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THE SOLAR ARRAY SYNTHESIS COMPUTER PROGRAM

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THE SOLAR ARRAY SYNTHESIS COMPUTER PROGRAM

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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 or 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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CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

TABLES

TABLES (Continued)

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.

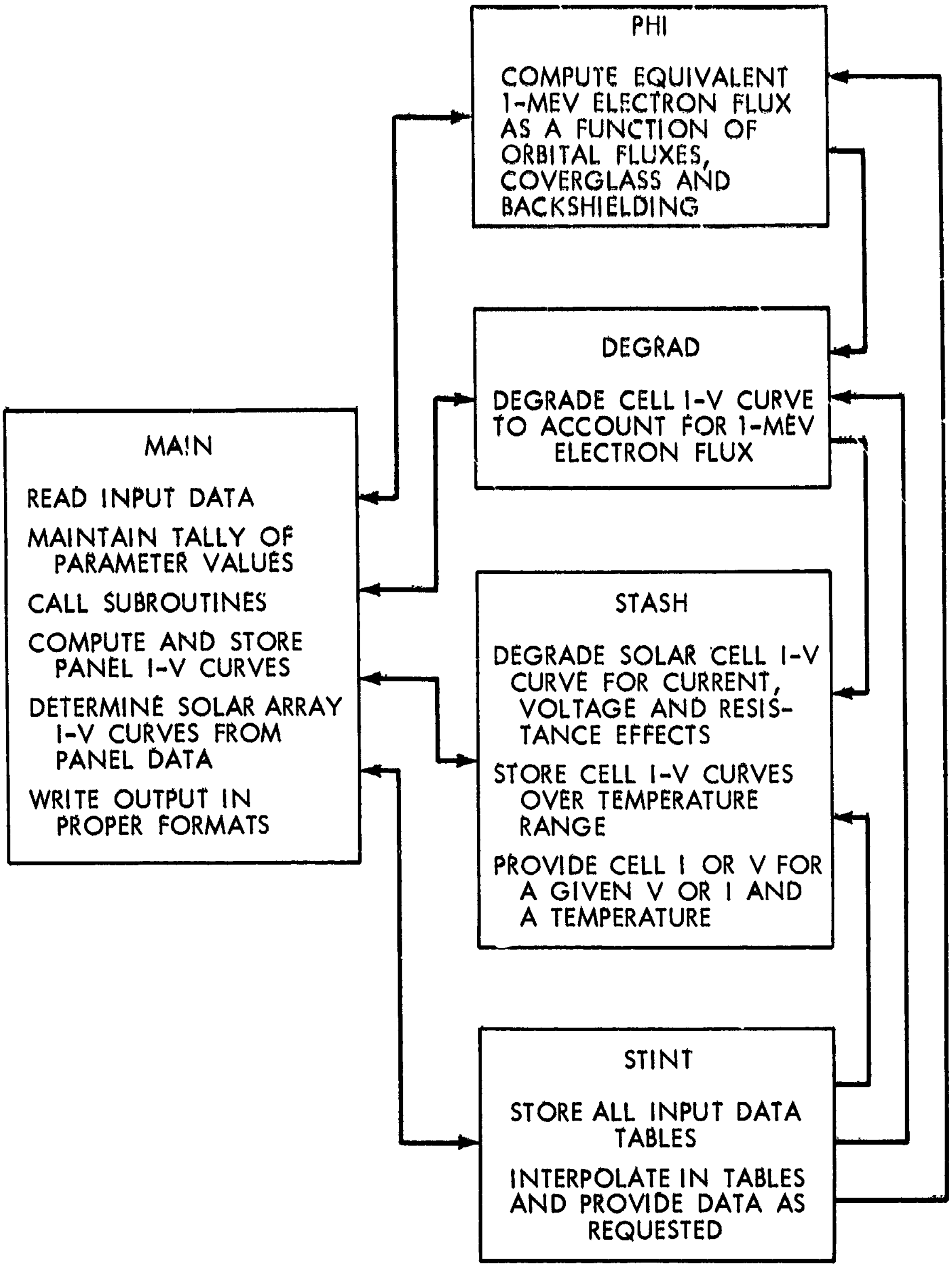

Figure 1. Subroutine Functions in Solar Array Synthesis Computer Program

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 Fa tors 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.

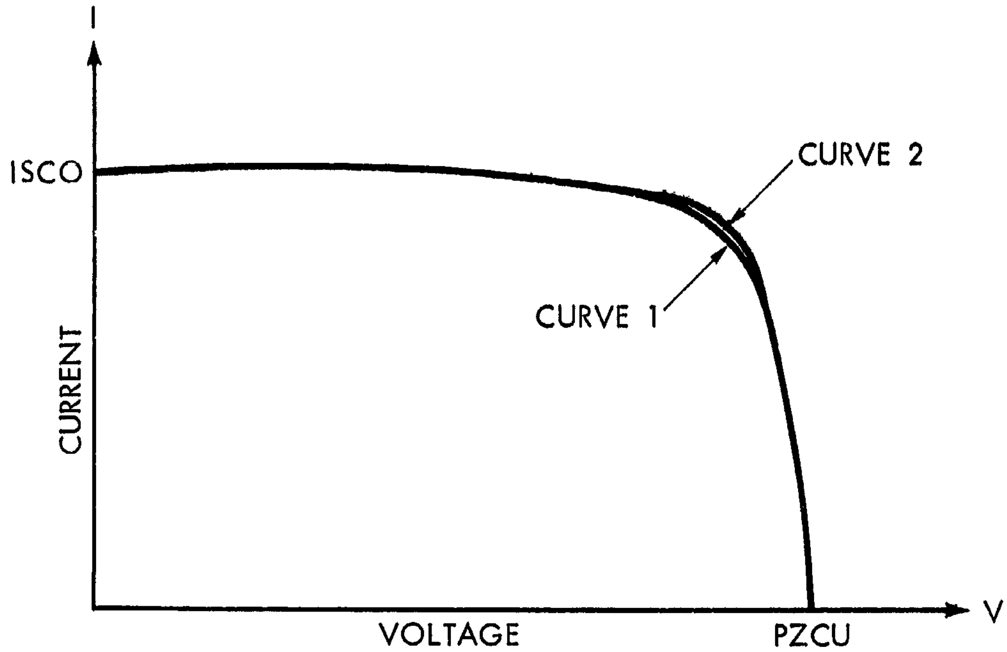

Figure 2. Curve Shape Correction

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.

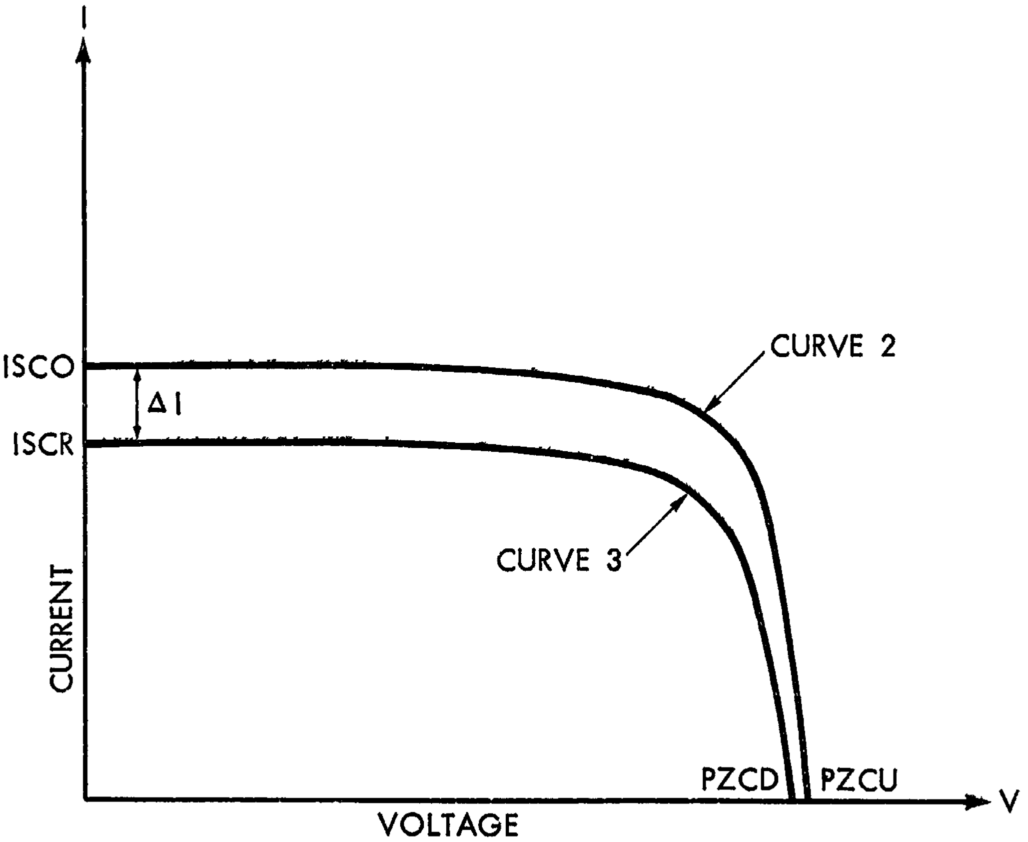

Figure 3. Short Circuit Current Correction

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

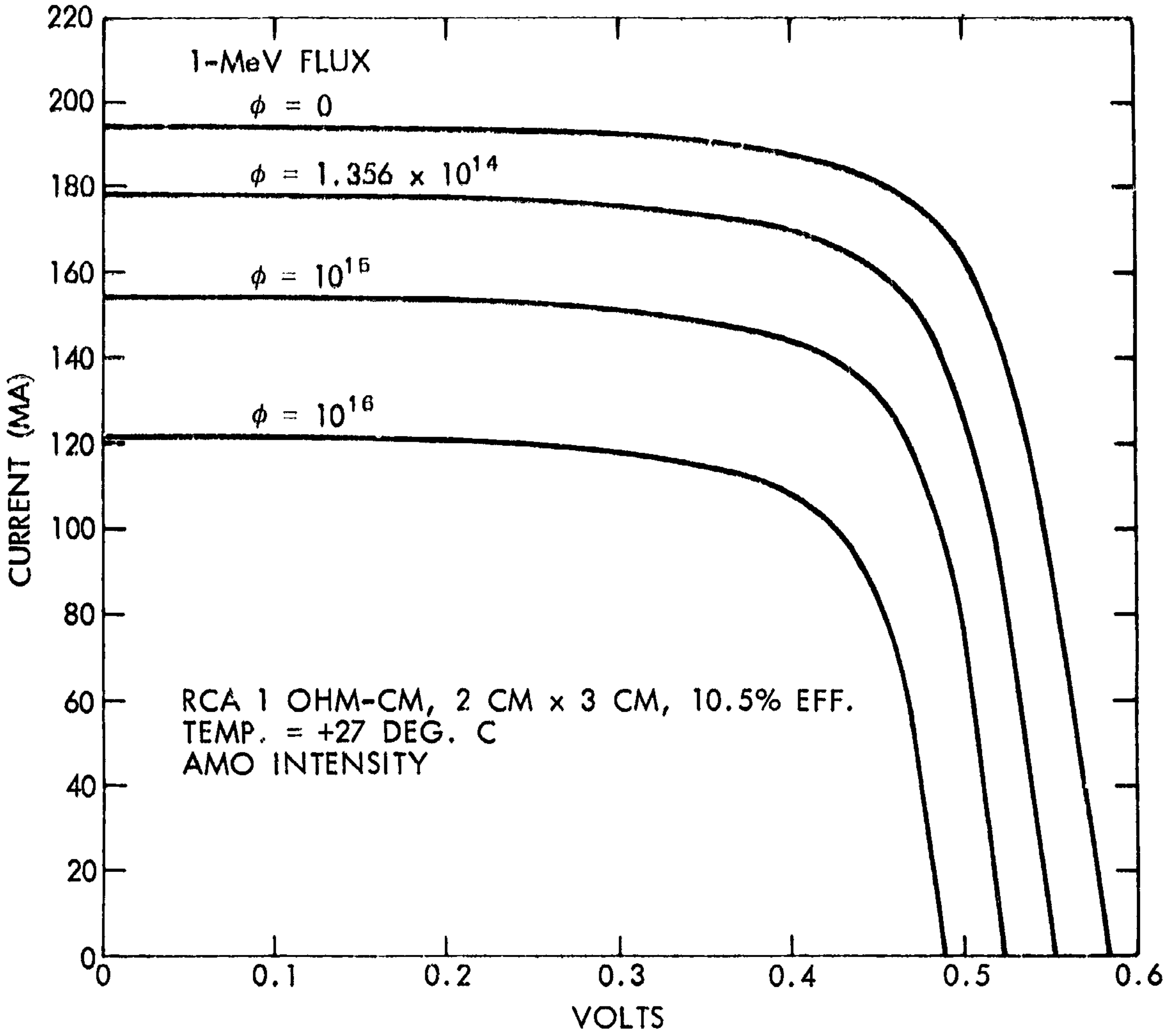

Figure 5. Solar Cell I-V Curves at Various Flux Levels

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.

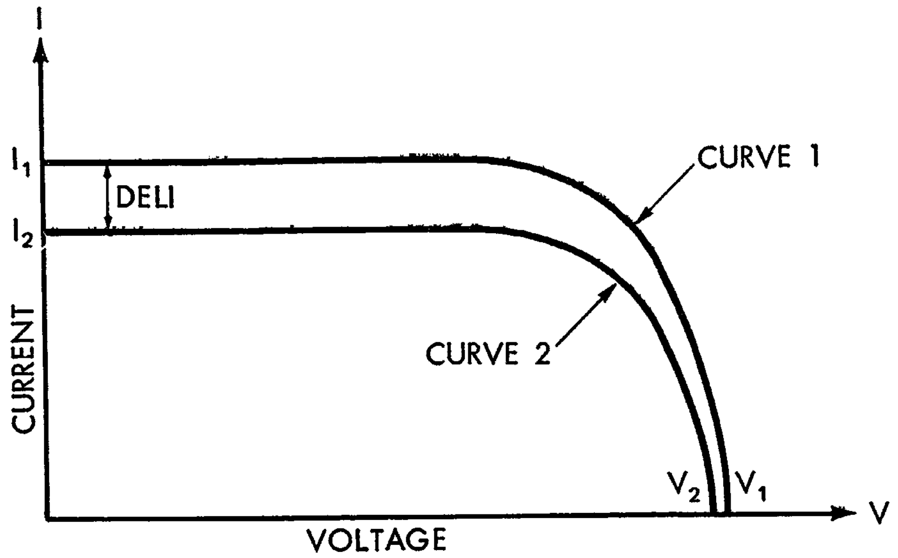

Figure 6. Short Circuit Current Degradation Effects

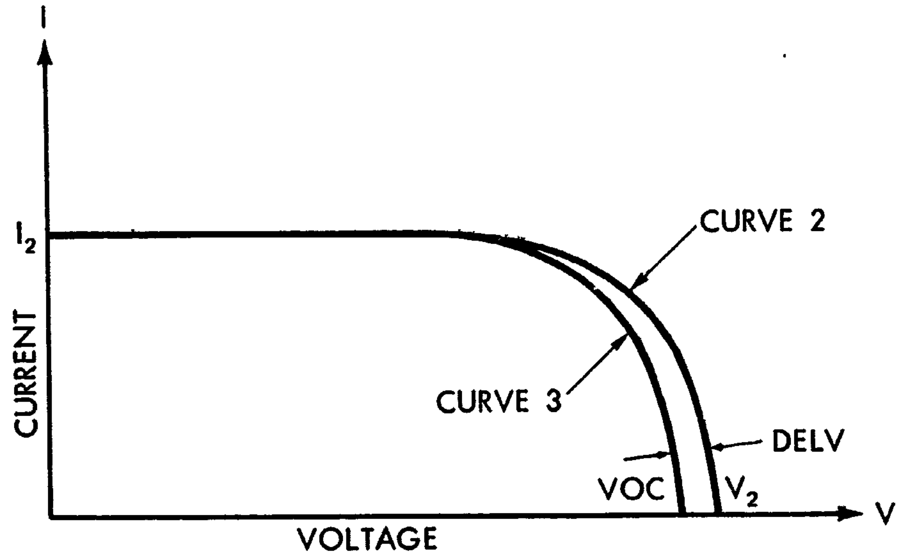

Figure 7. Open Circuit Voltage Degradation Effects

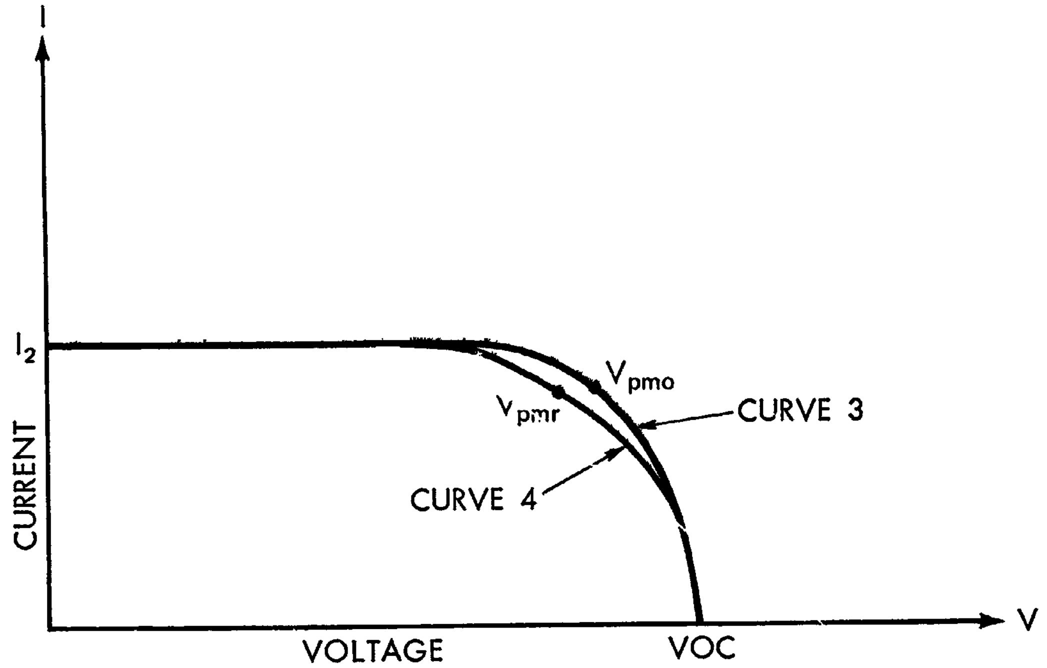

Figure 8. External Series Resistance Correction

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

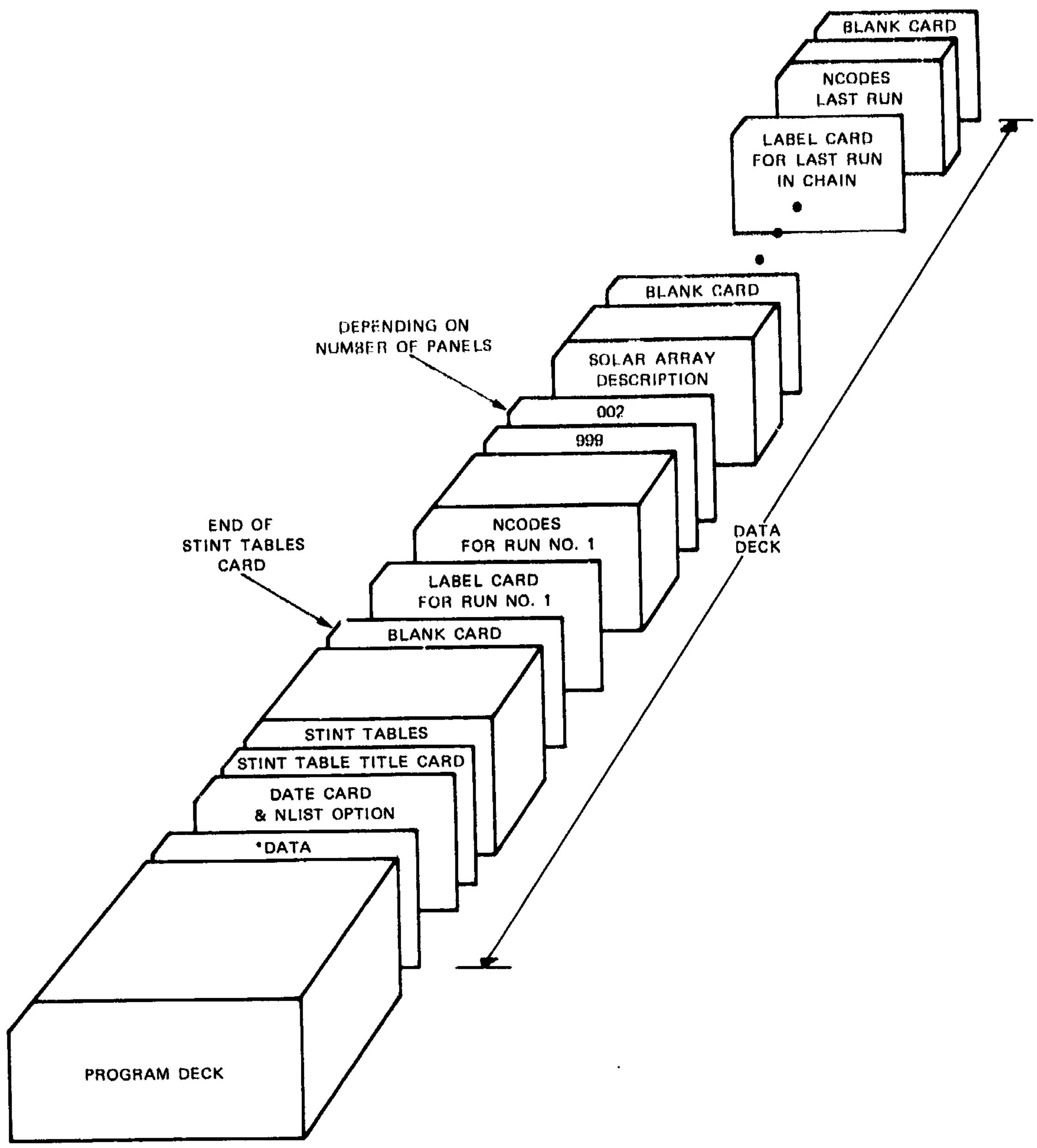

Figure 9. Program Assembly

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	PRO-GRAM 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.

ACKNOWLEDGMENT

The contribution of Mr. P. J. Hyland of RCA Astro-Electronics Division is recognized in the areas of simplifying the original engineering computations and translating these to FORTRAN Computer language.

Appendix A

```
C**** SOLAR ARRAY SYNTHESIS PROGRAM DEVELOPED FOR NASA (GSFC) BY RCA-AED
C****           PROGRAMMERS R.RASMUSSEN, P.J.HYLAND, JUNE 1968
      DIMENSION NDATE(3)
      DIMENSION T(20)
      DIMENSION XIA(20,100)
      DIMENSION XC(25),XS(25),NANGLE(25),NTEMPS(25)
C**** READ DATE
      IA=5
      IB=6
      READ  (IA,7000)NDATE(1),NDATE(2),NDATE(3),NLIST
      CALL SLITE (0)
      NRUN=1
      DO 6001 I=1,25
      XC(I)=0.0
      XS(I)=0.0
      NANGLE(I)=0
 6001 NTEMPS(I)=0
      TD=0.0
      DELTAT=1000.0
      SIGISC=0.0
      SIGVOC=0.0
      DI1=100.0
      DI2=100.0
      DI3=100.0
      DI4=100.0
      DV1=100.0
      DV2=100.0
      AVPMO=0.0
      AIPMO=0.0
      AVOCO=0.0
      THETA=100.0
      TNOT=0.0
      ADIODE=0.0
      DELTT=0.0
      ADDT=0.0
      FLUX=0.0
      CG=0.0
      BS=0.0
      BOHMS=0.0
      NDGRAD=0
      NEND=0
      NCELLT=1
      NKOST=2
      NELECT=3
      NPROTT=4
      NFLARE=5
      NALPHA=6
      NKDE=7
      NKDP=8
      NKDA=9
      NMVTBL=10
      NKDFL=8
      KEY=NLIST-1
C**** READ TABLES COMMENT CARD
  100 READ  (IA,7001)
C**** LOAD STINT TABLES
      CALL STINT (0.0,0.0,0.0,0.0,KEY,NGRIPE,0,0)
      IF (NGRIPE) 101,101,102
  102 WRITE (IB,7001)
      WRITE (IB,7002)
      PRINT 7002
      CALL EXIT
C**** READ RUN COMMENTS CARD
  101 READ  (IA,7003)
C**** PRINT HEADER CARD
      WRITE (IB,7004)NRUN,(NDATE(J),J=1,3)
```

```
      WRITE (IB,7001)
      WRITE (IB,7005)
      WRITE (IB,7003)
      WRITE (IB,7006)
C**** READ INPUT DATA,NCODES
  103 READ  (IA,7007)NCODE,PARAM
      IF (NCODE-999) 1103,106,1103
 1103 IF (NCODE) 105,105,5000
  106 READ  (IA,7007)NPANEL
      DO 6000 K=1,NPANEL
      READ  (IA,6600)P1,P2,P3,P4
 6600 FORMAT(10F10.5)
      XC(K)=P1
      XS(K)=P2
      NANGLE(K)=P3+.01
      NTEMPS(K)=P4+.01
 6000 WRITE (IB,6601)K,XC(K),XS(K),NANGLE(K),NTEMPS(K)
 6601 FORMAT (7HOPANEL  I3/ 16H SERIES CELLS = F5.1,20H PARALLEL STRINGS
     1 = F6.2,15H ANGLE TABLE = I2,14H TEMP TABLE = I2)
      WRITE (IB,6602)
 6602 FORMAT (1H0)
      GO TO 103
 5000 GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
     121,22,23,24,25),NCODE
    1 TD=PARAM
      WRITE (IB,201)NCODE,TD
      GO TO 103
    2 DELTAT=PARAM
      WRITE (IB,202)NCODE,DELTAT
      GO TO 103
    3 SIGISC=PARAM
      WRITE (IB,203)NCODE,SIGISC
      GO TO 103
    4 SIGVOC=PARAM
      WRITE (IB,204)NCODE,SIGVOC
      GO TO 103
    5 DI1=PARAM
      WRITE (IB,205)NCODE,DI1
      GO TO 103
    6 DI2=PARAM
      WRITE (IB,206)NCODE,DI2
      GO TO 103
    7 DI3=PARAM
      WRITE (IB,207)NCODE,DI3
      GO TO 103
    8 DI4=PARAM
      WRITE (IB,208)NCODE,DI4
      GO TO 103
    9 DV1=PARAM
      WRITE (IB,209)NCODE,DV1
      GO TO 103
   10 DV2=PARAM
      WRITE (IB,210)NCODE,DV2
      GO TO 103
   11 AVPMO=PARAM
      WRITE (IB,211)NCODE,AVPMO
      GO TO 103
   12 AIPMO=PARAM
      WRITE (IB,212)NCODE,AIPMO
      GO TO 103
   13 AVOCO=PARAM
      WRITE (IB,213)NCODE,AVOCO
      VOCOI=AVOCO
      GO TO 103
   14 THETA=PARAM
      WRITE (IB,214)NCODE,THETA
```

```
      THETA=THETA/100.0
      GO TO 103
   15 TNOT=PARAM
      WRITE (IB,215)NCODE,TNOT
      GO TO 103
   16 ADIODE=PARAM
      WRITE (IB,216)NCODE,ADIODE
      GO TO 103
   17 DELTT=PARAM
      WRITE (IB,217)NCODE,DELTT
      GO TO 103
   18 ADDT=PARAM
      WRITE (IB,218)NCODE,ADDT
      GO TO 103
   19 FLUX=PARAM
      WRITE (IB,219)NCODE,FLUX
      GO TO 103
   20 CG=PARAM
      WRITE (IB,220)NCODE,CG
      GO TO 103
   21 BS=PARAM
      WRITE (IB,221)NCODE,BS
      GO TO 103
   22 BOHMS=PARAM
      WRITE (IB,222)NCODE,BOHMS
      GO TO 103
   23 NDGRAD=PARAM+.01
      WRITE (IB,223)NCODE,NDGRAD
      GO TO 103
   24 NEND=PARAM+.01
      WRITE (IB,224)NCODE,NEND
      GO TO 103
   25 CONTINUE
      GO TO 103
C**** END DATA LOADER
C**** HOUSEKEEPING FOLLOWS
  105  IF (NDGRAD) 70,501,70
   70 DISC=(DI1/100.)*(DI2/100.)*(DI3/100.)*(DI4/100.)
      DV  =(DV1/100.)*(DV2/100.)
      IF(BOHMS-5.0)81,81,82
   81 DENFAC=0.065
      GO TO 83
   82 DENFAC=0.0
   83 PHITOT=FLUX
      IF(FLUX)71,73,72
   71 CALL PHI (CG,BS,NKDE,NKDP,NKDFL,NELECT,NPROTT,NFLARE,
     1NALPHA,NKDA,PHITOT)
      FLUX=PHITOT
   72 CALL DEGRAD (PHITOT,BOHMS,NCELLT,NMVTBL)
      CALL SLITE (1)
C**** INITIAL ENTRY INTO SUBROUTINE STASH,INITIALIZATION
   73 CALL STASH (DISC,THETA,AVPMO,AIPMO,TNOT,-1,NGRIPE,NCELLT,VOCOI,
     1ADDT,DELTT)
C
 **** SECOND ENTRY INTO SUBROUTINE STASH,INITIALIZATION
      CALL STASH (DV,DISC,SIGISC,SIGVOC,TNOT,0,NGRIPE,NCELLT,DENFAC,ADDT
     1,DELTT)
      IF(NGRIPE)74,76,74
   74 WRITE (IB,7009)
      CALL EXIT
   76 GO TO (80,30,501,501),NEND
   30 NRUN=NRUN+1
      GO TO 101
   80 CONTINUE
      CALL EXIT
```

```
  201 FORMAT (17,50H TD,ORBIT SUNTIME DURATION (MINUTES)
     1F12.4)
  202 FORMAT (17,50H DELTAT,TIME BETWEEN CALCULATIONS (MINUTES)
     1F12.4)
  203 FORMAT (17,50H SIGISC,ISC TEMP. COEF.(AMPS/DEG.C)
     1F12.6)
  204 FORMAT (17,50H SIGVOC,VOC TEMP. COEF.(VOLTS/DEG.C)
     1F12.6)
  205 FORMAT (17,50H DI1,ISC DEGRADATION FACTOR (PERCENT)
     1F12.4)
  206 FORMAT (17,50H DI2,ISC DEGRADATION FACTOR (PERCENT)
     1F12.4)
  207 FORMAT (17,50H DI3,ISC DEGRADATION FACTOR (PERCENT)
     1F12.4)
  208 FORMAT (17,50H DI4,ISC DEGRADATION FACTOR (PERCENT)
     1F12.4)
  209 FORMAT (17,50H DV1,VPM DEGRADATION FACTOR (PERCENT)
     1F12.4)
  210 FORMAT (17,50H DV2,VPM DEGRADATION FACTOR (PERCENT)
     1F12.4)
  211 FORMAT (17,50H AVPMO,VPM OF UNDEGRADED CELL (VOLTS)
     1F12.4)
  212 FORMAT (17,50H AIPMO,IPM OF UNDEGRADED CELL (VOLTS)
     1F12.4)
  213 FORMAT (17,50H AVOCO,VOC OF UNDEGRADED CELL (VOLTS)
     1F12.4)
  214 FORMAT (17,50H THETA,VOC DEGRADATION FACTOR (PERCENT)
     1F12.4)
  215 FORMAT (17,50H TNOT,SOLAR CELL REFERENCE TEMP.(DEG.C)
     1F12.4)
  216 FORMAT (17,50H ADIODE,ARRAY BLOCKING DIODE DROP (VOLTS)
     1F12.4)
  217 FORMAT (17,50H DELTT, TEMP. INCREMENT FOR STASH STORAGE (DEG.C)
     1F12.4)
  218 FORMAT (17,50H ADDT, HIGHEST STASH TEMP. MINUS TNOT (DEG.C)
     1F12.4)
  219 FORMAT (17,50H FLUX,DENI 1-MEV ELECTRON FLUX (ELEC/SQ.CM.)
     1E12.4)
  220 FORMAT (17,50H CG,COVER GLASS THICKNESS (MILS)
     1F12.4)
  221 FORMAT (17,50H BS,BACKSHIELDING THICKNESS (MILS. OF ALUM.)
     1F12.4)
  222 FORMAT (17,50H BOHMS,SOLAR CELL BASE RESISTIVITY (OHM-CM)
     1F12.4)
  223 FORMAT (17,50H NDGRAD,INITIALIZE STASH (1.0 OR 0.0)
     118)
  224 FORMAT (17,50H NEND,END OF RUNS KEY (1.0,2.0,3.0 OR 4.0)
     118)
  225 FORMAT (17,50H NLIST,STINT TABLE LISTING OPTION (1.0 OR 0.0)
     118)
C**** FORMATS
 7000 FORMAT (312,2X,I1)
 7001 FORMAT (72H
     1          )
 7002 FORMAT (34H  UNABLE TO READ TABLES, ABORT RUN)
 7003 FORMAT (72H
     1               )
 7004 FORMAT (12H1    RUN NO.13,18H  ON THIS DATE OF 12,1H-12,1H-12,75H
     1              SOLAR ARRAY SYNTHESIS PROGRAM
     2        /20H0    TABLE COMMENTS.)
 7005 FORMAT (18H0    RUN COMMENTS.)
 7006 FORMAT (30H0    NEW OR CHANGED PARAMETERS/1H0)
 7007 FORMAT (13,1X,F20.0)
 7008 FORMAT (35H0    ERROR IN TABLE LOOKUP, NGRIPE =I1)
 7009 FORMAT (25H STASH DID NOT INITIALIZE)
C**** START SOLAR ARRAY COMPUTATIONS
```

```
  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
  599 K=1
  600 CALL STINT (T(INCR),0.0,0.0,PANANG,1,NGRIPE,NANGLE(K),NANGLE(K))
      IF (NGRIPE)690,601,690
  690 NGRIPE=1
      GO TO 1000
  601 CALL STINT (T(INCR),0.0,0.0,PTEMP,1,NGRIPE,NTEMPS(K),NTEMPS(K))
      IF (NGRIPE)691,602,691
  691 NGRIPE=2
      GO TO 1000
  602 CALL STINT(PANANG,0.0,0.0,EFFECT,1,NGRIPE,2,2)
      IF (NGRIPE)692,603,692
  692 NGRIPE=3
      GO TO 1000
  603 JVOLT=1
      IF (EFFECT) 607,607,604
  604 AVOLT=FLOAT (JVOLT)-1.0+ADIODE
      ARG1=AVOLT/XC(K)
      IF(JVOLT-1)610,610,611
C**** GET VALUE OF FULL INTENSITY ISC FROM STASH
  610 CALL STASH(TLU,0.0,0.0,PTEMP,0.0,1,0.0,0.0,0.0,0.0,DELTT)
      DELI=TLU*(1.0-EFFECT)
      PHIL=1.0/EFFECT
      DELVOC=(0.026*(273.0+PTEMP)/300.0)*ALOG  (PHIL)
C**** GET VALUE OF FULL INTENSITY VOC FROM STASH
      CALL STASH(OCV,0.0,0.0,PTEMP,0.0,989,0.0,0.0,0.0,0.0,DELTT)
C**** GET VALUE OF VOLTAGE AT CURRENT DELI FROM STASH
      CALL STASH(VAI,0.0,DELI,PTEMP,0.0,988,0.0,0.0,0.0,0.0,DELTT)
      DELTAV=OCV-VAI-DELVOC
  611 IF(ARG1-DELTAV)606,605,605
  605 ARG1=ARG1-DELTAV
  606 CALL STASH(CELLI,0.0,ARG1,PTEMP,0.0,1,0.0,0.0,0.0,0.0,DELTT)
      PANELI=XS(K)*(CELLI-DELI)
      IF(PANELI)607,607,609
  607 PANELI=0.0
  608 K=K+1
      IF(NPANEL-K)502,600,600
  609 XIA(INCR,JVOLT)=XIA(INCR,JVOLT)+PANELI
      JVOLT=JVOLT+1
      IF(100-JVOLT)608,604,604
 1000 WRITE (IB,7008)NGRIPE
      CALL EXIT
  700 WRITE (IB,9000)ADIODE
      T(INCR+1)=0.0
      IBEG=1
      IEND=10
      DO 400 K=1,2
      AVOLT=0.0
      WRITE (IB,9001)(T(INCR),INCR=IBEG,IEND)
  401 DO 410 J=1,100
      WRITE (IB,9002)AVOLT,(XIA(INCR,J),INCR=IBEG,IEND)
      AVOLT=AVOLT+1.0
  402 DO 420 L=IBEG,IEND
      IF (XIA(L,J)-0.0)410,420,410
  420 CONTINUE
```

```
      GO TO 430
  410 CONTINUE
  430 IBEG=11
      IEND=20
      WRITE (IB,9003)
  400 CONTINUE
      NRUN=NRUN+1
      GO TO (80,80,80,101),NEND
 9000 FORMAT (60H1                                      SOLAR ARRAY I-V CURVES WI
     1TH  (F4.2,28H) VOLTS BLOCKING DIODE DROP   )
 9001 FORMAT (/17H TIME IN SUNLIGHT/11H  (MINUTES)10F10.2,//51X,16HCURRE
     1NT(AMPERES)/2X,5HVOLTS)
 9002 FORMAT (F5.1,6X,10F10.2)
 9003 FORMAT (1H1)
      END
      SUBROUTINE STINT (ARG1,ARG2,ARG3,FCT,KEY,NGRIPE,MINTBL,MAXTBL)
      DIMENSION NUMPTS(61),L1(60),L2(60),L3(60),STG(3600),DUMMY(10)
      DIMENSION NAME (14)
      EQUIVALENCE (NAT,L3(1))
C**** SIZE OF STG IS CALCULATED BY SUM OF ((1+N(ARG1))*(1+N(ARG2)))
      IA=5
      IB=6
      NGRIPE=0
      IF (KEY) 1,1,70
  646 FORMAT(1X,10E11.4,I2)
    1 NG=1
      NORMAL=1
      WRITE (IB,1357)
 1357 FORMAT (34H0  TABLE        DATE        CONTENTS)
      GO TO 55
 2000 NG=2
      NORMAL=2
      WRITE (IB,1257)
 1257 FORMAT (1H1)
 3000 RETURN
  775 NGRIPE=1
      RETURN
  776 NGRIPE=2
      WRITE (IB,9000)ARG1,ARG2,ARG3,MINTBL,MAXTBL
      RETURN
 9000 FORMAT (20H0 ERROR IN TLU,ARG1=E12.5,6H ARG2=E12.5,6H ARG3=E12.5,
     18H MINTBL=I4,8H MAXTBL=I4)
C     BEGINNING OF STINT
   55 NUMTBL=1
      NUMPTS(1)=0
  102 READ  (IA,57)DA1,DA2,DA3,K,L1(NUMTBL),L2(NUMTBL),NAME,   ISEQ
   57 FORMAT (A2,A3,A3,I4,2I2,13A4,A2,I2)
      WRITE (IB,1157)K,DA1,DA2,DA3,NAME
 1157 FORMAT (/I8,5X,A2,A3,A3,5X,13A4,A2)
  104 IF(ISEQ) 69,58,69
   58 IF (K)  99,99,1159
 1159 IF (K-60) 59,59,1103
   59 L8=L1(NUMTBL)
      N1=(L8-1)/9+1
      DO 68 IS=1,N1
      NAT=(IS-1)*9+1
      IF (IS-N1) 60,61,60
   60 L4=NAT+8
      GO TO 62
   61 L4=L8
   62 L5=NUMPTS(NUMTBL)+1
      L6=L5+NAT
      L7=L5+L4
      JJ=0
      L9=L2(NUMTBL)
      LM=L5+L8
```

```
      LN=LM+L9
  105 READ  (IA,64)(DUMMY(K),K=1,10),ISEQ
   64 FORMAT (10E7.0,I2)
      IF (KEY) 107,11,11
   11 WRITE (IB,646)(DUMMY(K),K=1,10),ISEQ
  107 STG(L5)=DUMMY(1)
      K=2
      DO 65 J=L6,L7
      STG(J)=DUMMY(K)
   65 K=K+1
      IF (ISEQ-((IS-1)*(L9+1)+JJ+1)) 69,66,69
   66 L6=LN+NAT
      L7=LN+L4
      L5=LM+1+JJ
      IF (JJ-L9) 67,68,69
   67 JJ=JJ+1
      LN=LN+L8
      GO TO 105
   68 CONTINUE
  109 LEE=NUMPTS(NUMTBL)+(L8+1)*(L9+1)
      IF (LEE-3600) 1100,1100,1101
 1100 IF (NUMTBL-60) 1102,108,1103
 1102 NUMPTS(NUMTBL+1)=LEE
  108 NUMTBL=NUMTBL+1
      GO TO 102
 1101 WRITE (IB,1111)LEE
      GO TO 775
 1103 WRITE (IB,1113)NUMTBL
      GO TO 775
 1111 FORMAT (17H TOO MANY POINTS  I8)
 1113 FORMAT (17H TOO MANY TABLES  I8)
   69 GO TO (775,776,776),NG
   70 IF (MINTBL-MAXTBL) 71,100,69
   71 DO 73 NAT=MINTBL,MAXTBL
      L4=NUMPTS(NAT)+1
      IF (ARG3-STG(L4)) 72,74,73
   72 IF(NAT-MINTBL)69,69,75
   73 CONTINUE
      GO TO 69
   75 L5=1
      L6=2
      L7=L4
  101 DO 9/ L8=L5,L6
      L4=NUMPTS(NAT)+1
      L9=L1(NAT)
      LM=L9+L4
      DO 77 LN=1,L9
      JJ=L4+LN
 2626 IF (ARG1-STG(JJ)) 76,78,77
   76 IF (LN-1) 69,69,79
   77 CONTINUE
      GO TO 69
   78 N1=-1
      GO TO 80
   79 N1=+1
   80 K=L2(NAT)
      DO 82 I=1,K
      IDATE=LM+I
      IF (ARG2-STG(IDATE)) 81,83,82
   81 IF (I-1) 69,69,84
   82 CONTINUE
      GO TO 69
   83 IS=-1
      GO TO 85
   84 IS=+1
   85 ISEQ=LM+L2(NAT)+LN+(I-1)*L9
```

```
      J=ISEQ-L9
      K8=LM+(I-1)
      K9=L4+LN-1
      IF (N1+IS) 86,88,91
   86 IF (STG(ISEQ)-999.E20) 87,69,69
   87 FCT=STG(ISEQ)
      GO TO 95
   88 IF (N1) 89,69,93
   89 IF (AMAX1 (STG(ISEQ),STG(J))-999.E20) 90,69,69
   90 FCT=STG(ISEQ)-(STG(IDATE)-ARG2)*(STG(ISEQ)-STG(J))/(STG(IDATE)
     1-STG(K8))
      GO TO 95
   91 IF (AMAX1 (STG(ISEQ),STG(J),STG(ISEQ-1),STG(J-1))-999.E20) 92,
     1 69,69
   92 FCT=((STG(IDATE)-ARG2)*((STG(JJ)-ARG1)*STG(J-1)-(STG(K9)-ARG1)
     1*STG(J))-(STG(K8)-ARG2)*((STG(JJ)-ARG1)*STG(ISEQ-1)-(STG(K9)-
     2ARG1)*STG(ISEQ)))/((STG(IDATE)-STG(K8))*(STG(JJ)-STG(K9)))
      GO TO 95
   93 IF (AMAX1 (STG(ISEQ),STG(ISEQ-1))-999.E20) 94,69,69
   94 FCT=STG(ISEQ)-(STG(JJ)-ARG1)*(STG(ISEQ)-STG(ISEQ-1))/(STG(JJ)-
     1STG(K9))
   95 GO TO (96,98,99),L8
   96 DUMMY(1)=FCT
   97 NAT=NAT-1
   98 FCT=DUMMY(1)-(STG(L7)-ARG3)*(DUMMY(1)-FCT)/(STG(L7)-STG(L4))
   99 GO TO (2000,3000),NORMAL
  100 NAT=MINTBL
   74 L5=3
      L6=3
      GO TO 101
C     END STINT   TABLE LOOK-UP
      END

      SUBROUTINE PHI (CG,BS,NKDE,NKDP,NKDFL,NELECT,NPROTT,NFLARE,
     1NALPHA,NKDA,PHITOT)
      IA=5
      IB=6
      GLASS=CG/6.0
      SCBACK=BS/5.0
      PHIELE = 0.0
      PHIPRO = 0.0
      PHIFLR = 0.0
      PHIALP = 0.0
      PHITOT = 0.0
C**** COMPUTE ELECTRON FLUX
      DO 1 I = 1,11
      DUM = FLOAT (I)
      CALL STINT (DUM,GLASS,0.0,XKDE,1,NGRIPE,NKDE,NKDE)
      CALL STINT (DUM,SCBACK,0.0,YKDE,1,NGRIPE,NKDE,NKDE)
      CALL STINT (DUM,0.0,0.0,XNE,1,NGRIPE,NELECT,NELECT)
      PHIELE = PHIELE + XNE*XKDE + XNE*YKDE
      IF (NGRIPE) 10,1,10
   10 NGRIPE = 5555
      GO TO 11
    1 CONTINUE
C**** COMPUTE PROTON FLUX
      DO 2 I = 1,18
      DUM = FLOAT (I)
      CALL STINT (DUM,GLASS,0.0,XKDP,1,NGRIPE,NKDP,NKDP)
      CALL STINT (DUM,SCBACK,0.0,YKDP,1,NGRIPE,NKDP,NKDP)
      CALL STINT (DUM,0.0,0.0,XNP,1,NGRIPE,NPROTT,NPROTT)
      PHIPRO = PHIPRO + XNP*XKDP + XNP*YKDP
      IF (NGRIPE) 20,2,20
   20 NGRIPE = 6666
      GO TO 11
    2 CONTINUE
```

```
C**** COMPUTE SOLAR FLARE PROTON FLUX
      DO 3 I = 1,18
      DUM = FLOAT (I)
      CALL STINT (DUM,GLASS,0.0,XKDL,1,NGRIPE,NKDFL,NKDFL)
      CALL STINT (DUM,SCBACK,0.0,YKDL,1,NGRIPE,NKDFL,NKDFL)
      CALL STINT (DUM,0.0,0.0,XNF,1,NGRIPE,NFLARE,NFLARE)
      PHIFLR = PHIFLR + XNF*XKDL + XNF*YKDL
      IF (NGRIPE) 30,3,30
   30 NGRIPE = 7777
      GO TO 11
    3 CONTINUE
C**** COMPUTE SOLAR FLARE ALPHA PARTICLE FLUX
      DO 4  I = 1,18
      DUM = FLOAT (I)
      CALL STINT (DUM,GLASS,0.0,XKDA,1,NGRIPE,NKDA,NKDA)
      CALL STINT (DUM,SCBACK,0.0,YKDA,1,NGRIPE,NKDA,NKDA)
      CALL STINT (DUM,0.0,0.0,XNA,1,NGRIPE,NALPHA,NALPHA)
      PHIALP = PHIALP + XNA*XKDA + XNA*YKDA
      IF (NGRIPE) 40,4,40
   40 NGRIPE = 8888
      GO TO 11
    4 CONTINUE
C**** COMPUTE TOTAL FLUX
      PHITOT = PHIELE + PHIPRO + PHIFLR + PHIALP
      WRITE (IB,100)
  100 FORMAT (58H1 SUMMATIONS OF ELECTRON,PROTON, AND SOLAR FLARE PARTIC
     1LES//89H   ELECTRONS       PROTONS       SOLAR FLARE PROTONS      SOLA
     2R FLARE ALPHA PARTICLES   TOTAL//)
      WRITE (IB,101)PHIELE,PHIPRO,PHIFLR,PHIALP,PHITOT
  101 FORMAT (1X,E12.4,2X,E12.4,E12.4,13X,E12.4,19X,E12.4)
      WRITE (IB,102)
  102 FORMAT (54H0 NOTE, THESE FLUXES ARE IN EQUIVALENT 1 MEV ELECTRONS)
      RETURN
   11 WRITE (IB,103)NGRIPE
      CALL EXIT
  103 FORMAT (15H0 ERROR IN TLU IS)
      END
      SUBROUTINE DEGRAD (PHITOT,BOHMS,NCELLT,NMVTBL)
      DIMENSION VVEC(101),XIVEC(101)
      COMMON VVEC,XIVEC
      IA=5
      IB=6
      VVEC(1) = 0.0
      XIVEC(1) = 0.0
      DO 1 I = 2,101
      XIVEC(I) = 0.0
    1 VVEC(I) = VVEC(I-1) + 0.01
      DO 3 I = 1,101
      CALL STINT (VVEC(I),0.0,0.0,XIVEC(I),1,NGRIPE,NCELLT,NCELLT)
      IF (NGRIPE)  2,3,2
    2 WRITE (IB,100)
  100 FORMAT (48H0 ERROR IN DEGRADATION ROUTINE TLU OF CELL CURVE)
      CALL EXIT
    3 CONTINUE
C**** TLU OF MILLIVOLTS AT ISC VS. TOTAL FLUX AND BASE RESTIVITY
      CALL STINT (PHITOT,BOHMS,0.0,XMV,1,NGRIPE,NMVTBL,NMVTBL)
      IF (NGRIPE) 4,5,4
    4 NGRIPE = NMVTBL
      WRITE (IB,101)NGRIPE
  101 FORMAT (25H0 ERROR IN TLU, TABLE NO.15)
C**** COMPUTE RR
    5 XISCO = XIVEC(1)
      RR = XMV/XISCO
C**** CHANGE VVEC
      DO 6 I = 1,101
      VVEC(I) = VVEC(I) + XIVEC(I)*RR
```

```
    6 CONTINUE
C**** FIND VOCO
      DO 7 I = 2,101
      N= I
      IF (XIVEC(I)) 8,8,7
    7 CONTINUE
    8 SLOPE = (XIVEC(N-1)-XIVEC(N-2))/(VVEC(N-1)-VVEC(N-2))
      DO 9 J = N,101
    9 XIVEC(J) = XIVEC(N-1)+(VVEC(J)-VVEC(N-1))*SLOPE
      VOCO = VVEC(N-1) + XIVEC(N-1)*(VVEC(N)-VVEC(N-1))/(XIVEC(N-1)
     1  -XIVEC(N))
C**** COMPUTE RI FOR TOTAL PHI
      IF (BOHMS - 1.0) 10,10,13
   10 IF (PHITOT - 1.0E15) 11,12,12
   11 IF (PHITOT - 4.0E12) 17,17,18
   12 RI = 3.3 - 0.167*0.4342944819*ALOG  (PHITOT)
      GO TO 16
   13 IF (PHITOT - 1.0E15) 14,15,15
   14 IF (PHITOT - 5.0E12) 17,17,19
   15 RI = 2.806 - 0.1325*0.4342944819*ALOG   (PHITOT)
      GO TO 16
   17 RI = 1.0
      GO TO 16
   18 RI = 1.0 - 7.13/((10.0)** 8.31)*((PHITOT-4.0E12)**0.451)
      GO TO 16
   19 RI = 1.0 - 2.78/((10.0)** 7.34)*((PHITOT-5.0E12)**0.41)
C**** COMPUTE DELTAI
   16 DELTAI = XISCO*(1.0 - RI)
C**** CHANGE XIVEC
      DO 20  I = 1,101
      XIVEC(I) = XIVEC(I) - DELTAI
   20 CONTINUE
C**** FIND PZC, POINT OF ZERO CURRENT
      DO 21  I = 2,101
      N = I
      IF (XIVEC(I))22,22,21
   21 CONTINUE
   22 SLOPE = (XIVEC(N-1)-XIVEC(N-2))/(VVEC(N-1)-VVEC(N-2))
      DO 23 J = N,101
   23 XIVEC(J) = XIVEC(N-1)+(VVEC(J)-VVEC(N-1))*SLOPE
      PZC = VVEC(N-1)+XIVEC(N-1)*(VVEC(N)-VVEC(N-1))/(XIVEC(N-1)
     1  -XIVEC(N))
C**** COMPUTE RV FOR TOTAL PHI
      IF (PHITOT - 1.0E14) 25,24,24
   24 RV = 1.779 - 0.0588*0.4342944819*ALOG  (PHITOT)
      GO TO 26
   25 IF (PHITOT - 3.0E12) 27,27,28
   27 RV = 1.0
      GO TO 26
   28 RV = 1.0 - 0.0222*((0.4342944819*ALOG  (PHITOT/3.0E12))**1.67)
C**** COMPUTE VOCR
   26 VOCR = VOCO*RV
      DELTAV = PZC - VOCR
C**** FINAL UPDATE OF VOLTAGES IN ARRAY
      DO 30  I = 1,101
      VVEC(I) = VVEC(I) - DELTAV
   30 CONTINUE
C**** COMPUTE ISCR,IPMR,VPMR
   31 DO 33  I = 1,101
      IF (VVEC (I)) 33,32,32
   32 XISCR = XIVEC(I)
      GO TO 34
   33 CONTINUE
   34 N = 1
      PWR = -1000000.0
   40 PWRT = VVEC(N)*XIVEC(N)
```

```
      IF (PWRT-PWR) 42,44,41
   41 N = N+1
      PWR = PWRT
      GO TO 40
   44 VPMR = VVEC(N)
      XIPMR = XIVEC(N)
      GO TO 45
   42 SLOPE = (XIVEC(N-1)-XIVEC(N))/(VVEC(N)-VVEC(N-1))
   43 VPMR = VVEC(N-1) + 0.00015
      XIPMR = XIVEC(N-1) - SLOPE*(VPMR - VVEC(N-1))
      PWRT = VPMR*XIPMR
      IF (PWRT-PWR) 45,45,48
   48 PWR = PWRT
      GO TO 43
   45 WRITE (IB,102)
  102 FORMAT (43H1 SOLAR CELL I-V CURVE IRRADIATION-DEGRADED)
      WRITE (IB,103)XISCR,XIPMR,VPMR,VOCR
  103 FORMAT (36H0   SHORT-CIRCUIT CURRENT (AMPS)  = F10.6/36H0   CURREN
     1T AT MAX PWR PT (AMPS)  = F10.6/36H0   VOLTAGE AT MAX PWR PT (VOLT
     2S) = F10.6/36H0   OPEN-CIRCUIT VOLTAGE (VOLTS)  = F10.6//)
      WRITE (IB,105)
  105 FORMAT (20H0 DEGRADED I-V CURVE//17H  VOLTS      AMPS//)
      DO 46  I = 1,101,2
      WRITE (IB,106)VVEC(I),XIVEC(I)
  106 FORMAT (2F12.6)
   46 CONTINUE
      RETURN
      END
      SUBROUTINE STASH (SIGISC,SIGVOC,DISC,DV,TNOT,KEY,NGRIPE,NCELLT,
     1VOCOI,ADDT,DELTT)
      DIMENSION VVEC(101),XIVEC(101),TEMP(15),VMAP(15,101),XIMAP(15,101)
      DIMENSION VOCT(15),XISCT(15),VMP(15),XIMP(15)
      DIMENSION PWRSTG(15)
      COMMON VVEC,XIVEC
C     DECIDE IF INITIALIZATION OR COMPUTATION
      IA=5
      IB=6
      NGRIPE=0
      IF(KEY)2000,3000,1000
C     INITIALIZATION - OBTAIN I AND V INPUT VECTORS
C     ***********************************************************
C     IN FIRST ENTRY
C     SIGISC IS DISC
C     SIGVOC IS THETA
C     DISC IS AVPMO
C     DV IS AIPMO
C     TNOT IS TNOT
C     KEY IS -1
C     NGRIPE IS NGRIPE
C     NCELLT IS NCELLT
C     VOCOI IS VOCOI
C     ADDT IS ADDT
C     DELTT IS DELTT
 2000 CALL SLITET (1, K001FX)
      GO TO (2005,5000), K001FX
 5000 VVEC(1)=0.0
      XIVEC(1)=0.0
      DO 2001 I=2,101
      XIVEC(I)=0.0
 2001 VVEC(I) = VVEC(I-1) + 0.010
      DO 2002 I = 1,100
      CALL STINT (VVEC(I),0.0,0.0,XIVEC(I),1,NGRIPE,NCELLT,NCELLT)
      IF(NGRIPE)2002,2002,2003
 2002 CONTINUE
      GO TO 2005
 2003 IF (XIVEC(I-1))2005,2005,12003
```

```
12003 RETURN
C     EXTRAPOLATE INPUT CURVE
C     LOCATE FIRST ZERO ELEMENT IN XIVEC
 2005 DO 2107 I = 2,101
      N=I
      IF(XIVEC(I))2106,2106,2107
 2107 CONTINUE
 2106 SLOPE=(XIVEC(N-1)-XIVEC(N-2))/(VVEC(N-1)-VVEC(N-2))
C     LOCATE POINT OF ZERO CURRENT FOR UNDEGRADED CURVE
      PZCU = VVEC(I) - XIVEC(I)/SLOPE
      DO 2108 J = N,101
 2108 XIVEC(J)=XIVEC(N-1)+(VVEC(J)-VVEC(N-1))*SLOPE
C     DO CURRENT DEGRADATION WITH GAMMA,TNOT,THETA
      XISC = XIVEC(1)
      GAMMA=SIGISC
      DELTAI=(1.0-GAMMA)*XISC
      RECIP=1.0/GAMMA
      THETA=SIGVOC


      DELTAV=(TNOT+273.16)*0.8614E-04*ALOG  (RECIP)
      DELTAV = DELTAV + (1.0 - THETA)*VOCOI
      DO 2600 I = 1,101
      XIVEC(I) = XIVEC(I) - DELTAI
      IF (XIVEC(I)) 2703,2703,2600
 2703 KIX = I - 1
      LOU = I+ 1
      DO 2622 L = LOU,101
 2622 XIVEC(L) = XIVEC(L) - DELTAI
      GO TO 2006
 2600 CONTINUE
 2006 CONTINUE
C     LOCATE POINT OF ZERO CURRENT FOR DEGRADED CURVE
      SLOPE = (XIVEC(KIX) - XIVEC(KIX-1))/(VVEC(KIX) - VVEC(KIX-1))
      PZCD = VVEC(KIX) - XIVEC(KIX)/SLOPE
      DELTAV = (PZCU - PZCD) - DELTAV
      DO 2704 I = 2,101
 2704 VVEC(I) = VVEC(I) + DELTAV
C     CURRENT DEGRADATION IS NOW COMPLETE
C     GO ON TO DO SERIES RESISTANCE DEGRADATION
C     STORE AIPMO AND AVPMO AND FETCH NEW BATCH OF VARIABLES
      AIPMO=DV
      AVPMO=DISC
      RETURN
C*****************************************************************
C     IN SECOND CALL
C     SIGISC IS DV
C     SIGVOC IS DISC
C     DISC IS SIGISC
C     DV IS SIGVOC
C     TNOT IS TNOT
C     KEY IS 0
C     NGRIPE IS NGRIPE
C     NCELLT IS NCELLT
C     VOCOI IS DENFAC
C     ADOT IS ADOT
C     DELTT IS DELTT
 3000 ALFA=SIGISC
      DENFAC=VOCOI
      TKI=DISC
      TKV=DV
      RES=((1.0-ALFA)*AVPMO/AIPMO)
      DO 3001 I = 1,101
 3001 VVEC(I)=VVEC(I)-XIVEC(I)*RES
C     SERIES RESISTANCE DEGRADATION IS NOW COMPLETE
```

```
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) = XIMAP(I,N)
      GO TO 4009
 4010 CONTINUE
 4009 CONTINUE
C     EDIT RESULTS
```

```
      WRITE (IB,7000)
      WRITE (IB,7001)(TEMP(J),J=1,15)
      WRITE (IB,7002)(XIMP(J),J=1,15)
      WRITE (IB,7003)(VMP(J),J=1,15)
      WRITE (IB,7006)(VOCT(I),I=1,15)
      WRITE (IB,7007)(XISCT(I),I=1,15)
      WRITE (IB,7008)(PWRSTG(I),I=1,15)
      DO 2040 J=1,30,2
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)
 2040 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)
      WRITE (IB,7000)
      WRITE (IB,7001)(TEMP(J),J=1,15)
      WRITE (IB,7002)(XIMP(J),J=1,15)
      WRITE (IB,7003)(VMP(J),J=1,15)
      WRITE (IB,7006)(VOCT(I),I=1,15)
      WRITE (IB,7007)(XISCT(I),I=1,15)
      WRITE (IB,7008)(PWRSTG(I),I=1,15)
      DO 2041 J = 31,60,2
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)
 2041 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)
      WRITE (IB,7000)
      WRITE (IB,7001)(TEMP(J),J=1,15)
      WRITE (IB,7002)(XIMP(J),J=1,15)
      WRITE (IB,7003)(VMP(J),J=1,15)
      WRITE (IB,7006)(VOCT(I),I=1,15)
      WRITE (IB,7007)(XISCT(I),I=1,15)
      WRITE (IB,7008)(PWRSTG(I),I=1,15)
      DO 2042 J = 61,90,2
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)
 2042 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)
      WRITE (IB,7000)
      WRITE (IB,7001)(TEMP(J),J=1,15)
      WRITE (IB,7002)(XIMP(J),J=1,15)
      WRITE (IB,7003)(VMP(J),J=1,15)
      WRITE (IB,7006)(VOCT(I),I= 1,15)
      WRITE (IB,7007)(XISCT(I),I=1,15)
      WRITE (IB,7008)(PWRSTG(I),I=1,15)
      DO 2043 J = 91,99,2
      WRITE (IB,7004)J,(XIMAP(I,J),I=1,15)
 2043 WRITE (IB,7005)J,(VMAP(I,J),I=1,15)
      RETURN
C     EDIT FORMATS
 7000 FORMAT (104H1  EDIT OF TEMPERATURE AND DEGRADATION CORRECTED SOLAR
     1 CELL I-V CURVES FOR SOLAR ARRAY SYNTHESIS PROGRAM)
 7001 FORMAT (14H0 TEMPERATURES15F7.0)
 7002 FORMAT (14H0 I-MAX PWR    15F7.4)
 7003 FORMAT (14H  V-MAX PWR    15F7.4)
 7004 FORMAT (4H0 I(I2,8H)         15F7.4)
 7005 FORMAT (4H  V(I2,8H)         15F7.4)
 7006 FORMAT (14H  VOLTS OC     15F7.4)
 7007 FORMAT (14H  AMPS  SC     15F7.4)
 7008 FORMAT (14H  MAX POWER    15F7.4)
C     LOOK UP CURRENT AND MAX PWR POINT GIVEN VCELL + TEMPERATURE
 1000 VCELL=DISC
      HELHOT=DV
      NK = (TEMP(1) - HELHOT)/DELTT
      NHI=NK+1
      NLO=NK+2
      IF (KEY - 989) 1334,1333,1334
C     FOR KEY = 989 INTO SIGISC PUT OPEN CIRCUIT VOLTAGE AT TEMPETATURE
 1333 SIGISC = VOCT(NLO)+((DV-TEMP(NLO))/DELTT)*(VOCT(NHI)-VOCT(NLO))
      RETURN
 1334 IF (KEY - 988) 1335,1336,1335
C     FOR KEY = 988 INTO SIGISC PUT VOLTAGE AT THE GIVEN CURRENT
 1336 DO 1402 J = 2,101
      N = J
```

```
      IF (VCELL- XIMAP(NLO,J))1402,1402,1403
 1402 CONTINUE
 1403 XILO = VMAP(NLO,N-1) + (VCELL - XIMAP(NLO,N-1))*  (VMAP(NLO,N) -
     1VMAP(NLO,N-1))/(XIMAP(NLO,N)-XIMAP(NLO,N-1))
      DO 1422 J = 2,101
      N = J
      IF (VCELL- XIMAP(NHI,J))1422,1422,1423
 1422 CONTINUE
 1423 CONTINUE
      XIHI = VMAP(NHI,N-1) + (VCELL - XIMAP(NHI,N-1))* (VMAP(NHI,N) -
     1VMAP(NHI,N-1))/(XIMAP(NHI,N) - XIMAP(NHI,N-1))
      GO TO 1210
 1335 CONTINUE
      IF(VCELL-VMAP(NLO,1))1100,1100,1001
 1100 XILO=XIMAP(NLO,1)
      GO TO 1010
 1001 DO 1002 J = 2,101
      N=J
      IF(VCELL-VMAP(NLO,J))1003,1003,1002
 1002 CONTINUE
 1003 XILO=XIMAP(NLO,N-1)+(VCELL-VMAP(NLO,N-1))*(XIMAP(NLO,N)-XIMAP(NLO,
     1N-1))/(VMAP(NLO,N)-VMAP(NLO,N-1))
 1010 IF(VCELL-VMAP(NHI,1))1200,1200,1020
 1200 XIHI=XIMAP(NHI,1)
      GO TO 1210
 1020 DO 1222 J = 2,101
      N=J
      IF(VCELL-VMAP(NHI,J))1023,1023,1222
 1222 CONTINUE
 1023 XIHI=XIMAP(NHI,N-1)+(VCELL-VMAP(NHI,N-1))*(XIMAP(NHI,N)-XIMAP(NHI,
     1N-1))/(VMAP(NHI,N)-VMAP(NHI,N-1))
 1210 FAKTOR=(HELHOT-TEMP(NLO))/(TEMP(NHI)-TEMP(NLO))
C     XICELL PUT INTO SIGISC
      SIGISC=XILO+(XIHI-XILO)*FAKTOR
      RETURN
      END
```

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    3.58    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    170.0  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 PROGILE              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