1,101                                               05 00600
      XIVEC(I) = XIVEC(I) - DELTAI                                    05 00610
      IF (XIVEC(I)) 2703,2703,2600                                    05 00620
 2703 KIX = I - 1                                                     05 00630
      LOU = I+ 1                                                      05 00640
      DO 2622 L = LOU,101                                             05 00650
 2622 XIVEC(L) = XIVEC(L) - DELTAI                                    05 00660
      GO TO 2006                                                      05 00670
 2600 CONTINUE                                                        05 00680
 2006 CONTINUE                                                        05 00690
C     LOCATE POINT OF ZERO CURRENT FOR DEGRADED CURVE                 05 00700
      SLOPE = (XIVEC(KIX) - XIVEC(KIX-1))/(VVEC(KIX) - VVEC(KIX-1))   05 00710
      PZCD = VVEC(KIX) - XIVEC(KIX)/SLOPE                             05 00720
      DELTAV = (PZCU - PZCD) - DELTAV                                 05 00730
      DO 2704 I = 2,101                                               05 00740
 2704 VVEC(I) = VVEC(I) + DELTAV                                      05 00750
C     CURRENT DEGRADATION IS NOW COMPLETE                             05 00760
C     GO ON TO DO SERIES RESISTANCE DEGRADATION                       05 00770
C     STORE AIPMO AND AVPMO AND FETCH NEW BATCH OF VARIABLES          05 00780
      AIPMO=DV                                                        05 00790
      AVPMO=DISC                                                      05 00800
      RETURN                                                          05 00810
C*****************************************************************   05 00820
C     IN SECOND CALL                                                  05 00830
C     SIGISC IS DV                                                    05 00840
C     SIGVOC IS DISC                                                  05 00850
C     DISC IS SIGISC                                                  05 00860
C     DV IS SIGVOC                                                    05 00870
C     TNOT IS TNOT                                                    05 00880
C     KEY IS 0                                                        05 00890
C     NGRIPE IS NGRIPE                                                05 00900
C     NCELLT IS NCELLT                                                05 00910
C     VOCOI IS DENFAC                                                 05 00920
C     ADDT IS ADDT                                                    05 00930
C     DELTT IS DELTT                                                  05 00940
 3000 ALFA=SIGISC                                                     05 00950
      DENFAC=VOCOI                                                    05 00960
      TKI=DISC                                                        05 00970
      TKV=DV                                                          05 00980
      RES=((1.0-ALFA)*AVPMO/AIPMO)                                    05 00990
      DO 3001 I = 1,101                                               05 01000
 3001 VVEC(I)=VVEC(I)-XIVEC(I)*RES                                    05 01010
C     SERIES RESISTANCE DEGRADATION IS NOW COMPLETE                   05 01020
```

```
C     DETERMINE VOC - LOCATE FIRST NEGATIVE ELEMENT IN XIVEC
      DO 3007 I = 2,101
      N=I
      IF(XIVEC(I))3006,3006,3007
 3007 CONTINUE
 3006 VOC=VVEC(N-1)+XIVEC(N-1)*(VVEC(N)-VVEC(N-1))/(XIVEC(N-1)-XIVEC(N))
C     FILL TEMPERATURE VECTOR
      IF (DELTT) 3012,3012,3013
 3012 ADDT = 120.0
      DELTT = 20.0
 3013 CONTINUE
      TEMP(1) = TNOT + ADDT
      VOCT(1)= VOC-ADDT*TKV
      DO 3202 I=2,15
      TEMP(I) = TEMP(I-1) - DELTT
 3202 VOCT(I)=VOC-(TEMP(I)-TNOT)*TKV
C     EXPAND I-V CURVE INTO FAMILY OF CURVES FOR 15 TEMPERATURES
C     OUTER DO FOR EACH TEMPERATURE ON INDEX I
      DO 3040 I=1,15
C     FIRST INNER DO FOR VOLTAGES ON INDEX J
      T2T1=TEMP(I)-TNOT
      DELTAV=TKV*T2T1
      DO 3204 J = 1,101
 3204 VMAP(I,J)=VVEC(J)-DELTAV
      XKIT=TKI*T2T1*SIGVOC
      DENOM=VOC-DENFAC-TKV*T2T1
C     SECOND INNER DO FOR CURRENTS ON INDEX J
      DO 3205 J = 1,101
      Z=VMAP(I,J)/DENOM
      Z6 = Z**8
      UMZ6=1.0-Z6
      IF(UMZ6)3300,3205,3205
 3300 UMZ6=0.0
 3205 XIMAP(I,J)=XIVEC(J)+XKIT*UMZ6
 3040 CONTINUE
C     FIND V AND I AT MAXIMUM POWER POINT FOR EACH TEMPERATURE
      DO 4005 I=1,15
      N=4
      PWR= -1000000.0
 4000 PWRT=VMAP(I,N)*XIMAP(I,N)
      IF(PWRT-PWR) 4002,4004,4001
 4001 N=N+1
      PWR=PWRT
      GO TO 4000
 4004 VMP(I)=VMAP(I,N)
      XIMP(I)=XIMAP(I,N)
      GO TO 4005
 4002 SLOPE=(XIMAP(I,N-1)-XIMAP(I,N))/(VMAP(I,N)-VMAP(I,N-1))
 4003 VMP(I)=VMAP(I,N-1)+0.00015
      XIMP(I)=XIMAP(I,N-1)-SLOPE*(VMP(I)-VMAP(I,N-1))
      PWRT=VMP(I)*XIMP(I)
      IF (PWRT-PWR) 4005,4005,4008
 4008 PWR=PWRT
      GO TO 4003
 4005 CONTINUE
      DO 100 I = 1,15
      PWRSTG(I) = VMP(I)*XIMP(I)
  100 CONTINUE
 4006 DO 4009 I = 1,15
      DO 4010 N = 1,101
      IF (VMAP (I,N))4010,4007,4007
 4007 XISCT(I) = XIMA .I,N)
      GO TO 4009
 4010 CONTINUE
 4009 CONTINUE
C     EDIT RESULTS
```

```
      WRITE (IB,7000)                                                   05 01690
      WRITE (IB,7001)(TEMP(J),J=1,15)                                   05 01700
      WRITE (IB,7002)(XIMP(J),J=1,15)                                   05 01710
      WRITE (IB,7003)(VMP(J),J=1,15)                                    05 01720
      WRITE (IB,7006)(VOCT(I),I=1,15)                                   05 01730
      WRITE (IB,7007)(XISCT(I),I=1,15)                                  05 01740
      WRITE (IB,7008)(PWRSTG(I),I=1,15)                                 05 01750
      DO 2040 J=1,30,2                                                  05 01760
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)                              05 01770
 2040 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)                               05 01780
      WRITE (IB,7000)                                                   05 01790
      WRITE (IB,7001)(TEMP(J),J=1,15)                                   05 01800
      WRITE (IB,7002)(XIMP(J),J=1,15)                                   05 01810
      WRITE (IB,7003)(VMP(J),J=1,15)                                    05 01820
      WRITE (IB,7006)(VOCT(I),I=1,15)                                   05 01830
      WRITE (IB,7007)(XISCT(I),I=1,15)                                  05 01840
      WRITE (IB,7008)(PWRSTG(I),I=1,15)                                 05 01850
      DO 2041 J = 31,60,2                                               05 01860
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)                              05 01870
 2041 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)                               05 01880
      WRITE (IB,7000)                                                   05 01890
      WRITE (IB,7001)(TEMP(J),J=1,15)                                   05 01900
      WRITE (IB,7002)(XIMP(J),J=1,15)                                   05 01910
      WRITE (IB,7003)(VMP(J),J=1,15)                                    05 01920
      WRITE (IB,7006)(VOCT(I),I=1,15)                                   05 01930
      WRITE (IB,7007)(XISCT(I),I=1,15)                                  05 01940
      WRITE (IB,7008)(PWRSTG(I),I=1,15)                                 05 01950
      DO 2042 J = 61,90,2                                               05 01960
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)                              05 01970
 2042 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)                               05 01980
      WRITE (IB,7000)                                                   05 01990
      WRITE (IB,7001)(TEMP(J),J=1,15)                                   05 02000
      WRITE (IB,7002)(XIMP(J),J=1,15)                                   05 02010
      WRITE (IB,7003)(VMP(J),J=1,15)                                    05 02020
      WRITE (IB,7006)(VOCT(I),I= 1,15)                                  05 02030
      WRITE (IB,7007)(XISCT(I),I=1,15)                                  05 02040
      WRITE (IB,7008)(PWRSTG(I),I=1,15)                                 05 02050
      DO 2043 J = 91,99,2                                               05 02060
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)                              05 02070
 2043 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)                               05 02080
      RETURN                                                            05 02090
C     EDIT FORMATS                                                      05 02100
 7000 FORMAT (104H1  EDIT OF TEMPERATURE AND DEGRADATION CORRECTED SOLAR05 02110
     1 CELL I-V CURVES FOR SOLAR ARRAY SYNTHESIS PROGRAM)               05 02120
 7001 FORMAT (14H0 TEMPERATURES15F7.0)                                  05 02130
 7002 FORMAT (14H0 I-MAX PWR   15F7.4)                                  05 02140
 7003 FORMAT (14H  V-MAX PWR   15F7.4)                                  05 02150
 7004 FORMAT (4H0 I(I2,8H)       15F7.4)                                05 02160
 7005 FORMAT (4H  V(I2,8H)       15F7.4)                                05 02170
 7006 FORMAT (14H  VOLTS OC    15F7.4)                                  05 02180
 7007 FORMAT (14H  AMPS  SC    15F7.4)                                  05 02190
 7008 FORMAT (14H  MAX POWER   15F7.4)                                  05 02200
C     LOOK UP CURRENT AND MAX PWR POINT GIVEN VCELL + TEMPERATURE       05 02210
 1000 VCELL=DISC                                                        05 02220
      HELHOT=DV                                                         05 02230
      NK = (TEMP(1) - HELHOT)/DELTT                                     05 02240
      NHI=NK+1                                                          05 02250
      NLO=NK+2                                                          05 02260
      IF (KEY - 989) 1334,1333,1334                                     05 02270
C     FOR KEY = 989 INTO SIGISC PUT OPEN CIRCUIT VOLTAGE AT TEMPETATURE 05 02280
 1333 SIGISC = VOCT(NLO)+((DV-TEMP(NLO))/DELTT)*(VOCT(NHI)-VOCT(NLO))   05 02290
      RETURN                                                            05 02300
 1334 IF (KEY - 988) 1335,1336,1335                                     05 02310
C     FOR KEY = 988 INTO SIGISC PUT VOLTAGE AT THE GIVEN CURRENT        05 02320
 1336 DO 1402 J = 2,101                                                 05 02330
      N = J                                                             05 02340
```

```
      IF (VCELL- XIMAP(NLO,J))1402,1402,1403                            05 02350
 1402 CONTINUE                                                          05 02360
 1403 XILO = VMAP(NLO,N-1) + (VCELL - XIMAP(NLO,N-1))*  (VMAP(NLO,N) -  05 02370
     1VMAP(NLO,N-1))/(XIMAP(NLO,N)-XIMAP(NLO,N-1))                      05 02380
      DO 1422 J = 2,101                                                 05 02390
      N = J                                                             05 02400
      IF (VCELL- XIMAP(NHI,J))1422,1422,1423                            05 02410
 1422 CONTINUE                                                          05 02420
 1423 CONTINUE                                                          05 02430
      XIHI = VMAP(NHI,N-1) + (VCELL - XIMAP(NHI,N-1))* (VMAP(NHI,N) -   05 02440
     1VMAP(NHI,N-1))/(XIMAP(NHI,N) - XIMAP(NHI,N-1))                    05 02450
      GO TO 1210                                                        05 02460
 1335 CONTINUE                                                          05 02470
      IF(VCELL-VMAP(NLO,1))1100,1100,1001                               05 02480
 1100 XILO=XIMAP(NLO,1)                                                 05 02490
      GO TO 1010                                                        05 02500
 1001 DO 1002 J = 2,101                                                 05 02510
      N=J                                                               05 02520
      IF(VCELL-VMAP(NLO,J))1003,1003,1002                               05 02530
 1002 CONTINUE                                                          05 02540
 1003 XILO=XIMAP(NLO,N-1)+(VCELL-VMAP(NLO,N-1))*(XIMAP(NLO,N)-XIMAP(NLO,05 02550
     1N-1))/(VMAP(NLO,N)-VMAP(NLO,N-1))                                 05 02560
 1010 IF(VCELL-VMAP(NHI,1))1200,1200,1020                               05 02570
 1200 XIHI=XIMAP(NHI,1)                                                 05 02580
      GO TO 1210                                                        05 02590
 1020 DO 1222 J = 2,101                                                 05 02600
      N=J                                                               05 02610
      IF(VCELL-VMAP(NHI,J))1023,1023,1222                               05 02620
 1222 CONTINUE                                                          05 02630
 1023 XIHI=XIMAP(NHI,N-1)+(VCELL-VMAP(NHI,N-1))*(XIMAP(NHI,N)-XIMAP(NHI,05 02640
     1N-1))/(VMAP(NHI,N)-VMAP(NHI,N-1))                                 05 02650
 1210 FAKTOR=(HELHOT-TEMP(NLO))/(TEMP(NHI)-TEMP(NLO))                   05 02660
C     XICELL PUT INTO SIGISC                                            05 02670
      SIGISC=XILO+(XIHI-XILO)*FAKTOR                                    05 02680
      RETURN                                                            05 02690
      END                                                               05 02700
```

Appendix B

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071768  0
 SAMPLE TABLES
08-13-6800012701 11.4 CRL BARE CELL 1 OHM-CM %NIMBUS D<                 00
       0.0     0.25    0.30    0.35    0.37    0.39    0.40    0.41    0.42    01
       0.1420  0.1420  0.1412  0.1412  0.1409  0.1400  0.1397  0.1390  0.1380  02
       0.43    0.44    0.45    0.46    0.47    0.48    0.49    0.50    0.51    03
       0.1369  0.1355  0.1332  0.1312  0.1289  0.1256  0.1210  0.1161  0.1088  04
       0.52    0.53    0.54    0.55    0.56    0.57    0.590   0.600   1.0     05
       0.1005  0.0925  0.0825  0.0700  0.0550  0.0388  0.0     -0.0125-0.012506
05-13-6800023601   RELATIVE ISC VS INCIDENCE ANGLE%KELLY COSINE<        00
       0.0     5.0     10.0    15.0    20.0    25.0    30.0    35.0    40.0    01
       1.0     0.99    0.98    0.965   0.94    0.905   0.86    0.81    0.75    02
       45.0    50.0    60.0    65.0    70.0    75.0    80.0    85.0    90.0    03
       0.69    0.63    0.48    0.385   0.30    0.20    0.12    0.04    0.0     04
       270.0   275.0   280.0   285.0   290.0   295.0   300.0   310.0   315.0   05
       0.0     0.04    0.12    0.20    0.30    0.385   0.48    0.63    0.69    06
       320.0   325.0   330.0   335.0   340.0   345.0   350.0   355.0   360.0   07
       0.75    0.81    0.86    0.905   0.94    0.965   0.98    0.99    1.0     08
07-30-6800031101   NIMBUS ORBITAL ELECTRONS 1 YR 600NM-1970               00
       1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0     01
       2.92&121.10&125.48&117.3 &1037.2&107.81&101.61&105.40 &91.72 &902
       10.0    11.0                                                        03
       5.91 &80.0                                                          04
07-30-6800041801   NIMBUS ORBITAL PROTONS 1 YR 600NM-1970                00
       1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0     01
       2.19&102.19&101.46&101.82&101.28&101.1 &101.1 &109.12 &97.3  &902
       10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    03
       5.48 &95.48 &94.74 &93.28 &92.56 &91.82 &912.8 &96.94 &90.0           04
05-13-6800051801   NIMBUS SOLAR FLARE PROTONS 1YR 600NM                  00
       1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0     01
       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     02
       10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    03
       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     04
05-13-6800061801   NIMBUS SOLAR FLARE ALPHA PARTICLES 1YR 600NM          00
       1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0     01
       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     02
       10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    03
       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     04
09-20-6800071107   DAMAGE FACTORS FOR ELECTRONS                          00
       1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0     01
0.0    0.01    0.06    0.18    0.38    1.3     2.9     4.35    5.5     6.5     02
1.0    0.0     0.03    0.13    0.3     1.15    2.7     4.15    5.3     6.15    03
1.5    0.0     0.02    0.08    0.2     1.02    2.5     3.92    5.15    6.1     04
3.0    0.0     0.0     0.03    0.1     0.75    2.05    3.28    4.6     5.7     05
6.0    0.0     0.0     0.0     0.02    0.47    1.55    2.85    4.1     5.3     06
9.0    0.0     0.0     0.0     0.0     0.25    1.1     2.15    3.3     4.6     07
200.0  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     08
       10.0    11.0                                                        09
0.0    7.4     7.8                                                         10
1.0    7.3     7.8                                                         11
1.5    7.3     7.8                                                         12
3.0    6.8     7.7                                                         13
6.0    6.5     7.5                                                         14
9.0    5.85    7.0                                                         15
200.0  0.0     0.0                                                         16
09-20-6800081808   DAMAGE FACTORS FOR PROTONS                            00
       1.0     2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0     01
0.0    20000.010000.07000.0 5400.0 4500.0 3900.0 3500.0 3100.0 2800.0 02
0.5    0.0     0.0     6000.0 5400.0 4500.0 3900.0 3500.0 3100.0 2800.0 03
1.0    0.0     0.0     0.0     0.0     3000.0 3700.0 3500.0 3100.0 2800.0 04
1.5    0.0     0.0     0.0     0.0     0.0     2000.0 3100.0 3100.0 2800.0 05
3.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     200.0   1400.0 06
6.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     07
9.0    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     08
200.0  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     09
       10.0    11.0    12.0    13.0    14.0    15.0    16.0    17.0    18.0    10
0.0    2700.0 2600.0 2500.0 2500.0 2500.0 2500.0 2500.0 2300.0 1000.0 11
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0.5     2700.0 2600.0 2500.0 2500.0 2500.0 2500.0 2500.0 2300.0 1000.0 12
1.0     2700.0 2600.0 2500.0 2500.0 2500.0 2500.0 2500.0 2300.0 1000.0 13
1.5     2700.0 2600.0 2500.0 2500.0 2500.0 2500.0 2500.0 2300.0 1000.0 14
3.0     2000.0 2100.0 2100.0 2100.0 2000.0 2000.0 2000.0 2000.0 1000.0 15
6.0     0.0    0.0    100.0  1000.0 1400.0 1500.0 1800.0 2000.0 1000.0 16
9.0     0.0    0.0    0.0    0.0    0.0    100.0  1500.0 2000.0 1000.0 17
200.0   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    18
09-23-6800091807   DAMAGE FACTORS FOR ALPHA PARTICLES                   00
        1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0    01
0.0     20000.015000.014500.013700.012500.011500.011000.010400.09800.0 02
1.0     10000.013000.014000.013700.012500.011500.011000.010400.09800.0 03
1.5     0.0    0.0    7000.0 11000.012000.011500.011000.010400.09800.0 04
3.0     0.0    0.0    0.0    0.0    0.0    2500.0 5200.0 7200.0 7900.0 05
6.0     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    06
9.0     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    07
200.0   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    08
        10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   09
0.0     9500.0 9500.0 9500.0 9500.0 9400.0 9200.0 8600.0 7000.0 4000.0 10
1.0     9500.0 9500.0 9500.0 9500.0 9400.0 9200.0 8600.0 7000.0 4000.0 11
1.5     9500.0 9500.0 9500.0 9500.0 9400.0 9200.0 8600.0 7000.0 4000.0 12
3.0     8000.0 7800.0 7700.0 7600.0 7600.0 7600.0 7700.0 7000.0 4000.0 13
6.0     1700.0 3650.0 5300.0 5700.0 6300.0 7000.0 7400.0 7000.0 4000.0 14
9.0     0.0    0.0    0.0    1600.0 4000.0 6400.0 7100.0 7000.0 4000.0 15
200.0   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    16
09-20-6600102302   NMVTBL CURVE SHAPE VOLTS VS PHI                      00
        0.0    1.0 &132.5 &136.0 &131.0 &142.0 &143.0 &144.0 &145.0 &1401
1.0     0.0    0.0    0.001  0.0032 0.005  0.0081 0.0103 0.012  0.0134 02
10.0    0.0    0.0    0.0    0.0012 0.0024 0.004  0.0051 0.0058 0.0064 03
        6.0 &148.0 &141.0 &151.5 &152.0 &152.5 &153.0 &153.5 &154.0 &1504
1.0     0.0145 0.0163 0.0177 0.0201 0.0219 0.0232 0.0244 0.0253 0.0261 05
10.0    0.0068 0.0077 0.0085 0.0104 0.0118 0.0130 0.014  0.0149 0.0156 06
        5.0 &156.0 &158.0 &151.0 &161.0 &17                            07
1.0     0.0275 0.0286 0.0304 0.0317 0.0457                             08
10.0    0.0168 0.0179 0.0195 0.0207 0.0329                             09
07-17-6800110201   ZERO INCIDENCE ANGLE                                 00
        0.0    120.0                                                   01
        0.0    0.0                                                     02
07-17-6800121601   NIMBUS SOLAR ARRAY TEMP VS TIME PROFILE              00
        0.0    5.0    10.0   15.0   20.0   25.0   30.0   35.0   40.0   01
        -60.0  -31.0  -11.0  5.0    17.0   27.0   36.0   42.0   47.0   02
        45.0   50.0   55.0   60.0   65.0   70.0   75.0                  03
        51.0   52.0   51.0   48.0   46.0   44.0   42.0                  04
 RUN NO.1  3 MONTH FLUX IS 7.9EXP13
  1 20.0
  2 5.0
  3 0.00007
  4 0.0022
  5 100.0
  6 100.0
  7 100.0
  8 95.0
  9 99.0
 10 100.0
 11 0.47
 12 0.1289
 13 0.590
 14 100.0
 15 28.0
 16 1.8
 17 10.0
 18 32.0
 19 79000000000000.0
 20 6.0
 21 15.0
 22 1.0
 23 1.0
```

```
 24 4.0
999
  2
94.0       92.0       11.0       12.0
92.0       18.0       11.0       12.0

 RUN NO.2  6 MONTH FLUX IS 1.58EXP14
  5 103.0
  6 101.0
  7 103.5
 14 101.0
 19 158000000000000.0
 24 3.0
```

END