SOFIP: A Short Orbital Flux Integration Program

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Goddard Space Flight Center
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ABSTRACT

A computer code has been developed to evaluate the space radiation environment encountered by geocentric satellites. The Short Orbital Flux Integration Program (SOFIP) is a compact routine of modular composition, designed mostly with structured programming techniques in order to provide not only maximum efficiency but also core and time economy and ease of use. The program in its simplest form, that is, stripped of all modules, produces for a given input trajectory a composite integral orbit spectrum of either protons or electrons. Additional features such as running printout, exposure index, peaks per orbit, percent time in electron trapping zones, differential spectrum, solar proton fluences, and punched output are available separately or in any combination with the inclusion of the corresponding (optional) modules. The code is described in detail, and the function and usage of the various modules are explained. A program listing and sample outputs are attached.
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INTRODUCTION

The need to predict reliably satellite exposure to trapped particle radiation was realized soon after the discovery of the terrestrial charged particle radiation belts, which coincided with the advent of spaceflight. A crude "Orbital Flux Integration" (OFI) code was developed at Goddard Space Flight Center as early as 1961. Over the years, a large, sophisticated, and complex OFI system evolved from these early beginnings (UNIFLUX1), a system that processed and analyzed the data into several different tabular and graphical presentations.

However, with the appearance of economical minicomputers and the corresponding emphasis on small software systems, attributes like "compact", "short", "fast", and "versatile" became very important.

In this paper a Short Orbital Flux Integration Program (SOFIP) is being presented which, excluding the plotting capability, affords all the options, choices, and variations of UNIFLUX, but with substantially reduced core requirements and running times.

Two basic guidelines influenced the creation of SOFIP: structured programming and modularized organization. These were followed to the greatest degree possible or desirable.

A detailed description of the routine is given in subsequent sections, including an analysis of the method employed in the determination of integral, difference, and differential fluxes.

A review of the program organization is given in Figure 1 which depicts the structure of the fully implemented (complete) code. Logic flow and decision branching is shown in Figure 2.

The arguments of its input and output vectors (variables and parameters) are presented and described in the appropriate sections. Code listing and sample outputs are attached.

SOFIP is written in standard FORTRAN-IV computer language. Card decks are available from the National Space Science Data Center in the O29 model IBM keypunch format (EBCDIC). The cards are labelled in columns 73-80 as SOFIPxxx, where the last three columns (xxx) contain the sequential numbering, which is incremented by one.

A comparison of the time required to compile, linkage edit, and execute SOFIP is given in Table 1. The data relate to full length and stripped versions of the code, and were obtained for both electron and proton runs, by processing 720 positions in each case.
The approximate amount of storage required by SOFIP is given in Table 2, for the various parts of the program, including also the environment models, in object form.

All results were obtained on GSFC's IBM 360/91 and, unless otherwise stated, using the FORTRAN IV G compiler.

THE CURRENT ENVIRONMENT MODELS

SOFIP is designed to use Vette's standardized models of the terrestrial trapped particle environment, as distributed by the National Space Science Data Center, Greenbelt, Maryland. New models are periodically being issued to replace older versions whenever additional data or information become available that permit a significant improvement in the environment description, or that indicate a change sufficiently important to warrant such an action. All models, both for protons and electrons, represent a static environment at a given fixed epoch. However, it was possible to infer from the data used in their construction a change in average quiet-time flux levels as a function of solar cycle. To date, a continuous temporal description of this cycle dependence has not been attempted. Instead, separate models were developed for solar minimum and solar maximum conditions for either species of particles.

Current at the time of this writing are the following models:

<table>
<thead>
<tr>
<th></th>
<th>Solar Max</th>
<th>Solar Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protons:</td>
<td>AP8-MAX (1970)(^2)</td>
<td>AP8-MIN (1964)(^2)</td>
</tr>
<tr>
<td>Electrons:</td>
<td>Inner Zone:</td>
<td>AE6 (1980)(^3)</td>
</tr>
<tr>
<td></td>
<td>Outer Zone:</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AEI7-HI (1980)(^5)-------</td>
</tr>
</tbody>
</table>

where the numbers in parentheses indicate the specific fixed epoch (year) for which they describe the average environment.

In regards to the outer zone electron models AEI7-HI and AEI7-LO it should be noted that:

(a) the version labelled "HI" favors Vampola's fits to the OV1-19 data, while the version labelled "LO" is representative of all the other outer zone data sets presently available at NSSDC.

(b) these models do not reflect solar cycle conditions and should be used indiscriminately for both min and max phases.

(c) they are interim models which recently replaced the solar min and max versions of the older AE4.
It should also be noted that the inner zone (solar max) AE6 does not contain any "Starfish" residuals because data now indicate that these electrons are no longer present.  

METHOD

Integral Flux

The composite orbit spectrum for integral energies gives the total vehicle encountered fluxes, averaged into intensities per second, for 30 discrete energy levels:

\[ S(>E_i) = c \Delta t \sum_{m=0}^{T} J_m(>E_i) \]

\[ c = 24/T \times 86400 \]

where the summation is performed for the entire simulated mission duration \( T \) in hours, and includes all fluxes with energies greater than \( E_i \). \( \Delta t \) is the integration step-size in seconds, \( J_m \) is the instantaneous integral flux obtained from the model for the \( i \)th energy level, and \( c \) is an averaging factor. Note that \( \Delta t \) must have values equivalent to integer minutes (See also note on page 7).

Difference Flux

The difference flux is calculated from the integral flux \( S(>E_i) \) for the 30 programmed energy levels:

\[ D(\Delta E_i) = S(>E_i) - S(>E_{i+1}) \quad \text{for } i = 1, 29 \]

\[ D(\Delta E_{30}) = S(>E_{30}) \]

where \( D \) is the difference flux in units of particles per square centimeter per second per energy interval. It is important to remember that \( E \) is not constant over either the proton or the electron spectra.

Differential Flux

Differential fluxes are only calculated when there exist 10 or more non-zero elements in the integral spectrum. That is, fluxes must be defined for at least ten discrete energy levels. In that case, the differential fluxes are obtained from the composite orbit spectrum by analytic differentiation, using the averaged instantaneous values of the total vehicle encountered fluxes at the selected energies:

\[ j(=E_i) = \frac{\partial S(>E_i)}{\partial E} \quad \text{for } i = 1, 30 \]
where \( j \) is the differential flux and \( E \) and \( S \) are the same as above. The results in the program output table represent the derivative of a cubic spline fitting procedure. If there are less than 10 non-zero elements available, the program bypasses these calculations.

**APPLICATION AND USE**

SOFIP contains two types of program sections: blocks, which are the essential parts of the program and must remain unaltered, and modules, which provide additional features and may be removed. For each block and module, the following points are discussed:

1. Function (including output produced, if any),
2. User input or user action necessary, and
3. Any restrictions, limitations, or other special considerations.

There are 11 modules in SOFIP, some of which are paired into packages which fulfill a single purpose. These packages and the output they produce are:

<table>
<thead>
<tr>
<th>Modules</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORBIT L-ZONE BREAKDOWN MODULE</td>
<td>Percent Time Table</td>
</tr>
<tr>
<td>PERCENT TIME MODULE</td>
<td></td>
</tr>
<tr>
<td>PEAKS PER ORBIT MODULE</td>
<td>Peaks per Orbit Table</td>
</tr>
<tr>
<td>OUTPUT TABLES MODULE 2</td>
<td></td>
</tr>
<tr>
<td>GEOMAGNETIC SHIELDING MODULE</td>
<td>Solar Proton Table</td>
</tr>
<tr>
<td>SOLAR PROTON MODULE</td>
<td></td>
</tr>
</tbody>
</table>

To obtain the desired results from one of these module packages, both modules in the particular package must be included in the run. If one module is included but the other is not, no data will be outputted from the calculation which those modules perform. However, such misuse of the module packages will neither cause the run to abend, nor affect the output of any other portion of the program.

**BLOCK Q: Initialization**

BLOCK Q performs the general initialization and preparation of the program. It contains all "type" declarations (REAL, INTEGER), and all dimension, equivalence, and format statements.

The user has only to be concerned with one aspect of this initialization: the selection of the environment model(s) to be used. Lines 39-44 of SOFIP contain COMMON statements for all of the current environment models, both proton and electron:
For a brief discussion of the models, see the section "The Current Environment Models".

To select a particular environment model:

1. Uncomment the COMMON statement which relates to the desired model, that is, remove the 'C' from column one,

2. Make sure all other COMMON statements are commented out,

3. Include in the deck to be submitted, the BLOCK DATA subroutine for the appropriate model.

Note that protons require only one model per run, while electrons require two, one for the inner zone and one for the outer zone. The two electron models are needed regardless of whether the trajectory to be processed visits only one of the two electron zones.

Because SOFIP performs calculations for only one particle species in a given run, the model(s) for only one species is needed. In other words, any one run will use either one proton model (AP8MAX or AP8MIN) or one inner zone electron model (AE6MAX or AE5MIN) and one outer zone electron model (AEI7HI or AEI7LO). The program cannot and does not check for invalid combinations of models, nor for BLOCK DATA subroutines and uncommented COMMONs statements incorrectly matched. These user errors will produce compilation, linkage, or execution errors.

Note also that there is no provision for changing models during execution. Therefore, in a multiple-orbit run, all trajectories are processed for the same species and models(s).

When SOFIP is run for electrons, a diagnostic message may be produced during compilation warning that the variable "DESCR" in line 51 of SOFIP has already been dimensioned. Do not change this dimensioning; it is necessary when the run is for protons. The warning may be ignored.

**BLOCK 1: Initialization**

BLOCK 1 performs the initialization of quantities which must be reinitialized after each orbit of a multiple-orbit run. In this block, the input variables are read and subsequently written out. Table 3 gives the input format and
a brief description of each parameter, two of which require some additional comments:

NRGYLV is the threshold-energy selector. Its value is an index into the ENERGY array. The desired value of NRGYLV is most easily obtained by looking at the Composite Orbit Spectrum from a SOFIP run for the correct particle species, and counting down to the desired energy level. The usual values are: electrons, NRGYLV=5 (0.5 MeV); protons, NRGYLV=4 (5.0 MeV).

CUTOFF determines the orbit time at which processing is to be terminated. If the end of the orbit tape is reached before orbit time reaches CUTOFF, the program will proceed as if CUTOFF had been equal to the time of the last point read. This will not cause any errors in the program.

BLOCK 2: Input

In BLOCK 2, the trajectory ephemeris tape is read. The program can read a tape written in either of two modes, BCD or binary. To read a BCD (EBCDIC, or formatted) tape:

1. The tape must have been written with format 6E18.8.
2. Comment out lines 133-134, 138-139, and 144.
3. Uncomment lines 132, 137, and 143.

To read a binary (unformatted) tape:

1. The first input variable, PSNTIM (see below) must have been written in single precision; the other five elements must have been written in double precision.
2. Comment out lines 132, 137, and 143.
3. Uncomment lines 133-134, 138-139, and 144.

For either input mode, each record of the tape must contain the following six variables in the order specified:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSNTIM</td>
<td>Orbit time in decimal hours (must start at 0.0)</td>
</tr>
<tr>
<td>PSNLON</td>
<td>East longitude in decimal degrees</td>
</tr>
<tr>
<td>PSNLAT</td>
<td>North latitude in decimal degrees</td>
</tr>
<tr>
<td>PSNALT</td>
<td>Geodetic altitude in kilometers above sea level</td>
</tr>
<tr>
<td>PSNB</td>
<td>Geomagnetic field magnitude in gauss</td>
</tr>
<tr>
<td>PSNL</td>
<td>McIlwain's magnetic shell parameter in earth radii</td>
</tr>
</tbody>
</table>

The input parameter ISKIP controls the number of records ignored each time a new point is called for by the program; only each ISKIPth point on the input tape is actually used in performing calculations.
The positional coordinates of longitude, latitude, and altitude are not used in the flux calculations; these calculations are performed with the magnetic parameters B and L only. Therefore, it is of no significance whether latitude relates to a geocentric or a geodetic reference frame (longitude is invariant in the two systems). The altitude, however, is used to determine the position of physical perigee in the case of eccentric trajectories.

NOTE: Do not use trajectories with stepsizes of less than one minute; they will cause the program to abend. Also, the stepsize must be constant for any one orbit, because the time integration assumes that the increment is not a function of orbit position i:

\[ \sum_i \text{Flux}_i \Delta t = \Delta t \sum_i \text{Flux}_i \]

**BLOCK 3: Calculations**

In BLOCK 3 some preparatory calculations are performed and the fluxes for the current position are obtained. No user action is necessary.

**Running Printout Module**

The "Running Printout Module" prints orbit and flux data for each position i used in the calculations when the input parameter KPRINT is equal to 1. If the input parameter KPRINT is not equal to 1, only each KPRINTth point is printed. The printed quantities are:

- Orbit time \( T_i \) decimal hours
- Latitude \( \lambda_i \) decimal degrees
- Longitude \( \phi_i \) decimal degrees
- Altitude \( h_i \) kilometers
- Field magnitude \( B_i \) gauss
- Magnetic shell parameter \( L_i \) earth radii
- Instantaneous flux \( F_i \) at the position i \((#/\text{cm}^2\cdot\text{sec})\)
- Time integrated flux \( F_i \Delta t \) integrated over the interval from i to i+1
- Orbital flux accumulation \( J = \sum_i F_i \Delta t \) sum of all fluxes encountered to this point

The first six quantities are the same as those read from the ephemeris tape. For the first position of the orbit, only the positional data are printed.

If running printout is not desired, delete this module.

**Orbit L-Zone Breakdown Module**

The "Orbit L-Zone Breakdown Module" determines the amount of time spent by the trajectory in each of the four zones into which magnetic space can be divided on the basis of electron trapping:

1. Inner zone: outside trapping region \( (1.0 < L < 1.1) \)
2. Inner zone: inside trapping region \(1.1 \leq L < 2.8\)
3. Outer zone \(2.8 \leq L < 11.0\)
4. External (no trapping) \(L > 11.0\)

These data will be used for further calculations in the "Percent Time Module".

Note that the "Orbit L-Zone Breakdown Module" must be used in conjunction with the "Percent Time Module". If the percent time information is not desired, delete both modules.

**Exposure Index Module**

The "Exposure Index Module" describes, for the selected processing energy, the radiation exposure in terms of nine intensity ranges, rising from "zero flux" through \(10^0 - 10^1\), \(10^1 - 10^2\), etc., to "more than \(10^7\) particles per square centimeter per second" in increments of one order of magnitude. The overall exposure of the trajectory to each intensity range (in decimal hours) and the total number of particles encountered while so exposed are recorded.

If the exposure index table is not desired, delete this module.

The exposure index is calculated for particles with \(E \geq \text{ENERGY} (\text{NRGYLV, species})\) where NRGYLV is the threshold energy selector variable (see section "BLOCK 2" for further discussion of NRGYLV).

**Peaks-Per-Orbit Module**

The "Peaks-per-Orbit Module" determines:

1. the instantaneous peak flux per period, in number of particles/cm²-sec with energies greater than or equal to the threshold energy selected by NRGYLV,
2. the time (in hours) and position (in \(h-\phi-\lambda\) and B-L coordinates) at which the peak flux is encountered, and
3. the total number of particles accumulated per period.

The "Peaks-per-Orbit Module" must be used in conjunction with the "Output Tables Module 2". If the peak data is not desired, delete both modules.

**Geomagnetic Shielding Module**

This module determines the amount of time the vehicle spends in regions of space where \(L > 5\), for later calculations in the "Solar Proton Module".
The "Geomagnetic Shielding Module", must be used in conjunction with the "Solar Proton Module". If Solar Proton data is not desired, delete both modules.

BLOCK 4: Looping

BLOCK 4 concludes the trajectory ephemeris read-loop. All blocks and modules between Block 2 (trajectory input) and Block 4 are executed for each inputted point of the trajectory. No user action is required.

BLOCK 5: Output Preparation

In BLOCK 5, the calculations for the composite orbit spectrum are performed. No user action is required.

Percent Time Module

The "Percent Time Module" takes the information stored in the "Orbit L-Zone Breakdown Module", i.e., the number of times the vehicle visits each of the four zones defined in that module, and calculates the percent of total orbit time spent in each; this data is then printed.

If the percent time table is not desired, delete both this module and the "Orbit L-Zone Breakdown Module".

Differential Spectrum Module

The "Differential Spectrum Module" calls subroutine DSPCTR, which calculates the differential spectrum from the total integral fluxes obtained from the environment models.

If the differential spectrum is desired, include subroutine DSPCTR and this module. If the differential spectrum is not desired, delete this module.

Solar Proton Module

This module calculates the exposure factor (i.e., the fraction of the orbit during which the vehicle is not geomagnetically shielded, but is exposed to the interplanetary intensities of energetic solar protons) from the value stored in the "Geomagnetic Shielding Module". It then calls the subroutine SOLPRO', which calculates probabilistic solar fluences at preselected energy levels as a function of mission duration $T$ and confidence level $Q$.

There are two elements in the solar proton module which the user may wish to alter to meet his specific needs:

1. Mission duration $T$: (REAL*4, variable name in code: T)
   
   $T$ determines the time interval, in non-fractional months, for which the solar proton calculations are to be performed. The code

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is preprogrammed for one year mission duration ($\tau=12$). If a different length of time is desired, edit card 276 accordingly. The permissible range of $\tau$ values is from 1 to 72 months.

2. Confidence level Q: (INTEGER*4; variable name in code: IQ)

Q denotes the level of confidence, in percent, which the user wishes to assign to the results; namely, that for the specified mission duration the calculated fluences are the smallest values that will not be exceeded by actually encountered intensities. The preprogrammed confidence level is 90%. If a different value of Q is desired, edit card 278 accordingly. Permissible values of the variable IQ are integers between 80 and 99, inclusive.

If the solar proton information is desired:

1. include this module and the "Geomagnetic Shielding Module", and

2. include subroutine SOLPRO in the deck to be submitted.

Otherwise delete the "Solar Proton" and "Geomagnetic Shielding Modules".

**Output-Punch Module**

This module produces a card deck containing some of the calculated results. Each card, with exception of the header cards, contains a label in columns 73-78 and a sequence number in columns 79-80. The label indicates the particle species and whether the card contains energies, integral fluxes, or differential fluxes. The sequence number will reflect the card's position in the particular section of the deck to which it belongs, e.g., integral fluxes, or solar proton energies; sequence numbers range from 1 to 5 (in the solar proton sections, 1 to 4).

See Table 4 for a description of the punched output.

If the "Solar Proton Module" was not included in the run, or if the trajectory was completely shielded geomagnetically, no cards for solar protons are punched.

**Output-Tables Module 1**

When the program is used in its simplest form, this module should be included if tabular output is desired. It produces a composite orbit spectrum table, containing:

1. Integral energy levels, in MeV,

2. Average orbit integrated spectrum, in particles per square centimeter per second,
3. Difference flux, in particles per square centimeter per second per $\Delta E$, and

4. A column labelled "differential flux", which contains only zeroes.

When the "Differential Spectrum Module" is included and if there are ten or more non-zero elements given in the integral spectrum, items (1), (2), and (3) remain the same, but (4) now contains average differential flux values, in units of particles per square centimeter per second per keV.

For more information on the calculation of either of these fluxes, see the section on "Method".

This module also prints two additional, independent tables for (a) the exposure index, and (b) the solar proton results. The exposure index table presents in the first column the intensity ranges, in the second column the total duration of trajectory exposure to each intensity range, and in the last column the total number of particles encountered while so exposed. The solar proton table lists in the header the mission duration $T_AU$, the confidence level $Q$, the number of anomalously large events $NALE$ predicted for $T_AU$ and $Q$, and the geomagnetically determined exposure factor used in the calculations, and presents two columns containing respectively the energy levels in MeV, and the total fluence per square centimeter for each energy.

If the "Solar Proton Module" and/or the "Exposure Index Module" have not been included in the run, then the corresponding tables do not appear in the print out.

If no tabular output is required, delete the "Output-Tables Module 1".

Output-Tables Module 2

This module prints the results calculated in the "Peaks-per-Orbit Module.". There are nine columns on this table. Column 1 is an orbit counting device, based on the period of the orbit. Column 2 gives the absolute instantaneous peak flux encountered during that orbit. Columns 3, 4, and 5 indicate the spacecraft position in geocentric coordinates at which the peak was encountered, while columns 6, 7, and 8 denote respectively the time and the magnetic B-L coordinates for this event. Finally, the last column indicates the total flux encountered during that particular orbit. It is advisable to disregard the last line on this table because many times that orbit is incomplete and the fluxes or positions shown do not correspond to true peaks.

BLOCK 6: Program Termination

In Block 6, the program returns to the beginning of BLOCK 1 where it checks whether there is another trajectory to be processed. If no other trajectory is to be processed, the run terminates. No user action is necessary.
ACKNOWLEDGEMENTS

We wish to thank Drs. R. Hilberg and M. Teague for many helpful discussions and constructive suggestions.
REFERENCES


Table 1

Running Times of SOFIP for 720 Input Positions on the IBM 360/91 Computer

<table>
<thead>
<tr>
<th></th>
<th>Compile</th>
<th>Link</th>
<th>Execute</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protons</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stripped</td>
<td>.06/.03</td>
<td>.00/.14</td>
<td>.06/.04</td>
<td>.12/.21</td>
</tr>
<tr>
<td>All</td>
<td>.11/.04</td>
<td>.00/.18</td>
<td>.08/.06</td>
<td>.19/.28</td>
</tr>
<tr>
<td><strong>Electrons</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stripped</td>
<td>.06/.03</td>
<td>.00/.15</td>
<td>.06/.04</td>
<td>.12/.22</td>
</tr>
<tr>
<td>All</td>
<td>.11/.04</td>
<td>.00/.18</td>
<td>.09/.06</td>
<td>.20/.28</td>
</tr>
</tbody>
</table>

Times are given in decimal minutes. The first figure in each entry is for CPU, and the second is for I/O. Values are averages of three runs for each type and species.
## Table 2

Core Requirements for SOFIP

<table>
<thead>
<tr>
<th></th>
<th>Core required for source program (in 1000 bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SOFIP</strong> &lt;sup&gt;+&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Stripped</td>
<td>11.8</td>
</tr>
<tr>
<td>All Modules</td>
<td>16.8</td>
</tr>
<tr>
<td><strong>TRARA1</strong> &lt;sup&gt;+&lt;/sup&gt;</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>TRARA2</strong> &lt;sup&gt;+&lt;/sup&gt;</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>SOLPRO</strong> &lt;sup&gt;+&lt;/sup&gt;</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>DSPCTR</strong> &lt;sup&gt;+&lt;/sup&gt;</td>
<td>8.4</td>
</tr>
<tr>
<td><strong>FORTRAN Library Functions</strong></td>
<td></td>
</tr>
<tr>
<td>Stripped</td>
<td>22.7</td>
</tr>
<tr>
<td>All Modules</td>
<td>24.6</td>
</tr>
<tr>
<td><strong>Environment Models</strong>: For proton runs</td>
<td>26.1 or 26.8</td>
</tr>
<tr>
<td>For electron runs</td>
<td>35.6 or 37.3</td>
</tr>
</tbody>
</table>

See table below for size of individual models

<table>
<thead>
<tr>
<th>Model</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP8MAC</td>
<td>26.1</td>
</tr>
<tr>
<td>AP8MIC</td>
<td>26.8</td>
</tr>
<tr>
<td>AEI7HI</td>
<td>17.5</td>
</tr>
<tr>
<td>AEI7LO</td>
<td>15.8</td>
</tr>
<tr>
<td>AE6MAX</td>
<td>19.8</td>
</tr>
<tr>
<td>AE5MIN</td>
<td>19.8</td>
</tr>
</tbody>
</table>

<sup>+</sup>Compiled under FORTRAN G

*Compiled under FORTRAN H

If SOFIP with all modules, TRARA1, TRARA2, SOLPRO, and DSPCTR are compiled under FORTRAN H, the results will be a total of 3.3K less than these.
TABLE 3
Input Parameters: Description and Format

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Format</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-12</td>
<td>3A4</td>
<td>NAME*</td>
<td>Any 12-character alphanumeric description of vehicle or orbit</td>
</tr>
<tr>
<td></td>
<td>20-22</td>
<td>I3</td>
<td>INCL*</td>
<td>Approximate orbit inclination in degrees</td>
</tr>
<tr>
<td></td>
<td>30-35</td>
<td>I6</td>
<td>IPRG*</td>
<td>Approximate orbit perigee in kilometers</td>
</tr>
<tr>
<td></td>
<td>40-45</td>
<td>I6</td>
<td>IAPG*</td>
<td>Approximate orbit apogee in kilometers</td>
</tr>
<tr>
<td></td>
<td>50-51</td>
<td>I2</td>
<td>MODEL*</td>
<td>Number of field model (from ALLMAGB) used in calculation of magnetic parameters B and L in conversion of trajectory ephemeris</td>
</tr>
<tr>
<td></td>
<td>60-68</td>
<td>F9.6</td>
<td>PERIOD</td>
<td>Mathematical period of orbit in decimal hours</td>
</tr>
<tr>
<td></td>
<td>70-76</td>
<td>F7.2</td>
<td>BLTIME*</td>
<td>Epoch for which the coefficients of the field model were evaluated for the B-L calculations, in decimal years A.D.</td>
</tr>
<tr>
<td>2</td>
<td>1-2</td>
<td>I2</td>
<td>NRGYLV</td>
<td>Threshold energy selector for running printout, exposure index, and peaks</td>
</tr>
<tr>
<td></td>
<td>10-13</td>
<td>I4</td>
<td>ITAPE*</td>
<td>Orbit tape identifier</td>
</tr>
<tr>
<td></td>
<td>20-21</td>
<td>I2</td>
<td>NTABLS</td>
<td>Number of copies of tables to be produced</td>
</tr>
<tr>
<td></td>
<td>30-35</td>
<td>F6.2</td>
<td>CUTOFF</td>
<td>Orbit time (in decimal hours) at which run is to be terminated</td>
</tr>
<tr>
<td></td>
<td>40-41</td>
<td>I2</td>
<td>ISKIP</td>
<td>Program will process only every ISKIPth point on trajectory tape. ISKIP=1, all points are processed.</td>
</tr>
<tr>
<td></td>
<td>50-51</td>
<td>I2</td>
<td>KPRINT</td>
<td>The &quot;Running-Printout-Module&quot;, if included in the run, will print only every KPRINTth point of the trajectory points read. Note: KPRINT=0 will cause the program to abend.</td>
</tr>
</tbody>
</table>

Format of input: (3A4,7X,I3,7X,I6,4X,I6,4X,I2,8X,F9.6,1X,F7.2 /I2,7X,I4,6X,I2,8X,F6.2,4X,I2,8X,I2)

*Starred quantities are not required for calculations, but are used only for labelling output.
TABLE 4
Punched Output: Description and Format

<table>
<thead>
<tr>
<th>Card</th>
<th>Variable(s)</th>
<th>Format</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NAME(3), INCL, IPRG, IAPG, MODEL, BLTIME</td>
<td>3A4,1X,12,'/','I5,','I6,1X,'1(#/CM<strong>2-SEC) D(#/CM</strong>2-SEC-KEV) MOD/TM='I1,'/'</td>
<td>Header card containing vehicle identification*, inclination*, perigee*, apogee*, the units of the differential and integral fluxes which are to be puncted, and the model number (from ALLMAG*) and epoch for which the B and L of the trajectory tape were calculated.</td>
</tr>
<tr>
<td>2-6</td>
<td>ENERGY(30, ITYPE)</td>
<td>1PE12.4</td>
<td>The 30 integral threshold energies, in MeV, for the particle species considered in this run.</td>
</tr>
<tr>
<td>7-11</td>
<td>AIFLXS(30)</td>
<td>1PE12.4</td>
<td>The orbit integrated, integral fluxes for the 30 energy levels punched previously, averaged into units of particles/cm²·sec.</td>
</tr>
<tr>
<td>12-16</td>
<td>DIFSFC(30)</td>
<td>1PE12.4</td>
<td>The differential fluxes obtained from the preceding integral spectrum in units of particles/cm²·sec·keV. Zeros will be punched if the &quot;Differential Spectrum Module&quot; was omitted.</td>
</tr>
<tr>
<td>17</td>
<td>IQ,T, INALE, EXPFCT</td>
<td>'SOLAR PROTONS #ENERGIES=20 Q='I2,' TAU='F4.1,' NALE='I1,' EXPFCTR='F5.2</td>
<td>Header card giving the number of Solar Proton energy levels processed, and containing confidence level Q, mission duration tau, number of AL events for given Q and tau, and geomagnetic shielding effect in the form of an exposure factor.</td>
</tr>
<tr>
<td>18-21</td>
<td>SPNRG(20)</td>
<td>1PE12.4</td>
<td>The 20 integral threshold energies, in MeV, for the solar flare protons.</td>
</tr>
<tr>
<td>22-25</td>
<td>F(20)</td>
<td>1PE12.4</td>
<td>The total unattenuated interplanetary solar flare proton fluences for the preceding integral spectrum, modified by the exposure factor punched above, and for the Q and tau given in the solar proton header card, in units of particles/cm².</td>
</tr>
</tbody>
</table>

*taken directly from input
FIGURE 1: MODULAR STRUCTURE AND ARRANGEMENT OF SOFIP

<table>
<thead>
<tr>
<th>Block</th>
<th>Description</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 0</td>
<td>Initialization of Program</td>
<td>38-88</td>
</tr>
<tr>
<td>Block 1</td>
<td>Initialization of Data Parameter Input</td>
<td>89-130</td>
</tr>
<tr>
<td>Block 2</td>
<td>Input Positional Data From Tape (Trajectory)</td>
<td>131-146</td>
</tr>
<tr>
<td>Block 3</td>
<td>Obtain Fluxes Perform Calculations</td>
<td>147-174</td>
</tr>
<tr>
<td></td>
<td>Running Printout Module Print Positional Data</td>
<td>175-192</td>
</tr>
<tr>
<td></td>
<td>Orbit L-Zone Breakdown Module Count Times Each Zone Is Visited</td>
<td>193-201</td>
</tr>
<tr>
<td></td>
<td>Exposure Index Module Store Fluxes and Times By Intensity Ranges</td>
<td>202-213</td>
</tr>
<tr>
<td></td>
<td>Peaks Per Orbit Module Determine Peaks and Position, Plus Total, Per Period</td>
<td>214-237</td>
</tr>
<tr>
<td></td>
<td>Geomagnetic Shielding Module Determine Whether Position Is Geomagnetically Ally Shielded (Step Count for L ≤5)</td>
<td>238-240</td>
</tr>
<tr>
<td>Block 4</td>
<td>End of Read Loop</td>
<td>241-243</td>
</tr>
<tr>
<td>Block 5</td>
<td>Output Preparation</td>
<td>244-254</td>
</tr>
<tr>
<td></td>
<td>Percent Time Module Calculate Percentage of Total Time Spent in Each Zone</td>
<td>255-271</td>
</tr>
<tr>
<td></td>
<td>Differential Spectrum Module Call Subroutine DSPCTR</td>
<td>272-273</td>
</tr>
<tr>
<td></td>
<td>Solar Proton Module Call Subroutine SOLPRO</td>
<td>274-287</td>
</tr>
<tr>
<td></td>
<td>Output Punch Module Punch Integral and Differential Spectra, Solar Protons</td>
<td>288-307</td>
</tr>
<tr>
<td></td>
<td>Output Module Table 1 With Orbit Integrated Spectrum and With or Without Differential Spectrum and/or Exposure Index and/or Solar Protons</td>
<td>308-381</td>
</tr>
<tr>
<td></td>
<td>Output Module Table 2 Peaks and Position Plus Total Per Period</td>
<td>382-396</td>
</tr>
<tr>
<td>Block 6</td>
<td>Program Termination</td>
<td>397-401</td>
</tr>
</tbody>
</table>
********************************************************************
** SHORT ORBITAL FLUX INTEGRATION PROGRAM **
** FOR USE WITH NSSDC'S STANDARD ENVIRONMENT MODELS **
** DESIGNED AND TESTED BY STASSINOPoulos, HEBERT, HUTLER, & MAYTH **
** CODE 601, NASA/Goddard Space Flight Center; Greenbelt, Md. 20771 **
** SINGLE PRECISION DECK FOR FORTRAN IV (FORTRAN/77 PUNCH) **
** TRAJECTORY INPUT FROM UNFORMATTED BINARY OR BCD FORMATTED TAPE **
********************************************************************

*** INPUT PARAMETERS: ***
** NAME : 12-CHARACTER MISSION (OR PROJECT) NAME **
** INCL : APPROXIMATE INCLINATION OF ORBIT PLANE IN DEGREES **
** IPRG : APPROXIMATE PERIGEE ALTITUDE IN KILOMETERS **
** IAPG : APPROXIMATE APOGEE ALTITUDE IN KILOMETERS **
** MODEL : NUMBER OF FIELD-MODEL USED IN B/L CALCULATION **
** PERIOD : MATHEMATICAL PERIOD OF ORBIT IN HOURS **
** ALTUE : EPOCH OF FIELD-MODEL USED IN B/L CALCULATION **
** NRGYLV : THRESHOLD-ENERGY SELECTOR FOR RUNNING PRINTOUT **
** ITAPE : B/L ORBIT TAPE IDENTIFIER, < 10000 **
** NTABS : # OF OUTPUT-TABLE SETS PER TRAJECTORY **
** CUTOFF : ORBIT DURATION IN DECIMAL HOURS **
** ISkip : POSITION SKIPPING CONTROL **
** KPRINT : RUNNING PRINTOUT CONTROL **

*** INPUT VARIABLES: ***
** PSNTIM : POSITIONAL TIME (DECIMAL HOURS) **
** PSNLON : " LONGITUDE (DEGREES) **
** PSNLAT : " LATITUDE (DEGREES) **
** PSNLALT : " ALTITUDE (KILOMETERS) **
** PSNB : " FIELD MAGNITUDE (GAUSS) **
** PSNL : " SHELL PARAMETER (EARTH RADII) **

********************************************************************
** TO READ BCD FORMATTED ORBIT TAPES, UNCOMMENT LINES 133-134 & 143 **
** COMMENT OUT LINES 133-134,138-139, & 144 **
** TO READ UNFORMATTED BINARY ORBIT TAPES, UNCOMMENT LINES 133-134 **
** 138-139, & 144. COMMENT OUT LINES 132,137, & 143 **

********************************************************************
** COMMON /AP8MAC/DECR(8),LIST(1) **
** COMMON /AE6MAX/DECR(8),LIST(1) **
** COMMON /AE17HI/DECR(8),LIST(7(1) **
** COMMON /AE17LO/DECR(8),LIST(7(1) **
** COMMON /AE5MIN/DECR(8),LIST(1) **

L-1
C *** *************** BLOCK 1: INITIALIZATION ******************
10 READ(5,4,END=999) NAME,INCL,IPRG,IAPIG,MODEL,PERIOD,TIME,NGYLYV,
  NTABLES,CUTOFF,SKIP,PRINT
  IYPE=1
  MITE(3,3) = NAME,INCL,IPRG,IAPIG,I=1,7
  NORM=1
  IPASS=1
  IPRINT=PRINT
  ASSIGN 110 TO NG02
  L=0
  LSUB=1)
  EXPECT=0.0
  XMIN=MAX
  ISWICH=1
  IF(DESCR(1).EQ.48) GO TO 15
  ITYPE = 2
  ASSIGN 120 TO NG02
  IF(DESCR(2).EQ.MAX) XMIN=MIN
  IF(DESCR(2).EQ.407) TYPIL(3,2)=LOW
  GO TO 17
15 IF(DESCR(2).EQ.MAX) XMIN=MIN
17 DO 20 I=1,4
   LCOUNT(I)=0
20 NOLLLL(I) = MOD(LLL(I),MODEL)
   TAU = PERIOD
   FLXSM = 0.0
   OFLXSM = 0.0
   PEAK = -1.0
   DO 30 NRNG=1,10
   ENRNGS(NRNG) = ENERGY(NRNG,NRNG,NRNG,NRNG,ITYPE,ITYPE)
   EXPMTM(NRNG) = 0.0
30 EXPRLX(NRNG) = 0.0
   DO 35 NRGSP=1,29
35 EXPRLX(NRNG) = 0.0
   DO 40 NRG=1,30
40 EXPRLX(NRNG) = 0.0
C *** WRITE OUT INPUT PARAMETERS
   WRITE(6,1)NAME,INCL,IPRG,IAPIG,ITYPE,MODEL,PERIOD,TIME,NGYLYV,
  NTABLES,CUTOFF,SKIP,PRINT
C *** ************************** BLOCK 2: INPUT ***********************
$DUMMY, PSNB1, DUMMY, PSNL1, DUMMY
TMLAST = PSNTIM
50 DO 60 ISKP=1,ISKP
C READ(9,5,END=400,ERR=10) PSNTIM,PSNLO,PSNLAT,PSMALT,PSNB,PSNL
READ(9,5,END=400,ERR=10) PSNTIM,PSNLO,DUMMY,PSNLAT,DUMMY,PSMALT,
$DUMMY, PSNB, DUMMY, PSNL, DUMMY
60 CONTINUE
IF(PSNTIM.LE.CUTOFF) GO TO 65.
C *** DUMMY READ LOOP TO READ TO END OF FILE
C 66 READ(9,5,END=400,ERR=10) A dummy
66 READ(9,5,END=400,ERR=10) A dummy, A dummy
GO TO 66
65 CONTINUE
C *** *************** BLOCK 3: CALCULATIONS **********************
C *** CALCULATE KPSTEP (NUMBER OF MINUTES BETWEEN POINTS ON R/L TAPE)
GO TO (70,60), IPASS
70 KPSTEP = INT((PSNTIM-TMLAST)*0100000.0)
80 TMLAST = PSNTIM
C *** TEST L-VALUE & BYPASS FLUX CALCULATIONS IF WARRANTED
IF(PSNL.GT.0.0.AND.PSNL.LT.1.0) GO TO NGO2(110,120)
DO 100 NRG=1,30
100 FLUXES(NRG) = 0.0
GO TO 170
C *** OBTAIN COMMON LOGARITHM OF POSITIONAL FLUXES (ALGFLX)
C *** PROTONS
110 CALL TRARAD(DESCH,LIST,PSNL,PSNB,ENERGY(1,1),ALGFLX(1),30)
GO TO 140
C *** ELECTRONS
120 IF(INT(100.0*PSNL+0.2).LE.280) GO TO 130
CALL TRARAD(DESCH,LIST,PSNL,PSNB,ENERGY(1,2),ALGFLX(1),30)
GO TO 140
130 CALL TRARAD(DESCH,LIST,PSNL,PSNB,ENERGY(1,2),ALGFLX(1),30)
C *** CONVERT LOG-FLUX TO FLUX
140 DO 150 NRG=1,30
FLUXES(NRG) = 10.0**ALGFLX(NRG)
150 IF(FLUXES(NRG).LT.1.000) FLUXES(NRG) = 0.0
C *** SUM FLUXES FOR (A) RUNNING PRINTOUT, (B) TABULAR OUTPUT
FLXSUM = FLXSUM+FLUXES(NRG)*FLAT(KPSTEP)/60.
DO 160 NRG=1,30
160 AIFLXS(NRG) = AIFLXS(NRG)+FLUXES(NRG)
170 CONTINUE
C *** *********************** RUNNING PRINTOUT MODULE ********************
GO TO (200,210), IPASS
200 WRITE (6,2) MODEL, MODLAL, ALTIME, NAME, INCL, IPRG, IAPG, ITAPE, PERIOD,
$EXAMIM
WRITE (6,201) (TYPVAL(I,ITYPE),I=1,3), ENERGY(NRGYLV,ITYPE)
201 FORMAT(10,21X,18A4,1(E1,6G9.3,1MEV) " ***
$ * LAT. ALT. FIELD LINE ORBIT POSITIONAL TIME-INT
SG ORBITAL/"1,T2X,1-H,1,T37,"-L TIME FLUX PSTNL SOFIP142
$FLUX FLUX(SUM)X"1 (DEG) (DEG) (KM) (GAUSS) (F.R.) (HRS)\$IFIP143
$ */CM**2/SEC"
WRITE(6,202)PSNTM1,PSNL1,PSNL1,PSML1,PSNL1,PSNL1
202 FORMAT(1,1,T41,F9.5,T2,F7.2,1X,F6.2,1X,F4.1,1X,F5.2,T40,)
$7(2X,1PE10.3))
210 IF(MOD(IPRINT,KPRINT).NE.0) GO TO 220
TFLUX = FLUXES(NRGYLV)*FLOAT(KPSTEP)*60.*
WRITE(6,202)PSNTIM,PSNLOK,PSNLAT,PSNALT,PSNH,PSNL ;
$FLUXES(NRGYLV),TIFLUX,FLXSUM
220 IPRINT=IPRINT
C *** ******************************** ORBIT L-ZONE BREAKDOWN MODULE ********************************** SOFIP193
C *** ******** THIS MODULE MUST BE USED WITH PERCENT TIME MODULE *************** SOFIP194
C *** STORE TIME IN INNER & OUTER ZONE, EXTERNAL
IF(PSNL.LT.0.0.OR.PSNL.GT.11.0) GO TO 250
IZ = IZONE(INT(PSNL/.1))
LCOUNT(IZ) = LCOUNT(17) + 1
GO TO 260
250 LCOUNT(4) = LCOUNT(4)+1
260 CONTINUE
C *** ******************************** EXPOSURE INDEX MODULE ********************************** SOFIP201
C *** STORE FLUXES AND TIMES IN INTENSITY RANGES
GO TO(270,240),IPASS
270 ISWITCH=ISWITCH+1
C *** *************** PEAK AND TOTALS PER ORBIT MODULE *********************** SOFIP213
C *** DETERMINE ORBIT NUMBER AND TOTAL FLUXES PER ORBIT
IF(PSNTIM.LT.TAU) GO TO 300
PEAK = -1.0
TAUFLX(NORBIT) = FLXSUM-DFLXSM
DFLXSM = FLXSUM
NORBIT=NORBIT+1
TAU = NORBIT * PERIOD
IF(NORBIT.LE.50) GO TO 300

L-5
C *** DETERMINE FLUX PEAKS AND POSITIONS PER ORBIT
300 IF (FLUXES(NRGYL) .LE. PEAK) GO TO 310
PKFLX(NORBIT) = FLUXES(NRGYL)
PKT1(NORBIT) = PSTM
PKLNK(NORBIT) = PNKL
PKLAT(NORBIT) = PNLAT
PKALT(NORBIT) = PNALT
PKH(NORBIT) = PSHK
PEAK = FLUXES(NRGYL)
310 CONTINUE

C *** GEOMAGNETIC SHIELDING MODULE
C *** THIS MODULE MUST BE USED WITH SOLAR PROTON MODULE
C IF(INT(PSN1L,GE.5 .OR. PSNL .LE.400) .AND. L=L+1)
C *** BLOCK 4; LOOOING (READ-LOOP ENDS HERE)
C IF(PASS=2
GO TO 50
400 CONTINUE

C *** BLOCK 5; OUTPUT PREPARATION
C *** COMPOSITE ORBIT SPECTRUM
400 IF(COUNTS = (KPS+1440.0) / (PSNFL+4400.0)
DO 410 NRG=1,30
AIFLXS(NRG) = AIFLXS(NRG)*AECTRS
IF(AIFLXS(NRG) .LE.0.0) GO TO 440
ALMFLXS(NRG) = ALOG(AIFLXS(NRG))
410 CONTINUE
440 DO 450 NRG=1,24
450 AIFLXS(NRG) = AIFLXS(NRG)-AIFLXS(NRG+1)
460 AIFLXS(30) = AIFLXS(30)
C *** PERCENT TIME MODULE
C *** THIS MODULE MUST BE USED WITH ORBIT L-ZONE BREAKDOWN MODULE
C *** CALCULATE AND PRINT PERCENT TIME TABLE
LSUM=0 COUNT(I) + LCOUNT (2) + LCOUNT (3) + LCOUNT (4)
IF(LSUM .LT.0.0) GO TO 470
DO 460 IL=1,4
460 PTIME(1)=FLOAT(LCOUNT(1))/KPS*1.66667/MLAST
PTIME(1)=PTIME(1)+TIME(2)
WRITE(6,401)TIL,PTIME(1),IL=1,4,PSTM
470 CONTINUE
401 LI FORM(1) PERCENT OF TOTAL LIFELIME SPENT INSIDE AND OUTSIDE
* STRAPPED PARTICLE RADIATION BELT ***
* INNER ZONE (1.0 < L < S0IF266
* 62.85) : 'F6,2, 'F6,2, 'F6,2
* OUTSIDE TRAPPING REGION (1.0 < L < S0IF267
* N 62.85) : 'F6,2, 'F6,2, 'F6,2, 'F6,2, 'F6,2, 'F6,2,
$Fk_2,1 \equiv /6x, \text{OUTER ZONE } (2.5 < L < 11.0) \equiv \int Fk_2,1 \equiv /6x, \text{TOTAL ORBIT TIME IS }$

C $*** \text{DIFFERENTIAL SPECTRUM MODULE} ***$

CALL DSPECT (ALNFIX(1), ENERGY(1,ITYPE), DIFSPC(1))

C $*** \text{SOLAR PROTON MODULE} ***$

C $*** \text{THIS MODULE MUST BE USED WITH GEOM, SHIELDING MODULE} ***$

T=12.
IT=1
I=0
ISWITCH=ISWITCH+2
IF(L<=0) GO TO 510
CALL SOLPRO(T,19,E,INALE)
EXPUM=FLOAT(L*ESTEP)*0.0166667
EXPCT=(EXPUM/WSTIM)
DO 500 J=1,20
  F(J)=F(J)*EXPCF
500 CONTINUE
510 CONTINUE

C $*** \text{OUTPUT PUNCH MODULE} ***$

C $*** \text{PUNCHES ENERGY, INTEGRAL DIFF FLUX, SOLAR PROTONS IF PRESENT} ***$

WRITE(7,605) NAME, INCL, IPKG, IAPG, MODEL, ALTIME
WRITE(7,602)((ENERGY(I-1)*EJ, J, ITYPE), JJ=1.4), XLAEL(I, ITYPE), II, II=1, SOFIP291

WRITE(7,602)((DIFIXS(I-1)*EJ, JJ=1.4), XLAEL(I, ITYPE), II, II=1, SOFIP293

WRITE(7,602)((DIFSPC(I-1)*EJ, JJ=1.4), XLAEL(I, ITYPE), II, II=1, SOFIP295

IF(L<=0) GO TO 600
WRITE(7,603) IT, ITMATE, EXPCT
WRITE(7,604)((SPANS(I-1)*EJ, JJ=1.4), PROTLA(1), II, II=1, SOFIP299
WRITE(7,604)((F(I-1)*EJ, JJ=1.4), PROTLA(2), II, II=1, SOFIP300

600 CONTINUE

602 FORMAT(1P6E12.4,1A,12)
603 FORMAT(SOLAR PROTONS #ENERGIES=20 D='1,12', TAU='1,F4.1,

604 FORMAT(1I14,1I1,1F5.2)
605 FORMAT(1I14,1I1,1D12.12)

C $*** \text{OUTPUT TABLES MODULE 1} ***$

DO 400 NTRBL=1, NTRAL
  WRITE(6,2) MODEL, MODRAG, ALTIME, NAME, INCL, IPKG, IAPG, ITAPE, PERIOD,
  XAMN
400 CONTINUE

GO TO (710,740,730,723), ISWITCH

C $*** \text{COMPOSITE ORBIT SPECTRUM AND EXPOSURE INDEX} ***$

L-7
700 WRITE (6,701) (TYPLKL(K,ITYPE),K=1,3),ENERGY(MRCYLV,ITYPE), S
(ENERGY(N,ITYPE),AFLX(N),DIFFLX(N),DIFSPC(N),FIRNGS(N), S
$FIRNGS(N+1),EXPT(N),EXPFLX(N),N=1,10),(ENERGY(N,ITYPE),AFLX(N)) S
$DIFLX(N),DIFSPC(N),N=1,30) S
701 FORMAT (*11,15('X'),3X,3A4,2X,16('X')/11,4X,49('X')/11) S
$T18,15(*1),1 COMPOSITE ORBIT SPECTRUM ,15(*1),TAG,** EXPOSURE S
$INDEX=ENERGY,J9,Y,2,T12,**EY **/*10,T12,**EY AVERAGED S
$DIFFERENCE AVERAGED DIFFE- INTENSITY EXPOSURE DESOFTP321 S
$TAL # OF/11,T18,LEVELS INTEGRAL FLUX INTEGRAL FLUX WEIGHTSOFTP322 S
$AL FLUX',10X'RANGES DURATION ACCUMULATED/** ,T18,**EY S
$#/CM**2/SEC #/CM**2/SEC/DE #/CM**2/SEC/KEV #/CM**2/SEC/KEV S
$1PE9,3,8X,1PE9,3,T18,2A4,TH1,7ZERO FLUX',1X,OPF10,3,1X,1PE13,3/11 S
$1PE9,3,7X,1PE9,3,8X,1PE9,3,T18,4,11,4X,OPF10,3,1PE13,3/11 S
$1PE9,3,7X,1PE9,3,8X,1PE9,3,T18,4,11,4X,OPF10,3,1PE13,3/11 S
$1PE9,3,8X,1PE9,3,7X,1PE9,3,T18,2A4,TH1,**EY,1X,OPF10,3,1X,1PE13,3/11 S
$TOTAL,1X,OPF10,3,1X,1PE13,3,2C(T18,OP9,4,1PE9,3,7X) S
$1PE9,3,8X,1PE9,3,7X,1PE9,3,**EY,1X,OPF10,3,1X,1PE13,3/11) S
$1TO 750 S
$OFTP320 S

C *** COMPOSITE ORBIT SPECTRUM ONLY S

710 WRITE (6,702) (TYPLKL(K,ITYPE),K=1,3),ENERGY(MRCYLV,ITYPE), AIFLXS(N), S
DIFLX(N),DIFSPC(N),N=1,30) S
702 FORMAT (*11,15('X'),3X,3A4,2X,16('X')/11,4X,49('X')/11) S
$T40,15(*1),1 COMPOSITE ORBIT SPECTRUM 15(*1)/**1,T40,**EY S
$AVERAGED DIFFERENCE AVERAGED DIFFE-1/**1,T40,LEVELS S
$INTEGRAL FLUX INTEGRAL FLUX RENTIAL FLUX/**1,T40,**EY S
$#/CM**2/SEC #/CM**2/SEC/DE #/CM**2/SEC/KEV #/CM**2/SEC/KEV S
$1OP9,4,T40,11,1PE9,3,4X,1PE9,3,**EY,1PE9,3/11) S
$1TO 750 S
$OFTP341 S

C *** COMPOSITE ORBIT SPECTRUM WITH SOLAR PROTONS AND EXPOSURE INDEX S

720 WRITE(6,703),(TYPLKL(K,ITYPE),K=1,3),IT,10,INALE,ENERGY(MRCYLV, S
$ITYPE),EXPT,ENERGY(N,ITYPE),AIFLXS(N),DIFLX(N),DIFSPC(N),S
$FIRNGS(N+1),EXPT(N),EXPFLX(N),N=1,10),ENERGY(MRCYLV, S
$FIRNGS(N,ITYPE),AIFLXS(N),DIFLX(N),DIFSPC(N),S
$FIRNGS(N+1),EXPT(N),EXPFLX(N),N=1,10),ENERGY(MRCYLV, S
$FIRNGS(N,ITYPE),AIFLXS(N),DIFLX(N),DIFSPC(N),N=1,30) S
703 FORMAT (*11,15('X'),3X,3A4,2X,16('X')/11,4X,49('X')/11) S
$6X,** SOLAR PROTONS **/*63X,'FOR TAU='T12,0,'=12,** HALE=SOFTP349 S
$1,11/3X,15(*1),1 COMPOSITE ORBIT SPECTRUM 15(*1),5X,WITH GENSOFTP350 S
$AG SHIELDING,5X,** EXPOSURE INDEX=ENERGY,J9,Y,4,T12,5,**EY **/*1/ SOFTP331 S
$6X,'EXPOSURR FACTOR=4,2,**/3X,**EY AVERAGED DIFFERSOFTP321 S
$SERENCE AVERAGED DIFF- ENERGY TOTAL S
$SITY EXPOSURE TOTAL **1/3X,LEVELS INTEGRAL FLUX INTERSSOFTP354 S
$SL FLUX RENTIAL FLUX LEVELS FLUENCE RANGESOFTP355 S
$SS DURATION ACCUMULATED/**1/3X,**EY #/CM**2/SEC #/CM**2/SECOFTP356 S
$SEC/DE #/CM**2/SEC/KEV #/MEV) #/CM**2/SEC/KEV S
$SEC (HOURS) PARTICLES/**1,T4,OP9,4,T9,11,1PE9,3,6X) S

L-8
C *** *************** DIFFERENTIAL SPECTRUM SUBROUTINE ***************
C *** CALCULATES FIRST DERIVATIVES OF INPUT SPECTRUM DEFINED BY FF VS XX
C *** INPUT: XX - 30 INTEGRAL THRESHOLD ENERGIES, IN MEV (R*4) DFSPEC004
C *** FF - ALOG OF THE INTEGRAL FLUXES FOR THE 30 ENERGY (R*4) DFSPEC008
C *** LEVELS, IN PARTICLES/CM2/SEC DFSPEC010
C *** OUTPUT: DD - DIFFERENTIAL FLUXES OBTAINED FROM THE INTEGRAL (R*4) DFSPEC012
C *** FLUXES, IN PARTICLES/CM2/SEC/KEV DFSPEC014
C *** THIS IS A MODIFIED VERSION OF A PROGRAM (DCS1EU) OBTAINED FROM DFSPEC018
C *** INSL LIBRARY 1: AUTHOR/IMPLEMENTOR = C.L. SMITH DFSPEC020
C **********************************DFSPEC022

SUBROUTINE DSPCTR(FF,XX,DD)
  IMPLICIT REAL*4(A-H,O-Z)
  REAL*4 DD,FF,XX
  DIMENSION P(30),X(30),O(30),H(500),FF(30),XX(30),DD(30)
  DATA EPSLN,OMEGA/L,0-6.1,0,0,1796400/
C *** DATA INITIALIZATION
  M=1
  DO 10 L=1,30
  IF(FF(L).EQ.0.) GO TO 15
  K=K-1
  F(K)=FF(K)+ALOG(1000.)
  X(K)=XX(K)*1000.00
  10   D(K)=X(K)
15   K=K+1
  IF(K.GT.10.) GO TO 170
C *** SMOOTHING INTEGRAL FLUX
  CALL SMOOTH(X,F,M)
C *** CALCULATE SECOND DERIVATIVES USING CENTRAL DIFFERENCES
  DO 30 I=1,M
       H(I)=X(I+1)-X(I)
30   DO 40 I=2,M
       H(I)=F(I+1)-F(I))/H(I)
40   DO 50 I=2,M
       H(2*H+I)=H(I-1)+H(I)
       H(3*H+K)=5*H(I+1)/H(2*K+I)
       H(4*K+I)=H(K+I)-H(K-I))/H(2*K+I)
       H(5*K+I)=H(4*K+I)+H(4*K+I)
50   H(5*K+1)=0.

L-10
H(6*K)=0.

C *** BEGIN ITERATION ON SECOND DERIVATIVES
KCOUNT=0
ETA=0.
KCOUNT=KCOUNT+1

DO 70 I=2,K
     W=(H(6*K+1)-H(3*K+1)*H(5*K+1-1)-(5-H(3*K+1))*H(5*K+1)-H(5*K+1)-H(5*K+1))/H(1)
     I=1
     DO 140 J=1,K
            IF (D(J),E0,X(I)) GT 50 GO TO 170
     END
     IF (D(J),E0,X(I)) GT 50 GO TO 50

C *** CONVERGENCE OBTAINED
DO 80 I=1,K
     H(7*K+1)=(H(5*K+1)-H(5*K+1)-H(1))/H(1)
     DO 140 J=1,K

C *** COMPUTE D(J)
     H1=D(J),E0,X(I)
     HT2=D(J),E0,X(I)
     HT2=H(J),E0,X(I)
     HT1=H(1),E0,X(I)
     D(J),E0,X(I)=H(5*K+1)+H(5*K+1)+H(5*K+1)+H(5*K+1))/H(1)

C *** SMOOTHING DIFFERENTIAL FLUX
     CALL SMOOTH(X,D,4)
     DO 160 I=1,K
     F(I)=2.*782818880***(F(I)-ALOG(1000.))
     END

C *** SMOOTH DATA BY 3-POINT AVERAGING OVER EQUAL INTERVALS
SUBROUTINE SMOOTH(X,F,H)
IMPLICIT REAL*4(A-H,0-7)
DIMENSION X(130),F(30)

L-11
FINTERT(X1,X2,X3,Y1,Y2,Y3,XIN)=Y1*(XIN-X2)*(XIN-X3)/
S((X1-X2)*(X1-X3)) + Y2*(XIN-X1)*(XIN-X3)/(X2-X1)*(X2-X3))
S + Y3*(XIN-X1)*(XIN-X2)/(X3-X1)*(X3-X2))
C
FI = F(1)
DO 20 I=2,M
SIZE1 = X(I) - X(I-1)
SIZE2 = X(I+1) - X(I)
C *** CHECK FOR EQUAL STEPSIZES
IF(DABS(SIZE1-SIZE2),LT.0.001) GO TO 200
IF(SIZE2,GT.,SIZE1) GO TO 210
C *** STEPSIZE DECREASES - FIT CURVE AND INTERPOLATE BACKWARD
F2 = F(I+1)
XINTER = X(I) - SIZE2
F1 = FINTER(X(I-1),X(I),X(I+1),FI,F(1),F2,XINTER)
GO TO 300
C *** STEPSIZE INCREASES - FIT CURVE AND INTERPOLATE FORWARD
210 F1 = FI
XINTER = X(I) + SIZE1
F2 = FINTER(X(I-1),X(I),X(I+1),FI,F(1),F(I+1),XINTER)
GO TO 300
C *** STEPSIZES ARE EQUAL - AVERAGE OVER EXISTING VALUES
200 F1 = F1
F2 = F(I+1)
C
C *** PERFORM AVERAGING
300 FNEW = (F1+2.0*F(1)+F2)/4.
FI = F(1)
F(I) = FNEW
20 CONTINUE
RETURN
END
**SUBROUTINE SOLPRO(TAU, IQ, F, INALE)**

C *** MODIFIED 9/77 TO RETURN INALE(# OF AL EVENTS) TO CALLING PROGRAM

C *** INTERPLANETARY SOLAR PROTON FLUX AT 1 AU (FROM E>10 TO E>200 MEV FOR

C *** ANOMALOUSLY LARGE (AL) EVENTS AND FROM E>10 TO E>100 MEV FOR

C *** ORDINARY (OR) EVENTS

C *** SINGLE PRECISION DECK IN STANDARD FORTRAN IV FOR IBM 360 MACHINES

C *** (FORCDC, O29 PUNCH) OR OTHER COMPATIBLE SYSTEMS.

C *** PROGRAM DESIGNED AND TESTED BY E.G. STASSINOPoulos, CODE 601.

C *** NASA GODDARD SPACE FLIGHT CENTER, GREENBELT, MARYLAND 20771.

C ***********************************************************************

C **** INPUT: TAU MISSION DURATION IN MONTHS (REAL*4)

C **** IQ CONFIDENCE LEVEL THAT CALCULATED FLUENCE F(N)

C **** WILL NOT BE EXCEEDED (INTEGER*4)

C **** OUTPUT: F(N) SPECTRUM OF INTEGRAL SOLAR PROTON FLUENCE FOR

C **** ENERGIES E>10*N (1<N<20) FOR AL EVENTS

C **** ENERGIES E>10*N (1<N<10) FOR OR EVENTS

C **** INALE # OF AL EVENTS FOR GIVEN TAU AND IQ

REAL NALE, NALECFL(7,20)/-1571,-2707,-1769E-1,-4428E-3,-.185E-5,-
.7754E-7,-.2939E-9,-.1870,-.1951,-.6559E-2,.1990E-3,-.3618E-5,-
.3740E-7,-.1599E-9,-.2007,-.1497,-.379E-3,.5730E-6,.4664E-6,-
.1764E-8,.1228,-.1936E-2,.2660E-4,-.1028E-6,.200E-6,-
.2214,-.1149,-.1871E-2,.2695E-4,-.1116E-6,.200E-6,-.2470E-6,.1042E-6,-
.1658E-2,.2367E-4,.9465E-7,.200E-6,.2509,.871E-1,.A300E-3,-
.8438E-5,.300E-7,.2932,.8932E-1,.1023E-2,.1029E-4,.300E-7,.3222E-7,-
.646E-1,.9992E-3,.9935E-5,.300E-7,.351E-7,.8417E-1,.1000E-7,-
.9956E-5,.300E-7,.3698,.7951E-1,.893E-3,.8940E-5,.300E-7,.2771E-7,-
.5473E-1,.1543E-4,.400E-7,.2818,.5072E-1,.2511E-4,.400E-7,.2845E-7,-
.4717E-1,.5664E-4,.400E-7,.2947,.4405E-1,.8507E-4,.400E-7,.2923E-7,-
.4111E-1,.1106E-3,.300E-7,.2981,.3853E-1,.1312E-3,.300E-7,.300E-7,.300E-7,.300E-7,.3132E-1,.1781E-3,.340E-7,.3141E-7,-
.324E-1,.165E-3,.400E-7,-.F(20),.G(20)

REAL ORFLX(5,9)/.154047E3,-522258E4,.714275E5,.432747E6,.955315
.7E6,.19804E3,.448784E4,.431848E5,.196046E6,.32552E6,.529120E3,-
.12227E5,.112869E6,.465086E6,.710572E6,.121141E0,.266412E5,-
.22677E6,.8572A6,.120444E7,.452062E4,.103248E6,.96085E6,-
.346028E7,.499852E7,.272028E4,.499088E5,.353056E5,.111929E7,-
.13338E6,.275597E4,.46918E5,.314729E6,.960383E6,.116597E7,-
.570997E4,.799689E5,.381074E6,.610714E6,.101E3,.400E-7,-
.3585E-1,.1529E-3,.400E-7,.300E-7,.3312E-1,.1781E-3,.340E-7,.3141E-7,-
.324E-1,.165E-3,.400E-7,-.F(20),.G(20)

INTEGER INDEX(20)/2*7,6,3*5,5*4,9*3/

1 FORMAT(1X,'TAU=',F4.0,' IQ=',I3,3X,'PARAMETER(S) EXCEED PROGRAM LIMITS')

2 FORMAT(2X,'FOR THE COMBINATION OF TAU AND IQ GIVEN, NO SIGNIFICANTSOLPR400')

L-13
SOLAR PROTON FLUXES ARE TO BE EXPECTED. TAU='F6.2', IO='I2')

IF(TAU.GT.72.,OR.IO.LT.80)GO TO 500
IP=100.IO
M=INDEX(IP)
NALE=0.
DO 300 J=1,M
300 NALE=NALE+NALECF(J,IP)*TAU**(J-1)
INALF=NALE+1.0001
IF(INALE.GT.0) GO TO 400
C *** CALCULATIONS FOR OR-EVENT CONDITIONS
IT=TAU
IF(IT.EQ.1.AND.IP.GT.16) GO TO 700
P=FLOAT(IP)/100.
OF=0.
DO 100 J=15
100 OF=DF+ORFLXC(J,IT)*P**(J-1)*1.E7
E=10.
DO 200 N=110
200 G(N)=EXP(0.0158*(30.-E))
F(N)=DF*G(N)
200 E=E+10.
GO TO 800
C *** CALCULATIONS FOR AL-EVENT CONDITIONS
400 E=10.
DO 600 N=120
600 F(N)=7.9E9*EXP((30.-E)/26.5)*INALE
600 E=E+10.
GO TO 800
700 WRITE(6,2) TAU,IO
GO TO 800
500 WRITE(6,1) TAU,IO
800 RETURN
END

L-14
NAME = TEST 90/2000
INCL = 90
IPRS = 2000
IAPG = 2300
ITAPE = 5110
MCODEL = 5
PERIOD = 2.119969
BLTIME = 1.974110
MROLEV = 4
NTADLS = 3
CUTOFF = 23.99
ISKIP = 1
KPRINT = 1

Parameter Output
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<th>Incident Energy</th>
<th>Total Lifetime Spent</th>
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</table>

**Percent of Total Lifetime Spent Inside and Outside Trapped Particle Radiation Belt**

**Inner Zone (L = 1.0 < L < 2.8)**

- **Inside Trapping Region (1.0 <= L < 1.1)**: 0.0%
- **Inside Trapping Region (1.1 <= L < 2.8)**: 51.60%

**Outer Zone (L > 11.0)**

- **External Energy (L > 11.0)**: 26.84%
**SOFIP** - SHORT ORBITAL FLUX INTEGR. PROGRAM FOR STANDARD NSSDC PROTON AND ELECTRON ENVR. MODELS (SPECIES CONSIDERED SEPARATELY)

**MAGNETIC PARAMETERS B AND L COMPUTED WITH GEOMAG. FIELD MODEL 5; IGRF 1965.0 80-TERM 1968 * COEFF. UPDATED TO: 1974.1 *

**PROJECT TEST 90/2000 * INCLIN= 90DEG * PERIOD= 2000KM * APS= 2000KM * JPL TAPE=DSIC 5 * PERIOD= 2,120HRS * SDL= 9 MINIMUM *

**FOR INFORMATION OR EXPLANATION CONTACT J.C. STASSIVEL & J.S. MCDALD AT NASA-GSFC, 800 GILDER, GREENBELT, MARYLAND 20771. TEL. (301) 344-8067 **

**MAGNETIC PARAMETERS B AND L COMPUTED WITH GEOMAG. FIELD MODEL 5; IGRF 1965.0 80-TERM 1968 * COEFF. UPDATED TO: 1974.1 **

**PROJECT TEST 90/2000 * INCLIN= 90DEG * PERIOD= 2000KM * APS= 2000KM * JPL TAPE=DSIC 5 * PERIOD= 2,120HRS * SDL= 9 MINIMUM **

**OUTPUT TABLE 1 WITHOUT DIFFERENTIAL SPECTRUM, SOLAR PROTONS, OR EXPOSURE INDEX - PROTONS**

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<th>AVERAGED INTEGRAL FLUX (#/CM²/SEC)</th>
<th>DIFFERENCE INTEGRAL FLUX (#/CM²/SEC)</th>
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**T-5**

Output Table 1 without Differential Spectrum, Solar Protons, or Exposure Index - Protons
**SOVIP : SHORT ORBITAL FLUX INTEGR. PROGRAM FOR STANDARD NSSDC PROTON AND ELECTRON ENVIR. MODELS (SPECIES CONSIDERED SEPARATELY)**

- MAGNETIC PARAMETERS B AND L COMPUTED WITH GEOMAG. FIELD MODEL IGRF 1965.0 B-TERM 1976.8 COEFF, UPDATED TO 1979.1
- PROJECT ISOVIP TEST * INCLIN 90DEG * PERIG. 200km * APODE 2000km * B/L TAPED TO-SIE * PERIOD= 2.12 MECS * SOLAR MINIMUM
- FOR INFORMATION OR EXPLANATION CONTACT E.G. STASSINOPOULOS AT NASA-GSFC CODE 601, GREENBELT, MARYLAND 20771, TEL. (301) 344-8067

**********************************************************

**ELECTRONS LO **

**********************************************************

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Output Table 1 without Differential Spectrum, Solar Protons, or Exposure Index - Electrons
**SOFP: SHORT ORBITAL FLUX INTEGR. PROGRAM FOR STANDARD NSSDC PROTON AND ELECTRON ENVIRO. MODELS (SPECIES CONSIDERED SEPARATELY) **
* MAGNETIC PARAMETERS H AND L COMPUTED WITH GEMAGN. FIELD MODEL SI: IGRF 1965.0 50-TERM 196/8 & COEFF. UPDATED TO: 1974.1 *
* PROJECT TEST 90/900 INCL=90DCG * PERI=2000KM * APO=2000KM * B/L TAPET=0016 * PERID=2.120HRS * SOLAR MAXIMUM *
* FOR INFORMATION OR EXPLANATION CONTACT E.G. STASSINE@NASA-GSFC.CO3E AT NASA-GSFC.CO3E GREENBELT, MARYLAND 20771, TE.(301)-344-8067 *

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** Exposure Index: Energy > 1.000 MeV **

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** Output Table 1 with Differential Spectrum, Solar Protons, and Exposure Index - Protons **

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T-77
### **Solar Protons**

#### Output Table 1 with Differential Spectrum, Solar Protons, and Exposure Index - Electrons
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T-9

Output Table 2 - Protons
### ELECTrons HI

**TABLE OF PEAK AND TOTAL FLUXES PER PERIOD: ENERGY > 0.50 MEV**

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Output Table 2 - Electrons