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SYNTHESIS OF CALCULATIONAL METHODS FOR THE DESIGN AND ANALYSIS OF RADIATION SHIELDS FOR NUCLEAR ROCKET SYSTEMS. VOLUME 9: FASTER - A FORTRAN ANALYTIC SOLUTION OF THF TRANSPORT EQUATION BY RANDOM SAMPLING

T. M. Jordar



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VOLUME 9

SYNTHESIS OF CALCULATIONAL METHODS FOR THE DESIGN AND ANALYSIS OF RADIATION SHIELDS FOR NUCLEAR ROCKET SYSTEMS

FASTER

A FORTRAN ANALYTIC SOLUTION OF THE

by

T. M. Jordan

Contract No. NAS-8-20414 Contract No. DCN-16-28-0029(IF)

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ABSTRACT

This report is Valume 9 of nine volumes of the final report on "Synthesis of Calculational Methods for the Design and Analysis of Radiation Shields for Nuclear Racket Systems". Presented in this volume is a description of the FASTER program, a <u>Fortran Analytic Solution</u> of the <u>Iransport Equation by Random sampling</u>.

FASTER is a Fortran IV Monte Carlo program which calculates energy dependent neutron or photon fluxes at points, surfaces and regions of complex geometries. This program contains all the data processing routines required for a wide variety of nuclear vehicle applications. The FASTER program is completely variable dimensioned, and hence, is capable of treating problems of varying complexity within the limitation of total computer storage. The program uses only the input ond output tope units and is operational on the 32K WANL and MSFC IBM 7094 computers--using overlay---and on the 64K CDC 6600 computer at the Westinghouse Telecomputer Center in Pittsburgh.

FASTER utilizes the general quadric surface equation for describing the geometry. The more common equations for planes, cones, elliptical cylinders and ellipsoids can also be used for input description of the surfaces.

The FASTER program handles either neutron or photon sources. Each source is described in rectangular, cylindrical or spherical coordinates and the source geometry is superimposed on the problem geometry. The spatial, angular, and energy source distributions are assumed to be separable and are input as tabulated relative distribution data.

The FASTER program deals with the entire spectrum of particle energies simultaneously, thus eliminating costly repetition of geometric calculations which are usually required for treating individual mono-energetic particles. The scattered particle energy spectra include the effect of every possible scattering event at each scattering point. This eliminates the variance associated with the random selection of a single event. Neutron transport calculations utilize averaged multigroup cross sections which are available from several standard tobulations. Photon transport problems utilize point cross sections and the Klein-Nishina equation for Compton scattering.



Biased random sampling is used exclusively in the selection of source and scattering points. In performing flux calculations at a point, the FASTER program includes the singularity of the point flux estimator in the biasing functions. This permits more economical and more accurate point solutions in source and/or scattering volumes.

Analytic estimation is used to compute point fluxes and/or surface and volume averaged fluxes. These fluxes can be processed within the program to obtain various responses such as dase rates and heating rates. Contributions to the fluxes are obtained by source, number of collisions, and scattering region. Legendre angular moments and length-of-flight moments of the fluxes and responses can also be obtained.

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SECTION 1.0 INTRODUCTION AND SUMMARY

A major problem in the analysis of nuclear rockets is accuracy in predicting neutron and photon radiation levels both internal and external to the radiation sources. The most useful and fundamental expression of these radiation levels consists of energy dependent fluxes at specified points. These point fluxes can be utilized with a variety of energy dependent functions to yield-integral quantifies such as dase rate and heating rate. These point quantities can also be spatially integrated to obtain averages or totals for various surfaces and volumes, e.g., neutron and photon reactor leakage and volumetric heating. The accurate calculation of point fluxes requires a detailed treatment of source and material distributions and of basic particle cross sections. Accurate and economical calculations are particularly difficult for space vehicles and nuclear rocket test stands because of their complex geometries. The FASTER program was developed to handle these geometrically complex problems.

Energy dependent fluxes can be obtained, in principle, for any radiation analysis problem by computing the flux contributions by order of scatter. The geometric complexity of most realistic problems, however, limits a conventional numerical integration to the uncollided and, at most, the single scattered flux components. Therefore, the method of random sampling, i.e., the Monte Carlo method is used in the FASTER program. The Monte Carlo method permits a calculation of the flux components to an arbitrary order of scatter while simplifying the numerical procedures.

The FASTER program is an integral part of the "final" design method schematically shown in Fig. 1. This "final" design method is described more fully in Volume 1 of this report. As depicted in the figure, it begins with the POINT program (Volume 2) which prepares cross section and other basic data for use in the ODD-K two-dimensional transport program. The ODD-K two-dimensional transport program (Volume 6) provides neutron and photon energy fluxes throughout the reactor geometry. The NAGS data processing program (Volume 7) processes these fluxes and calculates neutron and photon radiation levels and neutron and photon source distributions within the reactor system. These sources can be employed in either the KAP-V point kernel program (Volume 4) or the FASTER Monte Carlo program for obtaining





Figure 1. Schematic Diagram of the "Final" Design Method

radiation levels at locations internal and external to the reactor system. In addition, the FASTER program can compute heating rate distributions in the liquid hydrogen propellant (in either an on-axis or off-axis tank) and the radiation level af the poyload. Alternately, the DAFT program (Volume 8) can prepare neutron and photon energy and angular dependent fluxes at the reactor surface from the CDD-K program for use in the FASTER Monte Carlo code.

Distinctive features of the Monte Carlo method as employed in the FASTER program, are described in Section 2.0 and include:

1) application of random sampling to the spatial and angular integrations only,

2) consistent use of energy-averaged sampling functions,

3) approximation of importance functions by point kernel techniques,

4) analytic treatment of the energy variable over its entire range, and

5) zero variance energy integration of the scattered source equations.

The Monte Carlo method presented in this report is based on techniques described in References 1, 2, and 3. Cansiderable improvement in the treatment of point detectors has been made since these early efforts were reported. In particular, the singularity in the point detector flux estimator has been included in the spatial sampling functions without sacrificing g detailed treatment of geometric effects.

The FASTER program utilizes this improvement of the Monte Carlo method to perform neutron or photon transport calculations in complex geometries. Computer oriented features of this program include:

1) coded in FORTRAN IV,

2) completely variable dimensioned,

3) completely internal--- auxiliary tapes are not required, and

4) compatible with both the IBM 7094 and CDC 6600 computers.

The program logic is discussed in Section 3.0.

Subsequent sections of this report deal with the numerical techniques used in the FASTER program to implement the Monte Carlo method. First, is the geometric framework which utilizes the quadric surface equation. Basic features of the geometry described in Section 4.0 include:







1) separate description of surfaces,

 simple input for the more common planes, cones, elliptical cylinders, and ellipsoids with an internal expansion to obtain the coefficients of the general quadric equation,

3) exclusive use of the general surface equation in all computations,

4) region description by listing bounding surfaces,

 an internal calculation of the (±) sign associated with region boundaries by using the coordinates of an arbitrary point in each region,

6) geometry consistency check using "point-in-region,"

7) an internal calculation of "most-probable-next-regions" for boundary crossings,

8) an internal calculation of exterior boundaries, and

9) elimination of the (e, 8) boundary crossing search.

The FASTER program will treat multiple fixed sources where each source has separable spatial, angular and energy distributions. Other features of the fixed source description, described in Section 5.0, include:

1) rectangular, cylindrical and/or spherical coordinates,

 each spatial variable can be continuous or discrete, permitting a variety of point, line, surface, and volume source geometries,

 each angular variable can be continuous or discrete, running the range from monodirectional to angular,

 spatial and angular distributions are specified by tabulating relative distributions at discrete points, in particular the distributions calculated by the NAGS and DAFT programs.

 spectra are specified by tobulating either differential number or energy spectrum, or groupwise integrated number or energy spectrum, either one in an arbitrary group structure,

6) each source is normalized to total energy or particles.

Features of the treatment of cross sections for photons and neutrons are described in Section 6.0 and include:

1) compositions are accepted in 10^{24} atoms/cm³ or am/cm³.

2) microscopic cross sections can be in barns/atom or cm²/gm,

 photon total cross sections are defined at group boundaries and interpolated linearly in energy,

4) photon scattering uses the Klein-Nishina equation,

 photon energy absorption coefficients are computed internally by element and composite material,

group averaged neutron cross sections are accepted from several standard tabulations, e.g., GAM-1,

 neutron scattering cross sections are not limited in down scatter or order of the Legendre angular expansion,

 neutron cross sections are manipulated internally to define transport corrected values or to remove this correction,

 neutron kinetic heating responses are computed by element and composite material, and

. 10) hydrogen densities can be specified by region, eliminating the need of describing several composite materials which differ by hydrogen content only.

FASTER computes various flux moments in a collapsed set of energy groups for point, surface and/or volume detectors. All quantities are obtained by "analytic estimation", as shown in Section 7.0, and include:

1) groupwise number and energy flux, average energy, and variance,

2) groupwise differential and cumulative number and energy fluxes,

3) groupwise responses and total responses with limits on variance,

4) groupwise number flux and response function totals by source,

5) groupwise flux and response totals by scattering region,

6) groupwise flux and response totals by number-of-collisions.

7) Legendre angular moments of the groupwise flux and response totals, and

8) length-of-flight moments of the groupwise flux and response totals.

The sampling functions incorporated in FASTER, described in Section 8.0, are relatively easy to use. Typical random sampling input data or biasing data for point flux calculations consist of:

1) center and radius of a sphere enclosing all fixed sources,

2) group importance, e.g., flux-to-dose response,

3) linear buildup coefficient by group,

 relative importance by group of forward-to-backward scattering for heavy elements,

5) relative importance by group of forward-to-backward scattering for hydrogen, and

6) a set of adjustment factors (ratios \approx 1.0) applied to internally calculated sampling parameters.

Detailed input instructions are presented in Section 9.0 of this report. Section 10.0 contains a description of the input and output for a sample problem involving the calculation of photon and neutron fluxes at a point above a liquid hydrogen propellant tank. The FOR-TRAN IV listing of the FASTER program is given in Appendix C.

Computer times for the FASTER program depend on the problem complexity and the manner in which the program is used. Individual point detector flux calculations in and around a nuclear reactor require about 3 minutes per point for photons (23 groups) and 6 minutes per point for fast neutrons (13 groups). These times are typical for the IBM 7094 computer and yield computed variances in integral responses generally less than 10 percent.

Flux calculations for points in void regions and/or flux calculations for surfaces and volumes require more computer time per problem, but the fluxes are all obtained simultaneously. A typical photon problem involving volumetric heating rates for 50 regions of a reactor required about 1.2 hours on the IBM 7094 with computed variances generally less than 25 percent.

SECTION 2.0 THE MONTE CARLO METHOD

This section describes the Mante Carlo Method as used in the FASTER program. The first topic is a general discussion of order-of-scatter solutions of the transport equation. The order-of-scatter equations are written explicitly starting with the equation for the uncallided scalar flux. The basic concepts of random sampling are then summarized and applied directly to the order-of-scatter equations. This is followed by a discussion of point kernel estimates of optimal sampling functions. Finally, the equations for angular flux estimation are derived for point, surface, and volume detectors.

2.1 GENERAL COMMENTS

Fluxes at a point can be obtained in principle for any geometry by computing the order-of-scatter components, i.e., the uncollided flux, the single scattered flux, etc. This method utilizes a known fixed source distribution, which is numerically integrated with a simple attenuation kernel over the spatial extent of the source, to obtain the uncollided angular flux at all points in space. This uncollided flux is integrated with the scattering cross sections, over energy and solid angle, to yield the single scattered source distribution. Next, the pracedure is repeated to an arbitrary order of scattering, finally yielding the total flux within an inherent error given by the uncomputed higher order-of-scattering flux components.

The FASTER program utilizes the Monte Carlo method in performing the numerical integrations. The Monte Carlo method involves an application of random sampling to the evaluation of definite integrals and it can be applied to all of the Integrations involved in the order-of-scatter solution. Because this method is statistical in nature its application to each integration must be accompanied by an iteration procedure to reduce the associated variance. Therefore, it is desirable to perform as many of the integrations as possible by conventional techniques. For the ader-of-scatter solution utilized in the FASTER program, the Monte Carlo method is applied only to the spatial and angular integrations, i.e., the method is applied to the variables that camplicate direct numerical integration.



The application of the Monte Carlo method can proceed in many directions. The procedure used in the FASTER program involves the random selection of a single point characterizing the distributed fixed source. Then, the fixed source is evaluated at this point and the resulting point source is used to compute energy dependent uncollided fluxes throughout the geometry. Next, a first-scaller point is selected by random sampling. An energy-dependent angular flux (monodirectional) of this first scatter point is computed using the point representation of the fixed source. This energy dependent angular flux, when integrated with the scattering cross sections, yields a point representation of the single-scattered source for all scattered energies and directions. This single scattered point source is used to obtain the energy dependent single-scattered fluxes throughout the geometry. It is used to calculate the monodirectional flux at the next scattering point (obtained by random sampling). This procedure is continued to an arbitrary order-of-scatter and is repeated (starting with the fixed source) until the statistical error in computed fluxes is acceptable.

An implicit difficulty with this point-to-point procedure is the singularity in the attenuation kernel resulting from the inverse square law. This difficulty is present in the calculation of fluxes at both the next scatter point and at arbitrary detector points. It shall be seen later, that these difficulties are removed by considering the singularities in the random selection of the discrete position vectors.

An important consideration in every numerical integration is the selection of a procedure which will yield minimum error. Since, the Monte Carlo method is just another way of performing the spatial integrations, the same considerations are present. It is possible to devise many techniques for reducing the error in an integration performed by random sampling. The most fruitful technique involves the concept of spatial importance. Thus, in considering each possible source or scattering point, the following question is asked: How important will the selection of this point be to the final answer, i.e., how much flux, dose, etc. will eventually be derived from its selection?

Without solving the problem, there is one method which is readily available for approximating spatial importance. This is the point kernel method which approximates the

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importance of future scattering events by simple alterations of the attenuation kernel, i.e., removal theory for neutrons and buildup factors for photons. This procedure will not yield a zero variance (or error) flux calculation, but it will yield information as to the approximate importance of space points. This importance function includes the singularities already mentioned and also approximates the importance of material and fixed source distributions.

THE ORDER-OF-SCATTER EQUATIONS 2,2

The solution of the time independent transport equation can be obtained by computing the order-of-scatter components of the flux. This method utilizes a known, differential source density where the uncollided flux is given by the familiar equation:

$$\phi_{\mathfrak{o}}(\vec{r}, E) = \iiint S_{\mathfrak{o}}(\vec{r}', \vec{\mathfrak{A}}, E) = \underbrace{\exp\left[-\int_{\mathfrak{o}}^{s} \Sigma^{t}(\vec{r}' - s' \cdot \vec{\mathfrak{A}}, E) \, ds'\right]}_{s^{2}} dV \qquad (2.1)$$

where

đ

s = (r-r)/s

- T, T' are position vectors
- ភិ is a unit direction vector
- is the particle energy (Mey) Ε
- s, s' are scalar distances from 7 along 12 (cm)
- is a differential volume element (cm³) d٧
- S_ (7, 1, E) is the fixed differential source density

$$\begin{pmatrix} \frac{particles}{cm^3 \text{ steradion } Mev \cdot sec} \end{pmatrix}$$

 ϕ_o (\vec{r} , E) is the scalar flux $\begin{pmatrix} \frac{particles}{cm^2 \cdot Mev \ sec} \end{pmatrix}$
 Σ^t (\vec{r} , E) is the total cross section (cm^{-1}).



This integration can be performed using spherical coordinates in a coordinate system centered at the detector point by using the transformation

$$\vec{r} = \vec{r} - s\vec{\Omega}$$
$$dV = s^2 ds d\Omega$$
$$d\Omega = d\mu d\theta$$

- μ = the cosine of the polar angle
- θ = the ozimuthal angle

$$\phi_{0}\left(\vec{r}, \vec{t}\right) = \iiint_{0}^{\infty} \int_{0}^{\infty} \left(\vec{r}^{*} - s\vec{\Omega}, \vec{t}\right) = \exp\left[-\int_{0}^{s} \mathcal{I}^{\dagger}\left(\vec{r}^{*} - s'\vec{\Omega}, \vec{t}\right) ds'\right] ds d\Omega \qquad (2.2)$$

The most obvious reason for this transformation is that it removes the 1/s² singularity.

The angular flux at any point in the geometry can be obtained from the inner spatial integration of equation 2, 2:

The single scattered source density is given by an integration of the product of this angular flux and the total differential scattering cross

$$S_{1}(\vec{r},\vec{\Omega}, E) = \iiint_{q}^{\infty} \phi_{q}(\vec{r},\vec{\Omega}', E') \frac{d^{2}\Sigma}{d\Omega dE} (\vec{r},\vec{\Omega}', E' \rightarrow \vec{\Omega}, E) dE' d\Omega'$$
(2.4)

where

is the total differential scattering cross section (Reference 4, pg. 265). The single scal'uned source density yields the single scattered flux and the process is then repeated for higher order scattered sources and fluxes:

 $\frac{d^2 \Sigma}{d \Sigma d E} \quad (\vec{r}; \vec{\Omega}', E' \rightarrow \vec{\Omega}, E)$

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$$\mathfrak{p}_{k}\left(\vec{r}^{*}, \widehat{\vec{\Omega}}^{*}, E\right) = \int_{0}^{\infty} \widetilde{S}_{k}\left(\vec{r}^{*} - s \cdot \widehat{\vec{\Omega}}, \widehat{\vec{\Omega}}, E\right) \exp\left[-\int_{0}^{s} \Sigma^{\dagger}\left(\vec{r}^{*} - s^{*} \cdot \widehat{\vec{\Omega}}, E\right) ds^{*}\right] ds$$
 (2.5)

$$S_{k+1}(\vec{r},\vec{\Omega},E) = \iiint_{4\pi}^{\infty} \phi_{k}(\vec{r},\vec{\Omega}',E') \frac{d^{2}\Sigma}{d\Omega dE}(\vec{r},\vec{\Omega}',E' \rightarrow \vec{\Omega},E) dE' d\Omega'$$
(2.6)

where k is the number of scattering events which the particles have experienced.

The FASTER program uses random sampling techniques to perform the integrations of the order-of-icatter equations, 2.5 and 2.6, thereby giving the uncollided and scattered components of the flux. The program uses a groupwise representation of the energy dependence in conjunction with other numerical techniques--described in Sections 3.0 through 8, 0--in performing the integrations.

The remainder of this section is a general discussion of the application of random sampling to the order-of-scatter equations. In particular, consideration will be given to the development of sampling techniques which should minimize the error in the integration.

In devising optimal solutions of these order-of-scatter equations, it is noted that after computing the (k-1)th and lower order flux components, the unsolved portion of the problem, corresponding to the kth and higher order flux components, is given by a summation over the "future" components of the flux. This unsolved portion of the problem is denoted by $\Phi_{\geq k}$ ($\widehat{r}, \widehat{n}, E$)--the angular flux from particles having k or more collisions--and is given by a summation of equation 2.5:

$$\begin{split} & \phi_{\geq k}\left(\vec{r}, \, \vec{\Omega}, \, E\right) = \sum_{k'=k}^{\infty} \phi_{k'}\left(\vec{r}, \, \vec{\Omega}, \, E\right) \\ & = \int_{0}^{\infty} S_{\geq k}\left(\vec{r} - s \, \, \vec{\Omega}, \, \vec{\Omega}, \, E\right) \exp\left[-\int_{0}^{s} \Sigma^{\dagger}\left(\vec{r} - s^{\dagger} \, \, \vec{\Omega}, \, E\right) \, ds^{\dagger}\right] ds \qquad (2.7a) \end{split}$$

where $S_{\geq k}(\vec{r},\vec{a},E)$ is the differential scattered source density of particles having k or more collisions.

$$S_{\geq k} (\vec{r}, \vec{v}, E) = \sum_{k'=k}^{\infty} S_{k'} (\vec{r}, \vec{v}, E)$$

For example, in initiating the order-of-scatter solution, the unsolved portion of the problem is:

$$\Phi_{\geq 0}(\hat{\vec{r}}, \hat{\vec{\Omega}}, E) = \int_{0}^{S} S_{\geq 0}(\hat{\vec{r}} - s\hat{\vec{\Omega}}, \hat{\vec{R}}, E) \exp\left[-\int_{0}^{S} \hat{\vec{S}}^{\dagger}(\hat{\vec{r}} - s\hat{\vec{\Omega}}, E) ds^{\dagger}\right] ds \qquad (2.7b)$$

where $\phi_{\sum_{i}}(\vec{\tau}, \vec{\Omega}, E)$ is the total angular flux, $\phi(\vec{\tau}, \vec{\Omega}, E)$, from all orders-of-scatter and $S_{\sum_{i}}(\vec{\tau}, \vec{\Omega}, E)$ is the total differential source density, $S(\vec{\tau}, \vec{\Omega}, E)$, including the scattered source.

In computing the kth order-of-scatter flux component, all higher order components should also be considered. If attention is given to a minimum error calculation of $\Phi_k(\vec{r},\vec{n},E)$, this will not be the colculation which minimizes the error in $\Phi_{\geq k}(\vec{r},\vec{n},E)$. However, it may be adequate since the two calculations are quite similar, i.e., it is theoretically possible to define kernels such that:

$$\begin{split} \Phi_{\geq k}\left(\vec{r}, \vec{\Omega}, E\right) = & \int_{0}^{\infty} \left[\iiint_{k} \mathcal{O}_{0}^{\infty} \quad S_{k}\left(\vec{r} - s\vec{\Omega}, \vec{\Omega}^{\dagger}; E^{\dagger}\right) \\ \times \quad \exp\left[-\int_{0}^{s} \Sigma^{\dagger}\left(\vec{r} - s\vec{\Omega}, E\right) ds^{\dagger} \right] ds \end{split}$$
(2.6)

where the kernel K ($\vec{r} - s \ \vec{\Omega}, \ \vec{\Omega}', E' \rightarrow \vec{r}, \vec{\Omega}, \vec{E}$) usually varies more slowly than the material attenuation kernel.

This "resolvent" kernel will yield the solution with an integration over the fixed source. However, this kernel is as difficult to obtain as the order-of-scatter solution is and it involves a similar iterative process, Reference 5, pg. 522. The most well known examples of this kernel are the dose kernels derived from moments method colculations for point isotropic sources in infinite media(⁶).

Use of the "resolvent" kernel is not practical for geometrically complex problems. However, the "success" of the approximate dose kernels in complicated geometries leads naturally to their use in estimating the importance of future scattering events. The use of approximate kernels is discussed in more detail in Section 2.5.

2.3 RANDOM SAMPLING CONCEPTS

The concepts involved in applying random sampling to the integration of equations 2.5 and 2.6 are simplified notationally by considering the evaluation of a simple definite integral with a non-negative integrand:

$$I = \int_{R(x)} f(x) dx = \int_{R(x)} \frac{f(x)}{p^{*}(x)} p^{*}(x) dx = \int_{R(x)} f^{*}(x) p^{*}(x) dx$$
(2.9)

where
$$f^*(x) = f(x)/\rho^*(x)$$

R(x) is the range of x
 $p^*(x) \ge 0$
 $p^*(x) > 0$ if $f(x) > 0$
 $\int p^*(x) dx = 1$
R(x)
(2.10)

The conditions imposed on p*(x) permit its use as a sampling function for obtaining e values x_i of x. This function is properly called a probability density function for the random variable x.

The mean or expected value of f*(x) is simply;

$$\mathbb{E}\left[f^{*}(x)\right] = \int_{\mathbb{R}(x)} \left[f^{*}(x)\right] p^{*}(x) dx = 1$$
 (2.11)

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The expected value of the mean square variation of $f^*(x)$ from its expected value (the variance of $f^*(x)$) is defined by:

$$\sigma^{2} \left[f^{*}(x) \right] = E \left[(f^{*}(x) - 1)^{2} \right]$$

$$= \int_{\mathbb{R}(x)} \int_{\mathbb{R}^{2}(x)} \left[(f^{*}(x) - 1)^{2} \right] p^{*}(x) dx = \int_{\mathbb{R}(x)} \int_{\mathbb{R}^{2}(x)} \left[f^{*}(x) \right]^{2} p^{*}(x) dx - 1^{2}$$

$$= \int_{\mathbb{R}(x)} \frac{f^{2}(x)}{p^{*}(x)} dx - 1^{2}$$
(2.12)

Both the mean and variance of $f^*(x)$ involve analytic integrations. Of greater interest in numerical integrations are the sample mean:

$$I_n = \frac{1}{n} \sum_{i=1}^{n} f^*(x_i), x_i \text{ is randomly selected from } p^*(x)$$
 (2.13)

and the corresponding sample variance:

$$V_{n}^{2} = \frac{1}{n-1} \sum_{i=1}^{n} \left[f^{*}(x_{i}) - i_{n} \right]^{2} = \frac{1}{n-1} \left[\sum_{i=1}^{n} \left[f^{*}(x_{i})^{2} - n i_{n}^{2} \right] \right]$$
(2.14)

Simple manipulations (Reference 7, pg. 198) yield:

$$E\begin{bmatrix} I_n \end{bmatrix} = I$$

$$\sigma^2\begin{bmatrix} I_n \end{bmatrix} = \frac{1}{n} \sigma^2 \begin{bmatrix} f^*(x) \end{bmatrix}$$

$$E\begin{bmatrix} V_n^2 \end{bmatrix} = \sigma^2 \begin{bmatrix} f^*(x) \end{bmatrix}.$$

The last two equations imply that:

$$\sigma \left[\begin{bmatrix} I_n \end{bmatrix} \approx \frac{1}{n} \quad \bigvee_n^2 \tag{2.15} \right]$$

Finally, it is noted that since $f(x) \ge 0$ for all x in R(x), then the optimum (zero variance) integration is performed by sampling from:

$$\mathbf{p}^{\star}(\mathbf{x}) = \frac{\mathbf{f}(\mathbf{x})}{\mathbf{I}} \qquad (2.16)$$

since any discrete point will give the correct answer. Subsequent sections deal with approximate relationships which utilize this obvious result.

It should be noted that a transformation to the integration variable u, where du = $l^{-1} f(x) dx$, also yields a zero error result in a conventional numerical integration. In fact, the Monte Carlo and conventional integrations would be the same except for the technique used to obtain discrete points x_1 (random versus systematic).

2.4 INNER ITERATIONS

It was possible in developing the order-of-scatter equations to explicitly write an equation for the kth order scalar flux component which involved a k-fold volume integration (and a k-fold energy integration), i.e., spatial integrations over the fixed source volume, the single scattered source volume, . . . , the kth scattered source volume. The monner in which the order-of-scatter equations was developed obviated the need for explicitly displaying these volume integrations. However, in relating the discussion of Section 2.3 to the techniques used in solving the order-of-scatter equations, this k-fold volume integration must be recognized. In particular, the discrete random variable x_1 used in the preceding section 1s equivalent to a series of discrete position vectors $\vec{r}_{1,0} \circ \vec{r}_{1,1} \vee \vec{r}_{1,2} \cdots \cdot \vec{r}_{1,k} + \cdots$, obtained by random sampling.

Fortunately, the techniques used in the Monte Carlo integration of the order-ofscatter equations, i.e., the techniques used in relecting the discrete position vectors $\vec{r}_{j,k}$, $k = 0, 1, \ldots$, can be discussed in an orderly fashion without displaying the k-fold volume integrations. The discussion of the integrations is given below with the "outer" iteration index i of Section 2.3 suppressed. The "inner" iteration index k, corresponding to the kth order-of-scatter, will be retained.

The "order-of-scattering" inner iterants are obtained in a straight forward manner. A natural starting point is the equation for the kth component of the scalar flux:



$$\phi_{k}^{\dagger}(\vec{r}, E) = \iint_{4\pi} \phi_{k}(\vec{r}, \vec{\Omega}, E) d\Omega$$

$$= \iint_{4\pi} \int_{\pi} \int_{0}^{\infty} S_{k}^{0}(\vec{r} - s, \vec{\Omega}, \vec{\Omega}, E) \exp\left[-\int_{0}^{s} \Sigma^{1}(\vec{r} - s', \vec{\Omega}, E) ds^{*}\right] ds d\Omega$$

$$\phi_{k}^{\dagger}(\vec{r}, E) = \iiint_{k} S_{k}^{\dagger}(\vec{r}, \vec{\Omega}, E) \exp\left[-\int_{0}^{s} \Sigma^{1}(\vec{r} - s', \vec{\Omega}, E) ds^{*}\right] dV \qquad (2.17)$$

where dV is the general differential volume element, equivalent to $s^2 ds d \Omega$ in a spherical coordinate system centered at \vec{r} . This equation has been transformed into a general volume integration to display the singularity $(1/s^2)$ associated with the flux calculation.

This equation has a definite value and is manipulated in the same manner as equation 2.9, i.e., the integrand is multiplied and divided by an arbitrary sampling function:

$$\phi_{k}(\vec{r}, E) = \iiint \left\{ \frac{S_{k}(\vec{r}^{T}, \vec{\Omega}, E) \exp\left[-\int_{0}^{s} \Sigma^{T}(\vec{r} - s^{T}, \vec{\Omega}, E) ds^{T}\right]}{s^{2} p_{k}^{*}(\vec{r}^{T})} \right\} p_{k}^{*}(\vec{r}^{T}) dV$$

$$(2.18)$$

with the restrictions:

$$p_{k}^{*}(\vec{r'}) \geq 0$$

$$p_{k}^{*}(\vec{r'}) \geq 0 \quad \text{if } \iiint_{4^{*}} e^{\infty} S_{k}(\vec{r'}, \vec{\Omega}, E) \ dE \ d^{}\Omega \geq 0$$

$$\iiint_{k} P_{k}^{*}(\vec{r'}) \ dV = 1$$

$$(2.19)$$

This equation can be evaluated in a manner analogous to that used in equation 2.13 for the sample mean, i.e.: select $\vec{r_k}$ at random from p^*_k (7)

Then the contribution to the kth component of the scalar flux is given by:

$$\Delta \phi_{k}^{*}(\vec{r}, E) = \frac{S_{k}(\vec{r_{k}}, \widehat{n}, E)}{p_{k}^{*}(\vec{r_{k}})} = \frac{\exp\left[-\int_{0}^{s} \Sigma^{\dagger}(\vec{r}-s, \widehat{n}, E) ds^{\dagger}\right]}{s^{2}}$$
(2.20)

where $s = |\vec{r} - \vec{r_k}|$ and $\vec{\Omega} = (\vec{r} - \vec{r_k})/s$.

Note that the energy varies over its entire range, i.e., random sampling has been limited to the spatial variables. This is equivalent to defining an energy dependent angular point source which represents the kth scattered differential source density.

$$W_{k}^{s}(\widehat{\Omega}, E) = \frac{S_{k}(\widehat{r_{k}}, \widehat{\Pi}, E)}{P_{k}^{s}(\widehat{r_{k}})}$$
(2.21)

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since the remaining factor in equation 2, 20 is associated with the flux calculations and depends on the variable position vector \vec{r} . This point source is defined through the kth source distribution and can be evaluated for any desired direction $\vec{\Omega}$.

This procedure is also equivalent to representing the <u>kth</u> component of the differential source density by:

$$S_{k}^{*}(\vec{r},\vec{\Omega},E) = W_{k}^{s}(\vec{\Omega},E) \delta(\vec{r}-\vec{r}_{k})$$
 (2.22)

where $\delta(\vec{r} - \vec{r}_k)$ is the Dirac delta function This representation is particularly useful in later discussions where formal integrations over the kth scattered source volume are required. In particular, the point representation of the fixed source (k = 0) is:

$$W_{0}^{s}\left(\vec{\Omega}, E\right) = \frac{S_{0}\left(\vec{r_{0}}, \vec{R}, E\right)}{P_{0}^{s}\left(\vec{r_{0}}\right)}$$
(2.23)

The expected value of $S_{0}^{*}(\vec{r},\vec{\Omega},E)$ is just the fixed source distribution:

$$E\left[W_{o}^{\delta}\left(\vec{n}, -\delta\left(\vec{r}-\vec{r}_{o}\right)\right]\right] = \iiint_{o}\left[W_{o}^{\delta}\left(\vec{n}, E\right) -\delta\left(\vec{r}-\vec{r}_{o}\right)\right] P_{o}^{*}\left(\vec{r}_{o}\right) d\vec{r}_{o}$$

$$= \iiint_{o}\left[\int_{O} \frac{S_{o}\left(\vec{r}_{o}, \vec{n}, E\right) -\delta\left(\vec{r}-\vec{r}_{o}\right) P_{o}^{*}\left(\vec{r}_{o}\right) d\vec{r}_{o}}{P_{o}^{*}\left(\vec{r}_{o}^{*}\right)}$$

$$= S_{o}\left(\vec{r}, \vec{n}, E\right)$$

$$(2.24)$$

The definition of the energy dependent, angular, point sources for higher order scattered components is more involved. Assuming the inner iterations have progressed through the (k-1)<u>th</u> spatial integration, then the (k-1)<u>th</u> component of the source density is represented by the vector \vec{r}_{k-1} and the angular point source W_{k-1}^{s} ($\vec{\Omega}, E$). Then the <u>kth</u> scattered energy angular point source at \vec{r}_{k} is given by:

$$\begin{split} W_{k}^{s}\left(\widehat{n}, E\right) &= \iiint_{k}^{\infty} \frac{\phi_{k-1}\left(\widehat{r}_{k}^{t}, \widehat{n}^{T}, E^{t}\right)}{\mathsf{P}_{k}^{*}\left(\widehat{r}_{k}^{t}\right)} \frac{d^{2}\Sigma}{d\Omega dE} \left(\widehat{r}_{k}^{*}, \widehat{n}^{T}, E^{t}\right) \xrightarrow{} \widehat{n}, E \right) dE^{t} d\Omega^{t} \\ &= \iiint_{n}^{\infty} \left[\int_{0}^{\infty} \sum_{k=1}^{n} (\widehat{r}_{k}^{*} - s \, \widehat{n}^{T}, \widehat{n}^{T}, E^{t}) \exp\left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, \widehat{n}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] dE^{t} d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{t}\right) = \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, \widehat{n}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{T}\right) = \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, \widehat{n}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{T}\right) = \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, \widehat{n}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{T}, E^{t}\right) = \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, \widehat{n}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{T}, E^{t}\right) + \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, \widehat{n}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{T}, E^{t}\right) + \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \right] d\Omega^{t} \\ &= \rho_{k}^{*}\left(\widehat{r}_{k}^{T}, E^{t}\right) + \left[\int_{0}^{s} \sum_{k=1}^{t} (\widehat{r}_{k}^{*} - s^{T} \, \widehat{n}^{T}, E^{t}) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, E^{t}\right) \frac{dP}{d\Omega dE} \left(\widehat{r}_{k}^{T}, E^{t}\right) \frac{dP}{dP} \left(\widehat{r}_{k}^{T}, E^{t}\right) \frac{dP$$

$$= \iiint \left[\underbrace{\int_{0}^{\infty} W_{k-1}^{0}(\Omega', E') \exp\left[-\int_{0}^{\infty} \Sigma' (\tilde{r}_{k} - s' \Omega', E') ds'\right]}_{s^{2} P_{k}^{*}} \left[\frac{d^{*} \Sigma}{d\Omega dE} (r_{k} r_{k} \Omega', E' \rightarrow \Omega E) dE' \right] \delta(r - \tilde{r}_{k-1}) dV$$

$$= \int_{0}^{\infty} \left\{ \frac{w_{k-1}^{s} \left(\widehat{\Omega}_{k'}^{s} \in I \right) \exp \left[-\int_{0}^{s_{k}} \Sigma^{\dagger} \left(\widehat{\tau}_{k}^{s} - s' \cdot \widehat{\Omega}_{k}^{s} \in E' \right) ds \right]}{s_{k}^{2} P_{k}^{s} \left(\widehat{\tau}_{k}^{s} \right)} \right\} \frac{d^{2} \Sigma}{d\Omega dE} \left(\widehat{\tau}_{k}^{s} \widehat{\Omega}_{k}^{s} \in I \right) + \widehat{\Omega}, E) dE'$$
(2.25)

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where $s_k = \{\vec{r_k} - \vec{\vec{r_{k-1}}}\}$ and $\hat{\vec{\alpha}}_k = (\vec{r_k} - \vec{\vec{r_{k-1}}})/s_k$

Note that the (k-1)th source density , sponent was replaced by its equivalent point representation $W_{k-1}^{s}(\vec{\Omega}, E)$. Thus, this equation is an equality in the sense that the expected value of the right hand side is the left hand side.

It now becomes expedient to define an energy dependent point monodirectional quantity at $\vec{r_{\mu}}$ which characterizes the (k-1)<u>th</u> component of the flux:

$$W_{k-1}^{\phi}(E) = W_{k-1}^{\delta}(\vec{\Omega}_{k}, E) = \frac{\exp\left[-\int_{0}^{\delta_{k}} \Sigma^{\dagger}(\vec{\tau_{k}} - s'\vec{\Omega}_{k}, E) ds^{\dagger}\right]}{s_{k}^{2} e_{k}^{*}(\vec{\tau_{k}})}$$
(2.26)

The factor associated with random selection of the discrete position vector $\overline{r_k}$ has been included in this energy-dependent, point monodirectional representation of the flux to simplify the final equation for the kith scattered, angular point source:

$$W_{k}^{s}(\widehat{\mathbf{n}}, E) = \int_{0}^{\infty} W_{k-1}^{\phi}(E') \frac{d^{2} \Sigma}{d \mathbf{n} d E'} (\widehat{\mathbf{k}}; \widehat{\mathbf{n}}_{k'}, E' \longrightarrow \widehat{\mathbf{n}}, E) dE' \qquad (2.27)$$

The order of calculations may clarify this procedure:

- a) select \vec{T}_{k} from \vec{p}_{k} (\vec{r}^{+}) b) calculate $s_{k} = \left| \vec{T}_{k} - \vec{T}_{k-1} \right|$ c) calculate $\vec{n}_{k} = \frac{1}{\vec{T}_{k}} - \vec{T}_{k-1} \right| \vec{S}_{k}$ d) calculate W_{k-1}^{i} (\vec{n}_{k} , E) for the discrete direction \vec{n}_{k} $k = 1, W_{0}^{i}$ (\vec{n}_{k} , E); from equation 2, 23 for $\vec{n} = \vec{n}_{k}$ $k > 1, W_{k-1}^{i}$ (\vec{n}_{k} , E) from equation 2, 27 for $\vec{n} = \vec{n}_{k}$ using $W_{k-2}^{\phi}(E)$. e) calculate W_{b-1}^{ϕ} (F) using equation 2.26.
- f) then $W_{k}^{\delta}(\hat{\Omega}, E)$ con be calculated, as required for a given direction $\hat{\Omega}$, by using equation 2.27.

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Thus, $W_k^{L}(\overline{\Omega}, E)$ is not computed directly except as required for discrete directions. It is always available through the fixed source distribution for k = 1, or, for k > 1, through $W_{k-1}^{\Phi}(E)$ and the differential scattering cross sections. This is indicated in step d) obove.

For k = 1, the verification of the representation of the source given by equation 2.27 is obtained by calculating expected values:

$$\begin{split} & E\left[w_{1}^{s}(\vec{n},E)\delta(\vec{r}-\vec{r}_{1})\right] = \iiint_{0} \iiint_{1} \left[w_{1}^{s}(\vec{n},E)\delta(r-r_{1})\right] \vec{r}_{1}(\vec{r}_{1})\vec{r}_{0}(\vec{r}_{0})d\vec{r}_{1}d\vec{r}_{0}^{\lambda} \\ &= \iiint_{0} \iiint_{1} \left\{\int_{0}^{\infty} \frac{S_{0}(\vec{r}_{0},\vec{n}_{1},E^{*})\exp\left[-\int_{0}^{s}\sum_{1}^{t}(\vec{r}_{1}-s^{*},\vec{n}_{1},E^{*})ds^{*}\right] \\ & \times \frac{d^{2}\sum_{1}}{d\Omega dE} \left(\vec{r}_{1};\vec{n}_{1},E^{*}\rightarrow\vec{n}_{2}E\right)dE^{*}\right\}\delta(\vec{r}-\vec{r}_{1})\vec{r}_{1}(\vec{r}_{1})\vec{r}_{0}(\vec{r}_{0})d\vec{r}_{1}d\vec{r}_{0}^{\lambda} \\ & \iiint_{0} \left\{\int_{0}^{\infty} S_{0}(\vec{r}_{0}',\vec{n}',E^{*})\exp\left[-\int_{0}^{s}\sum_{1}^{t}(\vec{r}-s,\vec{n},E^{*})ds^{*}\right]\frac{d^{2}\sum_{1}(\vec{r}_{1},\vec{n}',E^{*}\rightarrow\vec{n}_{2}E)dE^{*}\right\}d\vec{r}_{0} \\ & \iiint_{0} \left\{\int_{0}^{\infty} S_{0}(\vec{r}_{0}',\vec{n}',E^{*})\exp\left[-\int_{0}^{s}\sum_{1}^{t}(\vec{r}-s,\vec{n},E^{*})ds^{*}\right]\frac{d^{2}\sum_{1}(\vec{r}_{1},\vec{n}',E^{*}\rightarrow\vec{n}_{2}E)dE^{*}\right\}d\vec{r}_{0} \\ & S_{1}(\vec{r},\vec{n}',E) \end{split}$$

Verification for higher order components can be obtained by induction, i.e., by assuming:

$$\mathbb{E}\left[\mathbb{W}_{k}^{s}\left(\left. \widetilde{\mathfrak{a}} \right. E\right) \delta\left(\widetilde{r} - \widetilde{r}_{k} \right) \right] = \iiint_{0}^{m} \cdots \iiint_{k}^{m} \mathbb{W}_{k}^{s}\left(\left. \widetilde{\mathfrak{a}} \right. E\right) \delta\left(\widetilde{r} - \widetilde{r}_{k} \right) \mathbf{p}_{k}^{*}\left(\widetilde{r}_{k} \right) \cdots \mathbf{p}_{0}^{*} (\widetilde{r}_{0}) d\widetilde{r_{k}} \cdots d\widetilde{r_{0}} \right) \\ = S_{k}\left(\widetilde{r}, \left. \widetilde{\mathfrak{a}}, E \right) \right)$$



and then showing that

$$\mathbb{E}\left[\mathbb{W}_{k+1}^{s}\left(\vec{\mathfrak{n}}, \mathsf{E}\right)\delta(\vec{r} - \vec{r}_{k+1})\right] = S_{k+1}(\vec{r}, \vec{\mathfrak{n}}, \mathsf{E})$$

Similar verifications can also be obtained for arbitrary point kernels, e.g., those used for flux calculations (Section 2.6). The resulting integrations are similar to those above and are not shown.

The final set of procedures used in a single outer iteration is shown in Figure 2. The inner iterations cannot proceed indefinitely as is indicated by the arder-of-scatter solution. Therefore, the inner iterations are terminated using various criteria such as total number of iterations (collision cutoff), all energies below some minimum (energy cutoff), or all flux contributions being negligible (weight cutoff).

2.5 SAMPLING FUNCTIONS

At this point, the definitions of the sampling or probability density functions are arbitrary except for the canditions imposed in Equation 2, 19. The criterion selected for defining optimal functions is that the variance in the contributions from all future inner iterations be minimum.

After (k-1) inner iterations, the scalar flux will have been estimated to the extent of:

$$\phi_{(2.29)$$

The remainder associated with neglecting higher order components of the flux or, alternatively, the importance of these components is given by:

$$\phi_{\geq k}(\vec{r}, E) = \sum_{k'=k}^{\infty} \phi_{k'}(\vec{r}, E)$$
(2.30)

Since a detailed treatment of these "future" components is as difficult as solving the original problem---equation 2. 7a would be solved---various approximations must be made. It is noted

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Figure 2. The Monte Carlo Method - Inner Iterations

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that a single point criterion--independent of energy--is more easily applied, and much easier to estimate; e.g.

$$D_{k}(\vec{r}) = \int_{0}^{\infty} f(E) +_{k} (\vec{r}, E) dE$$
(2.31)

where f(E) is a response function of particular importance to the problem being solved, e.g., the flux to dose conversion factor if dose rates are being calculated. The solution and remainder corresponding to this response function are then given by:

$$\begin{split} & \mathsf{D}_{$$

The calculation of the latter quantity is also as difficult as solving the original problem. However, for estimating purposes, the "point-kernel method" is available for approximating the remainder:

$$\begin{split} D_{\geq k}\left(\vec{\tau}\right) &= -\sum_{k'=k}^{\infty} \int_{0}^{\infty} f\left(E\right) \oint_{k'}\left(\vec{\tau}, E\right) dE \\ &= -\sum_{k'=k}^{\infty} \int_{0}^{\infty} f\left(E\right) \iiint S_{k'}\left(\vec{t'}, \vec{n}, E\right) \exp\left[-\int_{0}^{s} \sum_{k'=k'=k'}^{t} \left(\vec{\tau} - s^{\dagger} \cdot \vec{n}, E\right) dv dE \\ &= -\inf_{s} \int_{0}^{\infty} \left\{ \underbrace{\int_{0}^{\infty} \left[\sum_{k'=k}^{\infty} S_{k'}\left(\vec{t'}, \vec{n}, E\right)\right] \exp\left[-\int_{0}^{s} \sum_{k'=k'=k'=k'}^{t} \left(\vec{\tau} - s^{\dagger} \cdot \vec{n}, E\right) dv dE \\ &= s \cdot D_{\geq k'}\left(\vec{\tau}\right) \end{split}$$

$$(2.34)$$



where

$$\widetilde{D}_{\geq k}(\vec{r}^{*}) = \iiint_{d_{\pi}} \left\{ \int_{0}^{\infty} \iint_{d_{\pi}} S_{k}(\vec{r}^{*}, \vec{n}', E) \times (\vec{n}^{*}, E, \eta(E)) \exp \left[-\eta(E) \right] f(E) d\vec{n}' dE \right\}_{3,2}^{\underline{d_{V}}} (2, 35)$$

$$s = \left[\vec{r} - \vec{\gamma}^{*} \right]_{1} \hat{\vec{n}} = (\vec{r}^{*} - \vec{\gamma}^{*}) / s$$

$$\eta(E) = \int_{0}^{\infty} \sum^{t} (\vec{r}^{*}, \vec{n}^{*}, E) ds^{t}$$

 $k(\vec{\Omega}', E, \eta(E))$ is some approximate representation of the response contributions by multiple scattering events, usually a simple function of the number of the mean-freepaths $\eta(E)$ between a source (or scattering) point and the detector point.

Equation 2, 35 not only estimates the importance of future scattering events but can also be used to estimate the importance of the "source", or scattering points. Since it is a feasible spatial importance estimator -- it is related in an approximate manner to the zero variance importance function -- and since it lends itself to a variety of further approximations, it plays an important role in the development of optimal sampling schemes.

Equation 2.35 can be manipulated in a manner similar to equation 2.18:

$$\widetilde{\mathsf{D}}_{\geq k}(\widetilde{\tau}) = \iiint \underbrace{\left[\int_{0}^{\infty} \iint_{\pi} S_{k}(\widetilde{r}', \widetilde{n}', E) \mathsf{K}(\widetilde{n}', E, \eta(E)) \exp\left[-\eta(E)\right] \mathsf{f}(E) \mathsf{d} \Omega' \mathsf{d} E}_{\mathsf{k}} \right]_{\mathsf{k}} (\widetilde{r}') \mathsf{d} \mathsf{V}}_{\mathsf{k}}$$

Equation 2.16 then implies that the optimum sampling function, yielding zero variance for $\widetilde{D}_{\geq k}(\vec{r})$, is given by:

$$P_{k}^{*}(\vec{r}') = \frac{1}{\widetilde{D}_{k}} \frac{\int_{0}^{\infty} \int_{4\pi}^{\infty} S_{k}(\vec{r}', \vec{\Omega}', E) \kappa(\vec{\Omega}', E, \eta(E)) \exp\left[-\eta(E)\right] f(E) d\Omega' dE}{s^{2}}$$
(2.36c)

This equation is still quite involved and its numerical implementation requires further simplification and approximation. The form of this equation may be clarified by examining its equivalent for a one velocity problem. Assuming a uniform infinite medium and isotropic sources, either fixed or scattered, this equation can be approximated by:

$$\mathbf{p}_{k}^{+}(\vec{r}') = \frac{S_{k}(\vec{r}') \exp\left[-\Sigma^{r}_{s}\right]/s^{2}}{\iiint S_{k}(\vec{r}') \exp\left[-\Sigma^{r}_{s}\right]/s^{2}} dV$$
(2.36b)

where Σ^r is an effective cross section giving the attenuation characteristics of the total flux from the kth scattered source and $S_k(\vec{r}^s)$ is the differential kth scattered source density. For point detectors, random sompling of the fixed source distribution, k = 0, can

utilize equation 2.36 directly.' The more important aspects of this equation are:

- a) it includes the spatial divergence $(1/s^2)$ from the detector;
- b) it retains the exponential falloff of source point importance due to material, attenuation, and
- c) it includes the fixed source distribution.

The techniques used in the FASTER program for sampling the fixed source are closely associated with equation 2.36b. An average source energy is used to define the necessary sampling parameters. The program includes, however, an explicit representation of the material distribution. The details of the sampling procedures are discussed in Section 8.3.

Applications of equation 2.36 to higher order flux components, k > 0, involves the scattered source definition using the (k-1)th point source representation:

$$P_{k}^{*}(\vec{\tau}^{*}) = \frac{1}{\vec{D} \geq k} \int_{0}^{\infty} \int_{4\pi}^{\infty} \int_{0}^{\infty} \tilde{W}_{k-1}^{s}(\vec{\Omega}^{*}, E^{*}) \frac{d^{2} \sum}{d \Omega dE} (\vec{\tau}^{*}, \vec{\Omega}^{*}, E^{*} \rightarrow \vec{\Omega}, E)$$

$$\frac{K(\vec{\Omega}^{*}, E, \eta(E)) \exp\left[-\int_{\Omega} \sum_{k=1}^{t} (\vec{\tau}^{*} - t, \vec{\Omega}^{*}, E) dt^{*} - \eta(E)\right]}{t^{2}s^{2}} f(E) dE^{*} d\Omega^{*} dE$$
where $t = |\vec{\tau}^{*} - \vec{\tau}_{k-1}|$, $\vec{\Omega}^{*} = (\vec{\tau}^{*} - \vec{\tau}_{k-1})/t$
(2.37a)

Again, a large degree of approximation is required for numerical calculations.

A one-velocity approximation may also clarify this equation. Using the assumptions used in equation 2.36, the sampling function can be approximated by:

$$\mathbf{p}_{k}^{*}\left(\mathbf{r}^{*}\right) = \frac{\exp\left[-\Sigma^{t}+\Sigma^{r}s\right]}{\iint \frac{\exp\left[-\Sigma^{t}+\Sigma^{r}s\right]}{\frac{1}{1^{2}s^{2}}} dV}$$
(2.37b)

where Σ^{t} is the total cross section.

For a point detector the following characteristics are noted for this scattering point sampling function:

- a) it includes the spatial divergence from both the source $(1/t^2)$ and the detector $(1/s^2)$
- b) it includes the exponential attenuation along both "legs" of the scattering triangle
- c) it includes the spatial and angular dependence of the scattering cross section, and
- d) it includes the angular dependence of the (k-1)th source component.

The FASTER program uses a one-velocity approximation of this sampling function with group averaged parameters being obtained at each scattering point. The material distribution and scattering angle effects are included by several alternate approximations. The details are discussed in Sections 8.4, 8.5, and 8.6.

Similar equations can be obtained for sampling functions which minimize the variance of volume and surface averaged flux calculations. However, these equations involve on integration over the spatial extent of these volumes and surfaces and the development is more complicated. These sampling functions have been approximated, therefore, by "solid angle" considerations as described in Section 8.0.



2.6 POINT ANGULAR FLUXES

The set of inner iterations yields a single estimate of the total differential source density:

$$S_{i}^{*}(\vec{r},\vec{n},E) = \sum_{k=0}^{\infty} W_{ik}^{*}(\vec{n},E) = \delta(\vec{r}-\vec{r}_{ik})$$
 (2.38)

where the index i corresponds to the <u>ith</u> repetition of this process, or a single outer iteration. Previous discussions verified that:

$$E\left[S_{\frac{1}{2}}^{*}\left(\vec{r},\vec{\Omega},E\right)\right] = S\left(\vec{r},\vec{\Omega},E\right) - R_{\frac{1}{2}} \qquad (2.39)$$

where R_i is a remainder corresponding to the termination of the inner iterations after a finite value of k, i.e., the neglected higher order-of-scatter components.

Repetitive application of these techniques (n outer iterations) yields the final estimate of the total differential source density:

$$S^{*}(\vec{\hat{r}},\vec{\hat{n}},E) = \frac{1}{n} \sum_{i=1}^{n} \left[\sum_{k=0} W_{ik}^{s}(\vec{\hat{n}},E) \delta(\vec{\hat{r}}-\vec{\hat{\tau}}_{ik}) \right]$$
(2.40)

This is not the end result, of course. The original intent was to obtain the flux at an arbitrary point. Equation 2.7b implies the total angular flux is abtained by the integration.

$$\phi\left(\widehat{r},\widehat{\Omega},E\right) = \int_{0}^{\infty} S\left(r - s\widehat{\Omega},\widehat{\Omega},E\right) \exp\left[-\int_{0}^{s} \int_{0}^{t} \left(\widehat{r} - s\widehat{\Omega},E\right) ds^{t}\right] ds^{t} \qquad (2,41)$$

This can be approximated using the above source density:

$$\phi^{*}\left(\widehat{r},\,\widehat{\Omega},\,E\right) = \int_{0}^{\infty} s^{*}\left(\widehat{r}-s\widehat{\Omega},\,\widehat{\Omega},\,E\right) \exp\left[-\int_{0}^{\infty} t\left(\widehat{r}-s^{*}\widehat{\Omega},\,E\right)\,ds\right] ds \qquad (2.42)$$



It is a straightforward task to show that the expected value of this approximation is, indeed, the total angular flux within an error ${\cal R}$ corresponding to the source errors $R_{\rm t}$ above:

$$\mathbf{E}\left[\phi^{*}\left(\vec{r},\vec{\Omega},\mathbf{E}\right)\right] = \phi\left(\vec{r},\vec{\Omega},\mathbf{E}\right) - \mathcal{K}$$
(2.43)

The verification involves integrations similar to those used to verify the representation of the differential source density, equations 2, 24 and 2, 28, and is not shown.

Substitution of equation 2.40 into equation 2.42 yields:

$$\begin{split} & \stackrel{\bullet}{\Phi}(\vec{r},\vec{\Omega},E) = \int_{0}^{\frac{n}{n}} \sum_{i=1}^{n} \left[\sum_{k=0}^{\infty} W_{ik}^{s}(\vec{\Omega},E) \delta(\vec{r}-\vec{\tau}_{ik}) \right] \exp\left[-\int_{0}^{s} \sum_{i=1}^{t} (\vec{r}-s^{i}\vec{\Omega},E) ds^{i} \right] ds \\ &= \frac{1}{n} \sum_{i=1}^{n} \sum_{k=0}^{\infty} \int_{0}^{\infty} W_{ik}^{s}(\vec{\Omega},E) \delta(\vec{r}-\vec{\tau}_{ik}) \exp\left[-\int_{0}^{s} \sum_{i=1}^{t} (\vec{r}-s^{i}\vec{\Omega},E) ds^{i} \right] ds \end{split}$$
(2.44)

where the order of the summations and integration has been reversed. To eliminate some of the notational clutter, the individual elements in the summation will be examined with the outer iteration index suppressed:

$$\Delta \phi_{\mathbf{k}}^{*}(\vec{r},\vec{\Omega},E) = \int_{0}^{\infty} W_{\mathbf{k}}^{s}(\vec{\Omega},E) \,\delta(\vec{r}-\vec{r}_{\mathbf{k}}) \exp\left[-\int_{0}^{s} \sum_{k=1}^{t} (\vec{r}-s^{*}\vec{\Omega},E) \,ds\right] ds \qquad (2.45)$$

This is also the procedure used in numerical calculations, i.e., individual contributions are computed without considering the iteration index.

The spatial integration is performed using the relationship:

$$\delta(\overline{r} - s\Omega - \overline{r_{k}}) = \delta(s - s_{k}) \frac{\delta(\overline{\Omega} - \overline{\Omega}_{k})}{s_{k}^{2}}$$
(2.46)

where:

$$s_k = \left| \overline{r} - \overline{r_k} \right|, \quad \overline{\Omega}_k = (\overline{r} - \overline{r_k})/s_k$$

Thus:

$$\begin{split} \Delta \phi_{k}^{*}(\overline{\tau},\overline{\Omega},E) = & \int_{0}^{\infty} W_{k}^{*}(\overline{\Omega},E) \, \delta(s-s_{k}) \, \frac{\delta(\overline{\Omega}-\overline{\Omega}_{k})}{s_{k}^{2}} \, \exp \left[-\int_{0}^{s} \Sigma^{\dagger}(\overline{\tau}-s^{*},\overline{\Omega},E) \, ds^{*} \right] \, ds \\ & = W_{k}^{*}(\overline{\Omega},E) \, \delta(\overline{\Omega}-\overline{\Omega}_{k})^{*} \frac{\exp \left[-\int_{0}^{s_{k}} \Sigma^{\dagger}(\overline{\tau}-s^{*},\overline{\Omega},E) \, ds^{*} \right]}{s_{k}^{2}} \end{split}$$

The delta function involving the direction vector complicates nothing. In particular, the corresponding contribution to the scalar flux is given by an integration over solid angle:

$$\Delta \Phi_{k}^{*}(\overline{r}, E) = \iint_{4\pi} \Delta \Phi_{k}^{*}(\overline{r}, \overline{\Omega}, E) d\Omega$$
$$= W_{k}^{*}(\overline{\Omega_{k'}}E) \cdot \frac{\exp\left[-\int_{0}^{s_{k}} \Sigma^{\dagger}(\overline{r} - s^{\dagger}\overline{\Omega_{k'}}E) ds^{\dagger}\right]}{s_{k}^{2}} \qquad (2.48)$$

as one would expect.

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As indicated in Section 2.4, the sampling functions which minimize the variance in the flux at the point \vec{r} , involve this point in a rather complicated manner. However, the techniques used in flux estimation are independent of these considerations and can be used for an arbitrary set of points. It should be noted that flux estimation for arbitrary points will "yield a fesult with an infinite variance^(B) unless these points are located in volumes which exclude source and scattering points. That is, the $1/s_k^2$ factor is the trouble maker and its deleterious effect can only be removed by including it in the sampling function or by excluding in sampling function or by excludeing source of s_k.

2.7 SPATIALLY AVERAGED ANGULAR FLUXES

 The problem of infinite variance flux estimates can also be removed by averaging the fluxes at arbitrary points over a specified surface or volume. While these averaged results are usually less desirable than a set of point results, there are instances when averages are the only requirement.

The contribution to a surface averaged flux is obtained by integrating the point result given by equation 2, 47:

$$\Delta \phi_{k}^{*}(\widehat{\Omega}, E)_{A} = \frac{1}{A} \iint_{A} W_{k}^{5}(\widehat{\Omega}, E) \delta(\widehat{\Omega} - \widehat{\Omega}_{k}) \frac{e^{\sum_{i}} \left[-\int_{0}^{5_{k}} \Sigma^{1}(\widehat{\tau} - s^{i}, \widehat{\Omega}, E) ds^{i} \right] dA}{s_{k}^{2}}$$
(2.49)

where A is the area of the specified surface, dA is a differential element of area, and $\hat{\tau}$ is a point on the surface. The integration is than transformed to an integration over solid angle about the point $\hat{\tau}_{1}$:

$$\Delta \phi_{k}^{*}(\vec{\Omega}, E)_{k} = \frac{1}{A} \iint_{A\pi} W_{k}^{s}(\vec{\Omega}, E) \delta(\vec{\Omega} - \vec{\Omega}_{k}) \frac{\epsilon_{h,P} \left[-\int_{0}^{s_{h}} \Sigma^{s}(\vec{r} - s^{\dagger}\vec{\Omega}, E) ds^{\prime} \right]}{s_{k}^{2}} \frac{s_{k}^{2} d\Omega_{k}}{|\vec{\Omega}_{k} \cdot \vec{n}|}$$
(2.50)

where dA = $s_k^2 d\Omega_k / |\tilde{\Omega}_k \cdot \tilde{n}|$, \tilde{n} is the unit normal to the surface of \tilde{r} , and a summation over multiple points on the surface which yield the same direction vector $\tilde{\Omega}_k$ is implicit. Note that the integration is performed using a differential element of solid angle $d\Omega_k$ since $\tilde{\Omega}_k$ is the direction vector determining the point (s) \tilde{r} on the surface. Using the reciprocol nature of the Dirac delta function and the material attenuation kernel, the integration yields:

$$\Delta \phi_{k}^{*}(\widetilde{n}, E)_{A} = \frac{1}{A} W_{k}^{s}(\widetilde{n}, E) \frac{\exp\left[-\int_{0}^{s(\widetilde{n})} \Sigma^{\dagger}(\widetilde{r}_{k} + s^{\dagger}, \widetilde{n}, E) ds^{\dagger}\right]}{\left|\widetilde{n} \cdot \widetilde{n}\right|}$$
(2.51)

where $s(\overline{\Omega})$ is the distance to the surface.

The contribution to a volume averaged flux is also obtained by integrating the point result.

$$\Delta \Phi_{k}^{*}(\widehat{n}_{k}E)_{V} = \frac{1}{V} \iiint_{V} W_{k}^{s}(\widehat{n},E)_{\delta}(\widehat{n}-\widehat{n}_{k}) \frac{\exp\left[-\int_{0}^{\delta_{k}} \Sigma^{\dagger}(\widehat{\tau}-s\widehat{n}_{k},E) ds^{\dagger}\right] dV}{s_{k}^{2}}$$
(2.52)

where V is the volume over which the flux is averaged.

The integration is transformed using a spherical coordinate system centered at $\vec{\tau}_k$:

$$\Delta \phi_{k}^{*}(\widehat{\Omega}, E)_{V} = \frac{1}{V} \iint_{A\pi s} \int_{D} W_{k}^{s}(\widehat{\Omega}, E) \,\delta(\widehat{\Omega} - \widehat{\Omega}_{k}) \frac{\exp\left[-\int_{0}^{\infty} \sum_{s}^{t} (s_{k}^{s} + s\widehat{\Omega}, E) ds^{s}\right]}{s_{k}^{2}} s_{k}^{2} ds_{k} d\Omega_{k} \qquad (2.53)$$

where $dV = s_k^2 ds_k d\Omega_k$ since $\overline{\Omega}_k$ and s_k define the points \overline{r} in the volume.



Using the same arguments as before, the integration yields:

$$\Delta \Phi_{k_{\perp}}^{*}(\widetilde{\Omega}, E) = \frac{1}{V} W_{k}^{s}(\widetilde{\Omega}, E) \int_{S, in V} exp \left[-\int_{0}^{s} \Sigma^{t}(\widetilde{\tau_{k}} + s^{t}\widetilde{\Omega}, E) ds^{t} \right] ds \qquad (2.54)$$

The integration over distance s, is limited to points \vec{r} on $\vec{r_k} + s\hat{\Omega}$ which lie in the volume. There may, of course, be several discrete intersections with the volume along $\hat{\Omega}$.

There are two interesting, special forms of this equation. Considering only one intersection with the volume, let $s(\overline{\Omega})$ be the distance to the volume and $\Delta s(\overline{\Omega})$ the distance in the volume. Then, if the volume is void:

$$\Delta \Phi_{k}^{*}(\widehat{\Omega}, E) = \frac{1}{V} W_{k}^{s}(\widehat{\Omega}, E) \exp \left[- \int_{0}^{s(\widehat{\Omega})} \Sigma^{\dagger}(\widehat{\tau}_{k} + s^{s}\widehat{\Omega}, E) ds^{\dagger} \right] \Delta s(\widehat{\Omega})$$
(2.55)

.

and if the volume has constant material properites:

$$\Delta \phi_{k}^{*}(\widehat{\Omega}, E)_{V} = \frac{1}{V} W_{k}^{s}(\widehat{\Omega}, E) \exp\left[-\int_{0}^{s(\widehat{\Omega})} \Sigma^{\dagger}(\widehat{\eta}_{k} \perp_{s}, \widehat{\eta}, E) ds^{*}\right] \frac{\left[1 - \exp\left[-\Delta s(\widehat{\Omega}) \Sigma^{V}(E)\right]\right]}{\Sigma^{V}(E)} \quad (2, 56)$$

where $\Sigma^{V}(E)$ is the total cross section at any point in the volume.

There is a possible difficulty with both the surface and volume averaged flux contributions since they are still defined for all directions $\hat{\Omega}$; i.e., a direct numerical integration to obtain various flux components could be prohibitive. If so, random sampling can be used. A general equation for the integration of an angular kernel $g(\overline{\Omega})$ is written first:

$$\Delta \mathbf{G}_{\mathbf{k}}^{*}(\mathbf{E}) = \iint_{A\pi} \Delta \phi_{\mathbf{k}}^{*}(\hat{\mathbf{n}}, \mathbf{E}) \left\{ \begin{array}{l} \mathbf{A} \\ \mathbf{V} \\ \mathbf{V} \end{array} \right\} \mathbf{g}(\hat{\mathbf{n}}) \, d\mathbf{\Omega}$$

$$= \iint_{A\pi} \left\{ \frac{\Delta \phi_{\mathbf{k}}^{*}(\hat{\mathbf{n}}, \mathbf{E})}{q^{*}(\hat{\mathbf{n}})} \left\{ \begin{array}{l} \mathbf{A} \\ \mathbf{V} \end{array} \right\} \mathbf{g}(\hat{\mathbf{n}}) \right\} \mathbf{q}^{*}(\hat{\mathbf{n}}) \, d\mathbf{\Omega}$$

$$\approx \frac{1}{L} \sum_{\ell=1}^{L} \frac{\Delta \phi_{\mathbf{k}}^{*}(\hat{\mathbf{n}}_{\ell}, \mathbf{E})}{q^{*}(\hat{\mathbf{n}}_{\ell})} \left\{ \begin{array}{l} \mathbf{A} \\ \mathbf{V} \end{array} \right\} \mathbf{g}(\hat{\mathbf{n}}) \right\} \mathbf{q}^{*}(\hat{\mathbf{n}}) \, d\mathbf{\Omega}$$

$$\approx \frac{1}{L} \sum_{\ell=1}^{L} \frac{\Delta \phi_{\mathbf{k}}^{*}(\hat{\mathbf{n}}_{\ell}, \mathbf{E})}{q^{*}(\hat{\mathbf{n}}_{\ell})} \left\{ \begin{array}{l} \mathbf{A} \\ \mathbf{V} \end{array} \right\} \mathbf{g}(\hat{\mathbf{n}}_{\ell})$$
(2.58)
where
$$\left\{ \begin{array}{l} \mathbf{A} \\ \mathbf{A} \\ \mathbf{V} \end{array} \right\}^{\prime} \text{ denotes either a surface or volume,}$$

$$\begin{array}{c} q^{*}\left(\widehat{\Omega}\right) \geq 0 \\ q^{*}\left(\widehat{\Omega}\right) > 0 \quad \text{if } \int_{0}^{\Delta \widetilde{\Phi}} k^{*}\left(\widehat{\Omega}, E\right) \left\{ \begin{array}{c} A \\ V \end{array} \right\} \quad \text{d} E > 0 \\ \end{array} \right\} \begin{array}{c} q^{*}\left(\widehat{\Omega}\right) \quad \text{is a sampling function (2, 59)} \\ \int_{4\pi}^{4\pi} q^{*}\left(\widehat{\Omega}\right) \, \text{d} \Omega = 1 \end{array} \right\}$$

L is the total number of discrete directions, and $\hat{\vec{\Omega}}_{f}$ is a discrete direction obtained by random sampling of $q^{\dagger}(\hat{\Omega})$.

This is equivalent to representing the averaged angular fluxes by:

$$\Delta \phi_{\kappa}^{*}(\widehat{\vec{n}}, E)_{A} = \frac{1}{A} \frac{1}{L} \sum_{\ell=1}^{L} \frac{W_{k}^{*}(\widehat{\vec{n}}, E)}{q^{*}(\widehat{\vec{n}}_{\ell})} \frac{\exp\left[-\int_{0}^{s(\widehat{\vec{n}})} \Sigma^{\dagger}(\widehat{\vec{r}}_{k} + s^{*} \widehat{\vec{n}}, E) ds^{*}\right]}{|\widehat{\vec{n}} \cdot \widehat{\vec{n}}|} \delta(\widehat{\vec{n}} - \widehat{\vec{n}}_{\ell})$$
(2.60)

$$\Delta \Phi_{k}^{*}(\widehat{n}, E)_{V} = \frac{1}{V} \frac{1}{L} \sum_{\ell=1}^{L} \frac{W_{k}^{*}(\widehat{n}, E)}{q^{*}(\widehat{n}_{k})} \int_{S} \exp\left[-\int_{0}^{S} \Sigma^{\dagger}(\widehat{r}_{k} + s^{*}\widehat{n}, E) ds^{*}\right] ds \quad \delta(\widehat{n} - \widehat{n}_{k})$$
(2.61)

for surfaces and volumes respectively since angular integrations with the arbitrary kernel $g(\overline{\Omega})$ yield equation 2,58 above.

The definition of $q^{\dagger}(\widehat{\Omega})$ which will minimize the error in the averaged flux angular integrations can be argued in a manner similar to the arguments used in defining the functions $p^{\dagger}_{k}(\widehat{r})$ used in selecting the source and scattering points. The arguments are simplified since future scattering contributions need not be considered--this is just an angular integration. The arguments are complicated by the fact that the same set of random discrete directions will probably (not necessarily) be used for all the surfaces and/or volumes over which fluxes are being averaged and these surfaces and/or volumes may occupy widely varying spatial positions.

2.8 CONCLUDING REMARKS

The previous sections-pertoired to a development of the Monte Carlo method which utilized random sampling for all of the spatial integrations. This is the procedure used in the FASTER program. In particular, the major equations used in the program are the numerical equivalents of:

- a) equation 2.36 for selecting source points,
- b) equation 2. 23 for the point representation of the source,
- c) equation 2.37 for selecting scattering points,
- equation 2.26 for the point representation of the flux of particles going into a collision,
- e) equation 2, 27 for the point representation of scattered sources,
- f) equation 2.47 for angular point flux estimation,
- g) equation 2.60 for surface averaged angular flux estimation, and
- equations 2.61, in conjunction with equations 2.55 and 2.56, for volume averaged angular flux estimation.



Each integration involved in calculating the order-of-scatter fluxes could have been performed by either random sampling or by conventional numerical integrations. In particular, most Monte Carlo programs use random sampling for the energy integrations as well as the spatial integrations and the entire calculational procedure is equivalent to the simulation of individual particle histories.^(P)

A variety of other combinations of integration techniques can be used. In particular, the variance associated with selecting discrete points from the fixed source in a Monte Carlo integration can be replaced by the systematic error involved in a conventional numerical integration over the spatial extent of the source volume. In fact, uncollided flux calculations can use various combinations of random sampling and direct numerical integration for the three spatial variables. One combined integration procedure is discussed in Appendix A.



3.0 PROGRAM LOGIC

The techniques described in Section 2. 0 permit a large degree of separation of conventional numerical techniques from random sampling techniques. This separability is utilized in the structure of the FASTER program through a series of subprograms that perform conventional calculations, such as, source interpolation at a point and a single scattering calculation for a fixed scattering angle. Another series of subprograms are used in the random selection of the parameters, e.g., the source point or scattering angle, for these conventional calculations.

3.1 DATA REQUIREMENTS

Several major divisions in the data required by the FASTER program have been made. Detailed input instructions for these data are given in Section 9.0.

Section 1 data, i.e., data in the first section of input, include the limits and controls for the FASTER calculations. The requisite data are described in Section 9.2.

Section 2 data are used in describing the geometry of the problem. Details of the geometric calculations performed by FASTER are given in Section 4.0. Data input instructions for geometric parameters are given in Section 9.3.

Section 3 data involve the description of the distributed sources. Calculations associated with these sources are described in Section 5.0. Input instructions for the description of sources are given in Section 9.4.

Section 4 data include the microscopic cross sections used to obtain the macroscopic attenuating and scattering properties of the non-void regions of the geometry. The calculations requiring these cross sections are described in Section 6.0. Detailed input instructions for the cross sections are given in Section 9.5.

Section 5 data are used to specify the final form of the computed results. This includes the description of the various points, surfaces and \vec{for} volumes for which the FASTER

program will compute multigroup fluxes. Details of the various flux component estimates used in FASTEP are given in Section 7.0. Input instructions for this section of data are given in Section 9.6.

<u>Section 6 data</u> pertain to the description of the random sampling functions. The sampling functions incorporated in FASTER are described in Section 8.0. Input instructions ⁷ för the sampling parameters.are given in Section 9.7.

3.2 PROGRAM FLOW

This section attempts to clarify the inter-relationships of data and calculational techniques by discussing the general flow within the FASTER program. The major subprograms of FASTER are also identified as to their function, i.e., which equations they contain.

The program is divided into two major parts. The first part involves data input and preparation and is controlled by the subroutine <u>DEFINE</u>. The second part involves the actual calculations and these are controlled by the subroutine <u>SOLVIT</u>.

Data Input and Preparation

DEFINE is the first routine called by FASTER. It calls other routines, in order, for the input of the data described in Section 9.0. The first subroutine entered is <u>STORER</u>. This routine reads the Section 1 data inputs and then allocates storage for all the dimensioned data. If multiple cases are run, it also manipulates the data arrays to account for dimension changes, etc.

Subroutine <u>GEOMIN</u> is then entered and all Section 2 data are input. After all , geometric inputs have been processed, the \pm sign associated with the boundaries of the regions are calculated using the input coordinates of an arbitrary point in each region. Then the geometry is checked using the input point-in-region coordinates and the function subprogram LOCATE, which computes the region(s) occupied by arbitrary points.

Section 3 data are input next in subroutine <u>SOURCE</u>. This includes the energy group structure and the definition and normalization of all the sources. Subroutine <u>INSECT</u> accepts' Section 4 cross section data and combines the microscopic data into the requisite macroscopic data. Section 5 data are input in subroutine <u>RESULT</u>. This includes the flux groups, flux conversion factors, and detector definitions.

Finally, the input sampling parameters—Section 6 data—are input by subroutine <u>RANDOM</u>

After all data are input, a check of an error count is made. If any errors were detected, the data for the next case is input. If no errors were detected, control is passed back to the FASTER program.

Calculations

With all requisite data well defined, control is passed from FASTER to SOLVIT. The SOLVIT routine passes control to one of two available calculational control subprograms. The first, <u>SOBER</u>, was written to compute surface and volume averaged fluxes and/or fluxes at multiple point detectors in void regions. The second control subprogram, <u>SOLVER</u> invest coded for the individual treatment of point detectors at arbitrary locations in the geometry.

As indicated, these routines perform almost identical functions. The following discussion attempts to describe both simultaneously. There may be minor variations from the actual order of some of the calculations, but they are unimportant in the overall picture. Some of the routines discussed below also require computations by other routines, however, this secondary control level will not be discussed.

The first step is the definition of a preferred point for use in the sampling procedures, In SOBER it is defined by input and is surrounded by a sphere with an input radius which encloses a volume in space where fluxes will be calculated. SOLVER contains an iteration over detector points and the preferred point is the detector point being treated. An average source group index, used in a one-velocity approximation of equation 2.36, is then computed by subroutine GROUP.

All other calculations are performed within the outer iteration loop. The first calculation within this loop is the random selection of a position vector $\vec{\tau}_0$ from thfixed source. This is done by one of two subroutines: <u>PSTAR</u>, if the sampling is





performed in the source geometry coordinate system or <u>SPHERE</u>, which approximates equation 2.36.

The calculations enter the inner iteration loop where they remain until terminated by one of the cutoff criteria, i.e., maximum number of inner iterations (collision cutoff), weight cutoff, or energy cutoff. The first iteration in this inner loop differs from all subsequent inner iterations because the source point is actually a point in a source volume. For all inner iterations after the first, it is actually a scattering (scattered source) point.

The first calculation in the inner loop involves the flux contribution to the point detectors. For each of these detectors, calculation of the distance and direction to the detector from the source point is performed by the function subprogram <u>VECTOR</u>. The calculation of the angular point source for the direction towards the detector is then performed by interpolation in the <u>SZERO</u> subroutine (equation 2, 23) if this is the first inner iteration, or by <u>SINGLE</u> (equation 2, 27) for subsequent inner iterations. If there is a non-zero source for this direction, the path lengths through the various regions lying between the source (scattering) point and the detector point are computed by subroutine <u>PATH</u>. The mean-free-paths (*mfp*) along the total path are then computed for each source group by subroutine <u>KERNEL</u> and the flux estimation performed in subroutine <u>DETECT</u> using equation 2, 47.

The next step is performed only in the SOBER inner iterations. It involves the random selection of discrete directions for calculating surface and volume averaged fluxes. These directions are obtained from subroutine <u>VSTAR</u>. A possible exception is the first inner iteration where they can be abtained from subroutine <u>QSTAR</u>. The source for each fixed direction vector are computed using SZERO or SINGLE. If non-zero, the regions lying along the direction vector are computed by PATH. Each of the regions lying along the direction vector is checked to see if it is a volume detector and should receive a flux contribution. If so, the mfp's up to the region are computed by KERNEL and the flux is computed by DETECT using contribution equation 2.61 in conjunction with equations 2.55 and 2.56. Each boundary crossing between regions is also checked to see if it is a surface detector. If it is, the normal derivative at the boundary is computed by subroutine <u>NORMAL</u>; the mfp's to the boundary are obtained from KERNEL and the flux contributions are then computed by DETECT using equation 2, 60.

The final step in each inner iteration is the random selection of the next scattering point. The overage flux contribution energy, as calculated by DETECT, is used to define an average energy group for the sampling procedures. The direction vector defining the scattering point is then obtained from VSTAR (or possibly QSTAR on the first inner iteration). The regions lying along the ray defined by this direction are computed by PATH. The distance to the collision point is obtained from <u>USTAR</u> (equation 2.37) and the previous source point is then evaluated for the direction vector from this prior point to the new point, using SZERO or SINGLE. If non-zero, the mfp's to the scattering point are obtained from KERNEL, and the point monodirectional fluxes are computed at the scattering point ding equation 2.26. ... The next inner iteration is initiated with the sources being abained from SINGLE using the: monodirectional fluxes. These inner iterations are continued until a cutoff is obtained.²

The outer iterations are continued to a specified maximum with a printout of the flux edits being performed by subroutine ANSWER at specified intervals.



SECTION

GEOMETRIC CONSIDERATIONS 4.0

The most important feature of the Monte Carlo method--in comparison with other "exact" solutions of the transport equation--is its applicability to complicated geometries. This feature is implemented in the FASTER program by utilizing the general quadric surface equation. The numerical analysis presented below follows that of Reference 10.

4.1 QUADRIC SURFACES

The general quadric equation for a specified surface 1 is:

$$\begin{array}{rcl} u_{1}(r) &=& \sigma_{0,1} &+& \sigma_{1,1} x &+& \sigma_{2,1} y &+& \sigma_{3,1} z \\ && & + & \sigma_{4,1} x^{2} &+& \sigma_{5,1} y^{2} &+& \sigma_{6,1} z^{2} \\ && & & + & \sigma_{7,1} x y &+& \sigma_{8,1} y z &+& \sigma_{9,1} z x \end{array}$$

where oi, i, i = 0, 1, 2, ..., 9 are constants, $\vec{r} = x\vec{i} + y\vec{i} + z\vec{k}$

 $x,\,y,\,z$ are rectangular coordinates (cm), and $i,\,j,\,k$ are unit vectors parallel to the x-, y-, and z- axes, respectively. The value of this equation, $u_i(\vec{r})$, is zero for points \vec{r} on the surface.

These surfaces are described independently of the regions which define the material distributions to eliminate redundant input. Provision has been made in the FASTER program for recognizing more simple surfaces such as planes, cones, elliptical cylinders and ellipsoids. The equations for these simple surfaces are expanded by subroutine GEOMIN to obtain the coefficients of the general equation above. These special surfaces are shown in Figures 7, 8, and 9 and the equations are tabulated in Table 1 of the Section 9.3 input instructions.

4.2 SURFACE CALCULATIONS

Since surfaces are described independent of geometric regions, it is possible to define several quantities which are used in geometric calculations. For this discussion, the following are defined:

$$\overline{r} = (x, y, z)$$
, the position vector of any point in space,
 $\overline{\Omega} = (a, \beta, \gamma)$, a unit vector defining the direction of a straight line,
or ray, emanating from \overline{t} , where a, β, γ are direction
cosines with respect to the x, y, and z axes, respectively,

s,
$$o \le s < \infty$$
 the scalar distance from $\overrightarrow{\tau}$ along $\overrightarrow{\Omega}$
 $\overrightarrow{\tau} = \overrightarrow{\tau} + s \overrightarrow{\Omega}$ a point on the ray
= $(x + as, y + \beta s, z + \gamma s)$

Intersection of a Line and a Surface

The value of the quadric equation at 🕇 is given by:

$$u_{i}(\vec{r}^{-1}) = u_{i}(\vec{r}) + 2s v_{i}(\vec{r}, \vec{\Omega}) + s^{2} w_{i}(\vec{r}, \vec{\Omega})$$
(4.2)

where $u_i(\vec{r})$ is given by equation 4.1 above and $v_i(\vec{r},\vec{\Omega})$ and $w_i(\vec{r},\vec{\Omega})$ are obtained by expanding this equation for \vec{r}' , and collecting the coefficients of s and s²:

$$\mathbf{v}_{i} \left(\vec{\tau}, \mathbf{\hat{\Pi}} \right) = \frac{1}{2} \begin{bmatrix} \alpha \alpha_{1,i} & + \beta \alpha_{2,i} & + \gamma \alpha_{3,i} \end{bmatrix}$$

$$+ \alpha \times \alpha_{4,i} & + \beta \gamma \alpha_{5,i} & + \gamma \times \alpha_{5,i} \end{bmatrix}$$

$$+ \frac{1}{2} \begin{bmatrix} (\alpha \gamma + \beta x) \alpha_{7,i} + (\beta z + \gamma \gamma) \alpha_{8,i} + (\gamma x + \alpha z) \alpha_{9,i} \end{bmatrix}$$

$$\mathbf{w}_{i} \left(\vec{t}, \mathbf{\hat{\Pi}} \right) = \alpha^{2} \alpha_{4,i} & + \beta^{2} \alpha_{5,i} & + \gamma^{2} \alpha_{5,i} \\ + \alpha \beta \alpha_{7,i} & -\beta \gamma \alpha_{8,i} & + \gamma \alpha \alpha_{9,i} \end{bmatrix}$$

$$(4.3)$$

Intersections of the ray with the surface are obtained by requiring:

$$u_i$$
 (\vec{r}^{-1}) = 0, i.e. this condition defines points on the surface using equation 4.2.

$$u_{i}(\vec{r}) + 2s_{i}v_{i}(\vec{r},\vec{n}) + s_{i}^{2}w_{i}(\vec{r},\vec{n}) = 0$$

$$(4.5)$$

a) one intersection if
$$w_i(\vec{r}, \vec{\Omega}) = 0$$
, $v_i(\vec{r}, \vec{\Omega}) \neq 0$
 $s_i = -u_i(\vec{r})/2 v_i(\vec{r}, \vec{\Omega})$ (4.6)
b) two intersections if $w_i(\vec{r}, \vec{\Omega}) \neq 0$, $v_i^2(\vec{r}, \vec{\Omega}) > u_i(\vec{r}) w_i(\vec{r}, \vec{\Omega})$
 $s_i = -v_i(\vec{r}, \vec{\Omega}) \pm \sqrt{v_i^2(\vec{r}, \vec{\Omega}) - u_i(\vec{r}) w_i(\vec{r}, \vec{\Omega})}$ (4.7)

Note that the case of two equal intersections is not admitted since this is equivalent to no intersection. For all real intersections, the appropriate sign for multiple intersections is determined in the following manner:

a) The rate of change of u_{j} (\vec{r} ') with respect to distance at the intersection is given by differentiation of equation 4.2:

$$\frac{\partial \mathbf{u}_{i}\left(\vec{r},\vec{r}\right)}{\partial s} = 2 \left[\mathbf{v}_{i}\left(\vec{r},\vec{n}\right) + \mathbf{s}_{i} \mathbf{w}_{i}\left(\vec{r},\vec{n}\right) \right]$$

$$s = \mathbf{s}_{i}$$
(4.8)

Using the intersection equation 4.7 above:

$$\frac{\partial u_{1}}{\partial s} \left(\vec{\tau}^{*}\right) \bigg|_{s=s_{1}} = 2 \left[v_{1}\left(\vec{\tau},\vec{\Omega}\right) + w_{1}\left(\vec{\tau},\vec{\Omega}\right) \left(\frac{-v_{1}\left(\vec{\tau},\vec{\Omega}\right) + \sqrt{v_{1}^{2}\left(\vec{\tau},\vec{\Omega}\right) - u_{1}\left(\vec{\tau}\right)w_{1}\left(\vec{\tau},\vec{\Omega}\right)}}{w_{1}\left(\vec{\tau},\vec{\Omega}\right)} \right) \right]$$

$$= \pm 2 \sqrt{v_{1}^{2}\left(\vec{\tau},\vec{\Omega}\right) - u_{1}\left(\vec{\tau}\right)w_{1}\left(\vec{\tau},\vec{\Omega}\right)} \qquad (4.9)$$

Thus this derivative must have the sign (\pm) used in the intersection equation.

b) It is noted that each surface defines two disjoint volumes, which, for the sake of a convention, are described as:

inner volume:
$$u_{i}(\vec{r}') < 0$$

outer volume: $u_{i}(\vec{r}') > 0$
(4. 10)

It follows that in crossing the surface from the inner volume, $u_1 (\hat{\tau}^*) < 0$, to the outer volume, $u_1 (\hat{\tau}^*) > 0$, along any straight line, that the rate of change of the value of the surface equation $\partial u_1 (\hat{\tau}^*) / \partial s$ is greater than zero at the intersection. Thus, if $u_1 (\hat{\tau}) < 0$ then the origin of the ray is inside the surface, and the first intersection with the surface is obtained from the quadratic equation 4.7 using the positive sign. A similar argument holds for crossing from the outside to the inside of the surface; i.e. if $u_1 (\hat{\tau}) > 0$, then $\partial u_1 (\hat{\tau}') / \partial s_1 < 0$ at the first intersection implying the negative sign.

Surface Normal

The normal vector to the surface at the intersection, used in surface averaged flux calculations, is calculated by subroutine NORMAL as:

$$\overline{n} = \frac{\nabla v_{i}(\overline{r})}{\left|\nabla v_{i}(\overline{r})\right|} = (c_{1}^{n}, c_{2}^{n}, c_{3}^{n})$$
(4.11)

where
$$\nabla = \overline{i} \frac{\partial}{\partial x^i} + \overline{j} \frac{\partial}{\partial y^i} + \overline{k} \frac{\partial}{\partial z^i}$$
 (4.12)

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$$\vec{n} |\Delta u_{i}(\vec{r}')| = [a_{1,i} + 2x' a_{4,i} + a_{7,i}, y' + a_{9,i}, z'] \vec{i} + [a_{2,i} + 2y' a_{5,i} + a_{8,i}, z' + a_{7,i}, x'] \vec{i} + [a_{3,i} + 2z' a_{6,i} + a_{9,i}, x' + a_{8,i}, y'] \vec{k}$$

$$= C_{1} \vec{1} + C_{2} \vec{1} + C_{3} \vec{k}$$

$$(4.13)$$

$$c_{i}^{n} = \frac{1}{\left[\sum_{i=1}^{3} c_{i}^{2}\right]^{1/2}}$$
, $i = 1, 2, 3$ (4.14)

4.3 REGIONS

Material Properties

The surfaces referred to in the previous section are used to describe the extent of geometric regions or zones having constant material properties. These properties are specified for each region, i, by a composition indicator $m_i (m_i < 0$ indicates that region i is void) and a separate hydrogen density p_i^h . The capability of specifying hydrogen densities by region simplifies the description of many problems, e.g., regions in a liquid hydrogen propellant tank. It is also helpful in describing hydrogen density variations in NERVA-type reactors where all other material properties are constant.

Source-in-Region

Additional regions may be required to correctly define the spatial extent of the fixed source volumes, i.e., khere is an optional sampling technique in the FASTER program (described in Section 8.3) which requires that only one source be superimposed over a region and that the source cover the region. Alternatively, each source may cover more than one region.



38.

This sampling technique is preferred since it requires much less <u>a priori</u> knowledge of the importance of various sources--point-kernel importance estimates are built in.

Region Boundaries

The geometric description of each region involves the listing of the surfaces which bound the region:

$$k_{j,i}$$
, $j = 1, 2, \cdots$ where $k_{j,i}$ is the index of the surface forming the ith boundary of the region.

Also required are the components of an arbitrary point in the regions

$$\vec{r}_{i}^{g} = x^{g}\vec{1} + y^{g}\vec{1} + z^{g}\vec{k}$$
 where (x^{g}, y^{g}, z^{g}) are specified.

Ambiguity Indices

The description of each region is completed in subroutine GEOMIN by computing an "ambiguity index" for each boundary surface. This ambiguity index indicates whether the region is inside or outside each of its boundaries. It also yields the sign to be used in calculating distances to quadratic or quadric boundaries. The ambiguity index is computed using equation 4. I:

$$\delta_{[i,i]} = - \frac{v_k(\hat{r}_i^9)}{|v_k(\hat{r}_i^9)|}, \quad k = k_{[i,i]}, \quad i = 1, 2, \cdots$$
(4.15)

Region Occupied by a Point

To ensure correct calculations, it is necessary that the ambiguity indices have the same sign for all points inside the region, i.e., a point \vec{r} is in region i If, and only if $\delta_{i,i}$: $v_{k,i}$ (\vec{r}) <0 for all boundaries. The region index calculation for an arbitrary point is performed by the function subprogram LOCATE.

Possible Region Description Errors

Restrictions must be imposed on possible region shapes to ensure that all points in a region are always on the same side of each region boundary. For example, the single region

indicated in Figure 3A is unacceptable since there are points in the region which are both inside and outside boundaries A and B. The obvious solution is to use two regions to describe such geometric shapes.

It is sometimes necessary to introduce fictitious boundaries. Figure 38 shows a typical situation requiring these boundaries. Examination of the shaded and cross hatched regions reveals that they form two sections of a single region since ambiguity indices of the boundaries have the same values for both sections. This condition can cause trouble if only one section of the region is desired, even if other regions occupy the second section. The specification of the fictitious boundary eliminates the problem without otherwise affecting the geometric calculations. These fictitious boundaries must be included in the initial surface descriptions.

Geometry Consistency Check

A rather simple check for correct geometric description involves a calculation of the region(s) occupied by each point $\frac{1}{12}^{9}$. If the point $\frac{1}{12}^{9}$ is in any region other than region i, the geometry representation is incorrect. This geometry check is performed by the GEOMIN subroutine using the LOCATE function subprogram.

4.4 RAY TRACING

. The procedure for ray tracing is similar to that discussed above for the intersection of a ray with individual surfaces. The cumulative path lengths through each region along a ray are computed at a single pass, in the order traversed, by subroutine PATH. As indicated before, the ray tracing calculations are related to the surfaces.

$$s_{1+1} = \min_{\substack{j = 1, 2, \cdots \\ i \neq i}} \left\{ s_{j,i} \text{ such that } s_{j,i} \ge s_{1}, \text{ and} \atop i \neq s_{1}, i \ge s_{1}, i = s_{1}, i \ge s_{1}, i = s_{1}, i \ge s_{$$

i = distance up to the region, and

$$s_{j,1} =$$
 is obtained from equation 4.6 or 4.7 for surface $k = k_{j,1}$
using the sign of $\delta_{j,1}$ for non-planar surfaces.





Figure 3. Problems in Region Descriptions

The surface crossed in leaving the region is that giving the minimum distance.

If the new total distance $s_{|+|}$ exceeds a specified maximum, e.g., the distance between two points, the distance through the region is adjusted and the ray tracing terminates. If not, the next region entered by the ray is computed by requiring that:

- a) the next region have the surface just crossed as a boundary,
- b) the next region be on the other side of this surface (opposite signs on ambiguity indices), and
- c) for all other boundaries

$$v_{k'}(\vec{r}+s_{j+1}\vec{\Omega}) \delta_{j',i'} \leq 0, \ k' = k_{j',i'}, \ j' = 1, 2, \dots$$
 (4.17)

which is evaluated using equation 4.2.

The index of the region entered in crossing the above boundary is saved as the most probable next region for subsequent ray tracings. If no region is accepted, the exterior of the geometry is assumed and an indicator set. After several subsequent failures, testing for this boundary is never performed.

The constants $u_k(\vec{n}, v_k(\vec{r}, \vec{n}))$, and $w_k(\vec{r}, \vec{n})$ and the intersections are computed only once during a given ray tracing. The current status of calculations for the $k \frac{h}{2}$ surface is indicated by n_k where

- a) $n_{L} = 0$ if the k th surface has not been involved as yet, in the ray tracing,
- b) $n_{L} = 1$ if the constants $u_{L}(\vec{r}), v_{L}(\vec{r}), \vec{\Omega}$, $w_{L}(\vec{r}, \vec{\Omega})$ have been computed,
- c) $n_{k} = 2$ if the constants and the intersections have both been calculated and at least one intersection is at a distance greater than the current cumulative distance s_{t} , and
- n_k = 3 if the constants and intersections have been computed but the intersections need no longer be considered e.g., if both are less than s₁, imaginary, etc.





SECTION

5.0 FIXED SOURCES

A number of numerical techniques can be used for describing fixed source distributions. Those employed in the FASTER program incorporate the assumption of separable variables. These techniques are general enough to permit the description of a variety of real source distributions and the distributions used in generating basic data.

5.1 SPATIAL AND ANGULAR VARIABLES

The FASTER program will handle multiple sources in rectangular, cylindrical or spherical geometries. The geometry for each source is superimposed over the various geometric regions. The source geometries for each of the multiple sources need not be the same. In all geometries there are three spatial variables (v_1, v_2, v_3) and two angular variables (v_4, v_5) . The relationships between these spatial and angular variables or shown in Figure 10 in the Section 9.4 input instructions.

Rectangular Geometry

The most simple geometry is that used for describing rectangular source volumes. The spatial variables (v_1, v_2, v_3) are the rectangular coordinates (x, y, z). The angular variables (v_4, v_5) are the azimuthal angle θ measured from the x-axis and the cosine of the polar angle, μ_r measured from the z-axis.

Cylindrical Geometry

The next allowed geometry, usually used in describing reactor sources, involves cylinders parallel to the z-axis. The spatial variables are:

$$v_1 = r = \sqrt{x^2 + y^2}$$
, the radius
 $v_2 = \theta = \tan^{-1}(y/x)$, the azimuthal angle measured
from the x-axis
 $v_3 = z$, the axial coordinate

The angular variables are measured in a coordinate system which rotates with the radius vector. The variables are:

 $v'_4 = \theta^{\dagger}$, the azimuthal angle measured from θ .

 v_5 , $\overline{\tau}$, μ_1^i , the cosine of the polar angle measured from the z-axis. This simplifies the description of angular sources on the surfaces of a cylindrical reactor.

Spherical Geometry

The final geometry, useful in describing sources such as capture gammas in the hemispherical bottom of a liquid hydrogen propellant tank, involves the spatial variables:

$$v_1 = \rho = \sqrt[4]{x^2 + y^2 + z^2}$$
, the spherical radius
 $v_2 = \theta = \tan^{-1}(y/x)$ the azimuthal angle measured from the x-axis.
 $v_3 = \mu = \frac{z}{\rho}$, the cosine of the polar angle measured from the z-axis.

The coordinate system used for the angular variables rotates with the spherical radius vector:

 ${}^{\nu}{}_5 \; \stackrel{\text{\tiny so}}{=} \; \mu^4$, the cosine of the polar angle measured from the spherical radius vector.

Source Translations

In addition, each source is given a translation vector $\vec{t}_t = (x_t, y_t, z_t)$ from the origin of the geometry coordinate system. Thus, the coordinates of the source points, expressed in the geometry coordinate system, are

$$\vec{\tau} = (x + x_t, y + y_t, z + z_t)$$



5.2 SPATIAL AND ANGULAR DISTRIBUTIONS

Each of the distributions for the spatial and angular variables is described separately by tabulating relative distributions

$$(v_{k,j}, f_{k,j}), k = 1, 2, \cdots$$

where $v_{k,\,j}$ is the kth value of the (th variable, and $f_{k,\,j}$ is the relative distribution at $v_{k,\,j}$.

Each variable v; may take on only one value v; = v; i.e.,

 $f(v_i) = \delta(v_j - v_{i,j})$. If more than one point is needed, then $f(v_i)$ is assumed to be continuous.

The continuous distributions are normalized in subroutine SOURCE by integrating a linear interpolation formula and requiring that:

$$\sum_{k=1}^{v_{k+1,j}} \int_{v_{k,j}}^{v_{k+1,j}} \frac{(v_{k+1,j}-v_{j})f_{k,j}+(v_{j}-v_{k,j})f_{k+1,j}}{v_{k+1,j}-v_{k,j}} v_{j}^{n} dv_{j} = 1$$
(5.1)

where n = 0 except for the radial distributions of cylindrical and spherical sources where n = 1 or 2, respectively.

The final representation of the spatial and angular distributions is the product of the individual distributions for the five source variables:

$$p(\vec{r}, \vec{\Omega}) = \prod_{\substack{i=1\\j=1}}^{5} f(v_i)$$
(5.2)



5.3 SOURCE SPECTRA

Particle energies generally decrease with the increase in the order of scattering and the FASTER program requires the same order in energies, i.e., a series of energy groups are defined with group 1 containing particles with the maximum energy. The same group structure is used for the source spectra and later for the cross sections. These energy groups are defined in subroutine SOURCE by:

Group
$$i : E_{j} \ge E(Mev) \ge E_{j+1}$$
 $i = 1, 2, \cdots$ (5.3)

Some relaxation is allowed on describing the source spectra in that an arbitrary group structure, with energy group boundaries of decreasing energy, can be used. Various quantities are accepted as input. They are all reduced, however, to one form; a differential number spectrum:

$$\eta_k \left(\frac{\text{particles}}{\text{Mev} \cdot \text{sec}} \right)$$
 at energy $E_k = 1, 2, \cdots$

where the $\mathbf{E}_{\mathbf{k}}$'s define the input energy group boundaries.

This spectrum is then integrated into the group structure for the problem using a linear interpolation formula for the energy variation. The final spectrum is expressed as the number of particles in each group and the average energy of these particles:

$$n_{\hat{l}}^{o} = \sum_{\substack{k=1\\ E_{\hat{l}k}^{i} < E_{\hat{l}k}^{h}}} \int_{E_{\hat{l}k}^{i}}^{E_{\hat{l}k}^{h}} \pi_{k}^{i}(E) dE \qquad (particles in group i) \qquad (5,4)$$

$$\begin{split} \overline{E_{i}^{o}} &= \frac{1}{n_{i}^{o}} \sum_{\substack{k=1 \\ l \mid k \in E_{ijk}^{h}}} \int_{E_{ijk}^{l}} \sum_{\substack{k=1 \\ l \mid k \in E_{ijk}^{h}}} \int_{E_{ijk}^{l}} \frac{p_{ijk}^{k}}{p_{ijk}} \left(E \right) E dE \quad (average energy of the particles (5.5) \\ & \text{in group } i \end{pmatrix} \end{split}$$
where
$$\begin{aligned} \eta_{k}(E) &= -\frac{(E - E_{k+1})\eta_{k} + (E_{k} - E)\eta_{k+1}}{E_{k} - E_{k+1}} \\ & E_{ijk}^{l} &= -\max(E_{i+1}, E_{k+1}) \\ & E_{ijk}^{h} &= \min(E_{ij}, E_{k}) \end{aligned}$$

$$(5.7)$$

The groupwise number spectrum n_{j}^{o} , $j = 1, 2, \cdots$, is then normalized to an input total source strength,

5.4 FIXED SOURCE ACQUISITION

Volume Sources

The definition of neutron and photon source distributions for reactor configurations can be a time-consuming task. For geometries where the discrete andinote (S_n) methods are applicable, source distributions can be obtained both efficiently and economically through their use. In particular, the coupled ODD-K - NAGS system (References 11, 12) can provide the relative distributions and spectra in the form required by the FASTER program. Included ore separable radial and axial distributions and spectra for all reactor regions.

Angular Surface Fluxes

The design of nuclear rocket engines is such that given the internal reactor arrangements it is possible to define the reactor leakage within an error involving external reactivity

effects and that inherent in the calculational method. This same leakage can then be applied to a variety of external problems such as individual external components or a liquid hydrogen propellant tank.

Assuming a detailed internal calculation, it is possible to numerically integrate the equation for the unperturbed angular flux at an arbitrary point in space outside the reactor:

$$\begin{split} \phi^{U}(\vec{r},\vec{\Omega},E) &= \int_{0}^{\infty} \sum_{i=1}^{\infty} (\vec{r}-s,\vec{\Omega},\vec{\Omega},E) \exp\left[-\int_{0}^{s} \sum_{i=1}^{t} (\vec{r}-s^{i}\vec{\Omega},E) ds^{i}\right] ds \\ &= \int_{s}^{s} S(\vec{r}-s,\vec{\Omega},\vec{\Omega},E) \exp\left[-\int_{0}^{s} \sum_{i=1}^{t} (\vec{r}-s^{i}\vec{\Omega},E) ds^{i}\right] ds \\ + \Psi(\vec{r},\vec{\Omega},E) &= \int_{0}^{s} S(\vec{r}-s_{0}\vec{\Omega}-t\vec{\Omega},\vec{\Omega},E) \exp\left[-\int_{0}^{t} \sum_{i=1}^{t} (\vec{r}-s_{0}\vec{\Omega}-t^{i}\vec{\Omega},E) dt^{i}\right] dt \\ &= -\phi(\vec{r}-s_{0}\vec{\Omega},\vec{\Omega},E) \end{split}$$

where
$$S(\vec{r}, \vec{\Omega}, E)$$
 is the total differential source density in the reactor, i.e., including scattering.
so is the distance to the reactor surface from \vec{r}
s₁ is the distance through the reactor from \vec{r}
 $\Phi(\vec{r} - s_{\vec{\Omega}}, \vec{\Omega}, E)$ is the angular flux at the reactor surface, i.e., at $\vec{r} - s_{\vec{\Omega}}$

. .

(For numerical integrations, the equation is sometimes transformed to an area integration c.er the reactor surface.)



A more general use of the angular leakage fluxes is as a surface source (or a "thin" volume source). The requisite data reduction of ODD-K angular leakage fluxes, both neutron and photon, is performed by the DAFT program.⁽¹³⁾ Included in this reduction are averages aver arbitrary mesh points, groups, etc.

• The external environment is then given by a set of equations analogous to those in Section 2.2, where:

$$\phi_{o}(\vec{r}, \vec{\Omega}, E) = \phi(\vec{r} - s_{o}\vec{\Omega}, \vec{\Omega}, E) \exp \left[-\int_{0}^{s_{o}} \Sigma(\vec{r} - s'\vec{\Omega}, E) ds' \right]$$
(5.9)

These reduced angular fluxes thus fit into the framework provided in the FASTER program for describing fixed sources, since the equation for the external uncollided flux is identical to that obtained for a surface source.

5, 5 SOURCE EVALUATION

The source was defined as a function of the variables v_1, v_2, \ldots, v_5 . For the order of scatter flux calculations, the source must be evaluated for a specified point \overline{v}_1 and disection $\overline{\Omega}$. This evaluation, when divided by the value $p_0^+(\overline{v}_0)$ of the sompling function used in obtaining the position vector \overline{v}_0 , yields the energy dependent angular point source $W_0^+(\overline{\Omega}, E)$. The source evaluation is performed by subvaluites SZERO and involves several variables transformations to obtain the source variables equivalent to \overline{r}_0^- and $\overline{\Omega}$:

a) define the source centered position vector,

$$\vec{r} = \vec{r}_{0} - \vec{r}_{1} = (x, y, z)$$

- b) calculate the spatial variables $(v_1, v_{2'}, v_3)$ from the rectangular coordinates using the transformation equations for the source geometry,
- c) calculate the direction vector rotation matrix, $R_{1,1}$, (See Figure 4.),
- calculate the direction cosines in the rotated coordinate system for which the angular distribution of the source is defined

$$c_{1}^{i} = \sum_{i=1}^{3} c_{1} R_{i}$$
, $i = 1, 2, 3$ where $\widehat{\Omega} = c_{1} \widehat{i} + c_{2} \widehat{i} + c_{3} \widehat{k}$


e) calculate the angular variables v_A and $v_{5'}$

$$v_4 = \tan^{-1} (c_2^{\prime}/c_1^{\prime}) \quad v_5 = c_3^{\prime}$$

A linear interpolation of the source variable distributions yields:

$$w_{j}^{s} = \begin{bmatrix} \frac{5}{\Pi} & f(v_{j}) \\ \frac{1}{p_{0}^{s}} & (\hat{r}_{0}) \end{bmatrix} n_{j}^{o} , \qquad i = 1, 2, \cdots$$

$$\overline{r}_{j}^{s} = \epsilon_{j}^{o}$$

$$(5.10)$$

where W_1^5 is the number of particles in group i and $\overline{E_1^5}$ is the average energy of the particles in group i. The average group energy $\overline{E_1^5}$ is just $\overline{E_1^6}$ as calculated during spectrum normalization.

Thus the general equation 2.23; for $W_0^s(\widehat{\Omega}, E)$ is reduced to a groupwise representation:

The angular dependence has been suppressed since, in the numerical calculations, only one discrete direction is considered at a time. Moreover, the order-of-scatter subscript has also been suppressed since it is used only as a counter in the numerical calculations.

The same representation of the point angular sources is used for higher order of-scatters i.e. for $W_k^s(\widehat{\Omega}, E)$. The equations are discussed in the next section.







Figure 4. Direction Vector Rotations



SECTION

6.0 TRANSPORT AND SCATTERING KERNELS

The equations used in the FASTEP program for defining the attenuating and scattering properties of homogeneous material compositions are described below. The general procedure involves a calculation of increasopic cross sections using input microscopic data. The two most common sets of units for microscopic data and compositions are both permitted in FASTER.

- u_ = 0 for microscopic cross sections in barns/atom
 - = 1 for microscopic cross sections in cm²/gm
- $v_{a} = 0$ for compositions in 10^{24} atoms/cm³
 - = 1 for compositions in gm/cm^3

i.e., the composition and cross section units can be mixed.

6.1 PHOTON CROSS SECTIONS

The equations used for photon cross sections are discussed in this section. Photon cross sections are defined at the boundaries of the energy groups defined by equation 5.3. The requisite data for the ith element is:

- A the atomic mass (a.m.u.) of the element
- Z. the atomic number of the element
- ${}^{\rho}m,i$ the density of the element in composite material m with units according to $\boldsymbol{\upsilon}_{p}$, and
- $\sigma_{j,i}^{\dagger}$ the microscopic total cross section for energy level $\,j\,$ with units according to $\,\upsilon_{\rm u}$

The total cross section, $\mathbf{x}_{i,m}^{f}$, is computed by subroutine INSECT for each energy level of each composite material by a summation over the element data:

$$\Sigma_{j,m}^{*} = \sum_{i=1}^{m} \left(\frac{0.6025}{A_i} \right)^{(u_c^{-} u_x^{-})} p_{m,i} \int_{j,i}^{m} (em^{-1})$$
(5.1)

The total electron density is calculated by:

$$n_{m}^{e} = \sum_{i=1}^{c} \left(\frac{0.6025}{A_{i}} \right)^{u_{c}} P_{m,i} Z_{i} = \left(\frac{10^{24} \text{ electrons}}{cm^{3}} \right)$$
(6.2)

where $(0.6025/A_1)^{5c}$ converts compositions to 10^{24} atoms/cm³, and $(0.6025/A_1)^{5x}$ converts cross sections to barns/atom.

The energy absorption coefficient by energy level is computed by element and material. The obsorbtion coefficients can then be used as a flux-to-heating conversion factor under conditions noted in Section 9.5 of the input instructions. The equation for the microscopic energy absorption coefficients assumes all interactions, except Compton scattering, are absorptions (Reference 4, pg. 159):

$$\mu_{j,i}^{\alpha} = \sigma_{j,i}^{\dagger} - \frac{1.995}{8} \left(\frac{0.6025}{A_i} \right)^{\nu_{x}} \left[\frac{\ln (1+2\eta)}{\eta^3} + \frac{2 (1+\eta) (2\eta^2 - 2\eta - 1)}{\eta^2 (1+2\eta)} + \frac{8 \eta^2}{3 (1+2\eta)^3} \right]$$
(6.3)

with units according to u_x and where $\eta = E_y/0.511$. 6.2 PHOTON TRANSPORT

The material attenuation kernel is written for the jth energy group as:

$$K_{1}^{\dagger}(\vec{r},\vec{r}^{\dagger}) = \exp\left[-\int_{0}^{s} \Sigma^{\dagger}(\vec{r}+s'\vec{0},\vec{E}_{1}^{-s})ds'\right], \ s = |\vec{r}-\vec{r}'|, \ \hat{\vec{\Omega}} = (\vec{r}-\vec{r}')/s$$

$$(6.4)$$

This kernel is evaluated using $\overline{E_j^5}$, the average group energy of the multigroup representation of the angular point sources defined in equation 5, 10. The assumption of transport without change in the average group energy simplifies this kernel.

The evaluation of this kernel uses a group averaged cross section obtained by a linear, energy interpolation of the cross sections at the group boundaries. Since each geometric region has constant material properties,



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where

is the distance in the 1th region traversed from \vec{r} to \vec{r} , and

 $\cdot \Sigma_{j}^{v}$ is the average total cross section for the region and group (

This total cross section can be composed of two parts; one representing the composite material and another representing the hydrogen in the region as discussed in Section 4.3.

This photon attenuation kernel is used to calculate fluxes, and, in particular, to define the point monodirectional flux components which are used to represent the next orderaf-scatter point source; i.e., equation 2.27

$$w_{j}^{\phi} = \frac{w_{j}^{s} \kappa_{j}^{s} (\vec{r}_{k-1}',\vec{r}_{k})}{\left|\vec{r}_{k}-\vec{r}_{k-1}\right|^{2} p_{k}^{s} (\vec{r}_{k})}, \quad \overline{E_{j}^{\phi}} = \overline{E_{j}^{s}}$$
(6.6)

where $\mathbf{p}_{k}^{\star}(\vec{r}_{k})$ is the value of the sompling function used to obtain \vec{r}_{k} .

This is merely a groupwise representation of equation 2, 27, where the average energy of the particles in each group at the scattering point is assumed equal to the average energy at the previous source point:

$$\begin{split} \mathbf{w}_{i}^{\phi} &= \int_{E_{i+1}}^{E_{i}} \mathbf{w}_{k}^{\phi}(\mathbf{E}) \, d\mathbf{E} \\ \\ \overline{\mathbf{E}}_{i}^{\phi} &= \frac{1}{\mathbf{w}_{i}^{\phi}} \int_{E_{i+1}}^{E_{i}} \mathbf{w}_{k}^{\phi}(\mathbf{E}) \, \mathbf{E} \, d\mathbf{E} \\ \\ &\approx \cdot \overline{\mathbf{E}}_{i}^{s} \end{split}$$



6.3 PHOTON SCATTERING

The photon scattering calculations performed in FASTER by subroutine StNGLE, use the Klein-Nishina equation for Compton scattering. All scattering is assumed to occur at the average group energy $\overline{E_i^{\phi}}$ so that the ratio of the energies before and after scattering for group j is:

$$R_{i} = \frac{0.511}{0.511 + E_{i}^{\phi}(1 - \mu)}$$
(6.7)

where $\mu = \hat{\vec{n}}_k \cdot \hat{\vec{n}}$, the cosine of the scattering angle, and

$$\vec{n}_{k} = (\vec{r}_{k} - \vec{r}_{k-1})/(\vec{r}_{k} - \vec{r}_{k-1})$$
 (6.8)

The scattered point source component--the scattered particles due to particles originally in group i--is then obtained from the Klein-Nishina equation:

$$\Delta W_{j}^{5} = W_{j}^{\phi} \frac{0.49875}{4\pi} N_{e} R_{j}^{2} \left[R_{j}^{\pm} + \frac{1}{R_{j}} - 1 \pm \mu^{2} \right]$$
(6.9)

where N_{e} is the total electron density for the region in which the scattering occurs-including that due to the separate hydrogen.

The scattered contributions are grouped, according to the average scattered energies, to yield the final representation of the scattered point source:

where $R_i \overline{E_i^{\phi}}^{\phi}$ is the average energy after scattering of particles originally in group i_i , and J' is the set of initial group indices i_i , for which this scattered energy is within the boundaries of group i'.

The angular point source at the scattering point is evaluated only for discrete directions $\hat{\Omega}$. Therefore, the angular dependence has been suppressed in this development.

6.4 NEUTRON CROSS SECTIONS

Neutron transport and scattering calculations utilize group averaged cross sections only. These can be obtained from various tabulations, e.g., Reference 14, which also discusses the averaging techniques.

The microscopic data for the ith element is supplied to the FASTER program by energy group j as-

 $\sigma_{i,i}^{t} \qquad \text{the average total cross section for element i and group i}$ $\sigma_{i+k,i}^{t} \qquad \text{the lth Legendre expansion coefficient for element i of the differential elastic scattering cross section for transfer from group i to group k, \\ \sigma_{i+k}^{ne}, \text{ on isotropic, weighted, non-elastic transfer cross section}$

 $\sigma_{j \rightarrow k, i}^{na} = \sigma_{j \rightarrow k, i}^{inelastic} + 2 \sigma_{j \rightarrow k, i}^{(n-2n)} + \dots$

The elastic scattering coefficients are assumed to contain the (21 + 1) factor associated with the Legendre series expansion.

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The INSECT subroutine will transport correct these neutron cross sections, or it will remove the transport correction under conditions noted in the input instructions in Section 9.5. In these cross section manipulations, the first two Legendre expansion coefficients of the group-averaged elastic scattering cross sections are computed first:

$$\sigma_{j,i} = \sum_{k} \sigma_{j \rightarrow k,i} \qquad (6.12)$$

is the average total elastic scattering cross section for

where

° i. i

the ith group of the ith element
=
$$3\bar{\mu}_{j,i} \sigma_{j,i}^{\circ}$$

$$\begin{split} \tilde{\mu}_{j,\,i} & \quad \text{is the average cosine of the scattering angle in the} \\ & \quad \text{laboratory coordinate system for group } j & \text{of the } \underline{ith} \\ & \quad \text{element.} \end{split}$$

. The correction of the group averaged total cross section yields the group averaged transport cross section ${\bf *}_{t}^{tr}$:

$$\sigma_{j,i}^{tr} = \sigma_{j,i}^{t} - \bar{\mu}_{j,i} \sigma_{j,i}^{0} = \sigma_{j,i}^{t} - \sigma_{j,i}^{1}/3 \qquad (6.13)$$

The removal of this correction requires the equation:

$$\sigma_{j,1}^{\dagger} = \sigma_{j,1}^{\dagger r} + \sigma_{j,1}^{\dagger}/3$$

If the total cross section is transport corrected, the corresponding correction to the group averaged elastic scottering cross section is applied to the in-group term of the isotropic Legendre expansion coefficient, $\sigma_{j=1,1}^{\circ}$ only:

$$\sigma_{i \leftarrow i}^{0, ir} \stackrel{:}{=} \sigma_{i \leftarrow i}^{0} - \sigma_{i, i}^{1} / 3 \qquad (6.14)$$

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Special attention is given to hydrogen since its presence in large amounts is not unequately represented by the above group-to-group transfer cross sections. Hydrogen cross sections are supplied as group averaged totals σ_1^h . The scattering cross section is then assumed to equal the total cross section and the angular dependence of the scattering is treated correctly as described in Section 6.5.

Macroscopic cross sections, by composite material, are computed by energy group in a manner similar to that for photon cross sections. This includes the total cross section $\Sigma_{j,m}^{\dagger}$ and the scattering cross sections $\Sigma_{j,m-k,m}^{\dagger}$ and $\Sigma_{j,k-k,m}^{ne}$ or the equivalent transport corrected cross sections.

Kinetic heating responses are computed by INSECT for each element and combined by composite material for use as heating conversion factors. Computed as average fractional energy loss cross sections, the groupwise equations are:

$$\sigma \left[1 - \left(\frac{\overline{E} \text{ out}}{(\overline{E} \text{ in })}\right)_{j,i} = \frac{2A_i}{(A_i + 1)^2} - \sigma_{j,i}^{\circ} \left(1 - \overline{\mu}_{j,i}^{\circ,m}\right)$$
(6.15)

where
$$E_{in}$$
 is the energy of neutrons going into the elastic collision,
 E_{out} is the energy of neutrons coming out of this collision,
 $1 \cdot \left(\frac{E_{out}}{E_{in}}\right)$ is the average fractional energy lass
 $e_{i,i}^{o}$ is the total elastic scattering cross section as given by
equation 6.12 for heavy elements ($A_i > 1$)
 $= e_i^{h}$ for hydrogen
 $\bar{\mu}_{i,i}^{c,m} \approx \frac{1}{A_i} \left[\bar{\mu}_{i,i}^{c,m} - 1 + \bar{\mu}_{i,i}, \sqrt{A_i^2 + \bar{\mu}_{i,i}^2 - 1} \right]$ for heavy elements
 $\bar{\mu}_{i,i}^{c,m} \approx \frac{1}{A_i} \left[\bar{\mu}_{i,i} + 1 + \bar{\mu}_{i,i}, \sqrt{A_i^2 + \bar{\mu}_{i,i}^2 - 1} \right]$ for heavy elements (6.16)
 $\bar{\mu}_{i,i}^{c,m} \approx 1$ is the average scattering angle cosine in the laboratory coordinate system.



6.5 NEUTRON ATTENUATION AND SCATTERING

The neutron attenuation kernel $K_1^{\dagger}(\hat{r},\hat{r}^{\dagger})$ is handled in the same manner as the photon attenuation kernel. The only difference is that there is no energy interpolation required to define the average group cross sections.

The neutron source from scattering is developed in two parts. The first calculation yields the neutron source contribution from heavy element scattering:

$$\Delta W_{j'}^{H} = \sum_{j=1}^{n} W_{j}^{\Phi} - \frac{1}{4\pi} \left[\Sigma_{j \neq j', m}^{ne} + \sum_{l=0}^{n} \Sigma_{j \neq j', m}^{l} P_{j}(\mu) \right]$$
(6.17)

where m denotes the material at the scattering point

$$\mu$$
 is the cosine of the scattering angle, $\mu = \vec{n}_k \cdot \vec{n}$
 $P_i(\mu)$ is the 1th Legendre polynomial, i.e., from Reference 16, pg. 308:
 $P_o(\mu) = 1$
 $P_i(\mu) = \mu$

$$P_{1}(\mu) = \frac{1}{1} \left[(21 - 1) \mu P_{1-1}(\mu) - (1 - 1) P_{1-2}(\mu) \right]$$
(6.18)

The neutron source for scattering from hydrogen is obtained only if $\mu > o$, i.e., scattering in the laboratory coordinate system is restricted to angles < 90 degrees. Then the scattered source contribution is computed as:

$$\Delta W_{i}^{h} = 4\mu \rho^{h} \sum_{\mathbf{f} \in \mathcal{J}^{h}} W_{i}^{\phi} \frac{\sigma_{i}^{h}}{4\pi}$$
(6.19)

where $\mu^{c.m} = 2\mu^2 - 1$, $d\mu^{c.m}/d\mu = 4\mu$, $E_{out}/E_{in} = \frac{1+\mu^{c.m}}{2} = \mu^2$,

 $i \in J'$ if $E_{i_1} > \mu^2 \quad \overline{E_{i_1}^{\phi}} \ge E_{i_1+1}$ i.e., if the scattered energy $\mu^2 \overline{E_{i_1}^{\phi}}$ is within the boundaries of group i'; and ρ^{h} is the local hydrogen density.



These two components are then combined to yield the final value of the neutron scattered point source:

$$W_{i'}^{s} = \Delta W_{i'}^{H} + \Delta W_{i'}^{h}$$

$$\overline{E_{i'}^{s}} = \frac{1}{W_{j}^{s}} \left[\overline{E_{i'}^{n}} \Delta W_{i'}^{H} + 4\mu_{\rho}^{h} \sum_{j \in J^{s}} W_{j}^{\phi} \frac{\sigma_{j}^{h}}{4\pi} \mu^{2} \overline{E_{j}^{\phi}} \right]$$
(6.20)

where the $\overline{E_{i_1}^n}_{i_1}i'=1,2,\ldots,$ are input average scattered energies for neutron scattering from theory elements.

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SECTION

7.0 FLUX ESTIMATION

The FASTER program computes multigroup neutron or photon flux components for arbitrarily located point, surface and/or volume detectors. The surface averaged fluxes are obtained for specified sections of surfaces which form boundaries of regions. Thus there may be two equivalent definitions of each surface detector, i.e., if two regions have the desired section of the surface as a common boundary. Volume averaged fluxes are obtained for specified regions of the geometry using the two special equations 2, 55 and 2, 56 for void regions and constant material density regions respectively.

7.1 ANGULAR FLUX CONTRIBUTIONS

The random sampling technique discussed in Section 2.7 is used in integrating the angular dependence of the point sources to obtain surface and volume averaged flux components. Therefore, the individual contributions for all detector types have a similar form involving discrete directions. A full set of indices will be used in the following summary of flux estimation equations, i.e., the contribution to the <u>ith</u> energy group from the <u>kth</u> inner literation of the 1th outer iteration is given by:

a) point detector at $\hat{\vec{r}}$

$$\Delta \phi_{ijk}^{*}(\vec{\Omega}) = \left\{ \frac{W_{j}^{s} \kappa_{j}^{+}(\vec{\tau}_{ik}')}{\left|r - \tau_{jk}\right|^{2}} \right\} \delta(\vec{\Omega} - \vec{\Omega}_{o})$$
(7.1)

$$\vec{n}_{0} = (\vec{\tau} - \vec{\tau}_{1k})/|\vec{\tau} - \vec{\tau}_{1k}|$$
b) surface detector of a distance s from $\vec{\tau}_{1k}$ along \vec{n}_{1}

$$\Delta \phi_{ijk}^{*}(\vec{n}) = \left\{ \frac{W_{ijk}^{*} K^{\dagger}(\vec{\tau}_{1k}, \vec{\tau}_{1k} + \vec{s}_{1})}{A \cdot L + \vec{n}_{1} - \vec{n} + q^{*}(\vec{n}_{1})} \right\} \delta(\Omega - \Omega_{0})$$

$$\vec{n}_{0} = \vec{n}_{1}$$
(7.2)

c) void volume detector at a distance s from
$$\vec{r}_{ik}$$
 along $\vec{\Omega}_{i}$

$$\Delta \Phi_{ijk}^{*}(\vec{\hat{n}}) = \left\{ \begin{array}{l} W_{1}^{*} \kappa_{1}^{*} (\vec{\hat{\tau}}_{ik}, \vec{\hat{\tau}}_{ik} + s \hat{n}_{1}) \Delta s} \\ \hline V \cdot L \cdot q^{*}(\vec{n}_{1}) \end{array} \right\} \delta(\vec{\hat{n}} - \vec{\hat{n}}_{0})$$
(7.3)
$$\vec{\hat{n}}_{0} = \vec{\hat{n}}_{1}$$

d) non-void volume detector at a distance s from \vec{r}_{ik} along $\vec{\Omega}_i$

$$\Delta \Phi_{ijk}^{*}(\widehat{\Omega}) = \begin{cases} W_{1}^{*} \kappa_{1}^{*} (\widehat{\tau}_{ik} + s\widehat{\Omega}_{1}) \\ \nabla \cdot L \cdot q^{*}(\Omega_{1}) \end{cases} + \frac{1 - \exp\left[-\Delta s \cdot \Sigma_{1}^{\vee}\right]}{\Sigma_{1}^{\vee}} \\ \delta(\widehat{\Omega} - \widehat{\Omega}_{0}) \end{cases}$$
(7.4)
$$\widehat{\Omega}_{0} = \widehat{\Omega}_{1}$$

or in general:

$$\Delta \phi_{ijk}^{\dagger} \left(\vec{\hat{\Omega}} \right) = \Delta \phi_{ijk} \quad \delta \left(\vec{\hat{\Omega}} - \vec{\hat{\Omega}} \right)$$
(7.5)



7.2 SCALAR FLUXES AND COMPONENTS

The full set of indices, outer iteration i, inner iteration k, and energy group i, was introduced to simplify the discussion of the final equations for the various flux components. Unless a flux component is used in a subsequent equation, there will be no symbol introduced on the left side of the equation for this component.

The FASTER program actually includes a group collapse, if desired, to a coarser group structure for the flux edits. This will be ignored in the equations below since it involves nothing more than an inner summation. Thus, a summation over energy groups before any other summation is implicit. Also implicit is a summation over multiple intersections and/or discrete directions for surfaces and volumes.

Scalar Number Flux (Sample Mean)

The total scalar flux in group j is obtained by an angular integration:

Other quantities are obtained in a similar manner. The index i is reserved for the energy dependence in all of the equations below.

Sample Variance of Scalar Flux

$$V_{j}^{2} = \frac{1}{n-1} \left[\sum_{i=1}^{n} \left(\sum_{k=0}^{n-1} \Delta \phi_{ijk} \right)^{2} - n \left(\phi_{j}^{0} \right)^{2} \right]$$
(7.7)

Relative Error

$$E_{j} = \sqrt{\frac{V_{j}^{2}/n}{\phi_{j}^{o}}}$$
(7.8)

Differential Number Flux

$$\phi_{i}^{o} / (E_{i} - E_{i+1})$$
 (7.9)

Cumulative Number Flux (E \geq E₁₊₁/

$$\sum_{i=1}^{l} \phi_{i}^{o}$$
(7.10)

Energy Flux

$$I_{i}^{o} := \frac{1}{n} - \sum_{i=1}^{n} \frac{\overline{E}_{i|k}^{s}}{E_{i|k}} \Delta \phi_{i|k}$$
 (7.11)

Average Group Energy

$$\overline{E}_{j} = l_{j}^{o} / \phi_{j}^{o}$$
(7.12)

Differential Energy Flux

ı°

$$/(E_{j} - E_{j+1})$$
 (7.13)

Cumulative Energy Flux $(E \ge E_{i+1})$

$$\sum_{i=1}^{l} f_{i}^{o}$$
(7.14)

Average Flux Between Outer Iterations n, and n,

$$\frac{1}{n_2 - n_1} = \sum_{i=n_1 + 1}^{n_2} \sum_{k=0}^{i} \Delta \phi_{ijk}$$
(7.15)

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riux Contribution from mth Fixed Source

$$\frac{1}{n} \sum_{i=1}^{n} \left\{ \left(\sum_{k=0}^{\Delta \phi} i_{jk} \right) \text{ such that } \vec{r}_{i,o} \text{ is in the } m \text{ th} \text{ source} \right\}$$

Flux Contribution from 1th Scattering Region

$$\frac{1}{n} = \sum_{i=1}^{n} \sum_{k=1}^{k=1} \left\{ \Delta \phi_{ijk} \text{ such that } \vec{r}_{ik} \text{ is in the } \underline{lth} \text{ region} \right\}$$
(7)

Flux Contribution from kth Order of Scatter

Azimuthally averaged Legendre moments of the angular flux can also be obtain from FASTER. In particular the zeroth moment is the scalar flux given by equation 7.6. first moment is the current. The equations used in obtaining these moments and the equa for externally monipulating these moments are summarized in Appendix B.

Length∼of-flight moments of the scalar flux are also computed by FASTER. They moments are discussed in Appendix B.

7.3 FLUX CONVERSIONS

Scalar fluxes are converted by group to more useful units using a linear interpo in energy:

$$D_{i} = \phi_{i}^{\circ} \frac{f_{i}(\overline{E}_{i} - E_{i+1}) + f_{i+1}(E_{i} - \overline{E}_{i})}{E_{i} - E_{i+1}}$$
(*

where $f_{\hat{\mathbf{i}}}$ is the point-wise energy dependent conversion factor or response function for $\underline{i}\underline{t}\underline{h}$ energy level.

The total response is also obtained with limits on its relative error:

$$D = \sum_{i=1}^{n} D_{i}$$
 (7.20)

$$E_{min} = \frac{1}{D} \left[\sum_{i} E_{i}^{2} D_{i}^{2} \right]^{1/2}$$
(7.21)

$$E_{mox} = -\frac{1}{D} \sum_{j} E_{j} D_{j}$$
(7.22)

The equation for E_{max} is obtained by applying the Schwarz inequality to the covariance of of the scalar fluxes in individual groups. Total responses are also obtained for each of the flux components and the angular and length-of-flight moments using equations like 7.19 and 7.20, above.



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SECTION

8.0 RANDOM SAMPLING TECHNIQUES

The preceding sections detailed the sampling functions in a formal manner only. This section describes the techniques used in the FASTER program for obtaining random discrete position vectors from the sampling functions and the considerations involved in defining these functions.

The development of sampling techniques for the FASTER program has proceeded historically from the approximation of the actual particle distributions to an approximation of optimal sampling functions. Both of these techniques are included in the FASTER program.

8.1 GENERAL SAMPLING PROCEDURES

The technique used by FASTER in selecting discrete values of a random variable x.

$$p'(x) dx = p(\xi) d\xi$$
 (8.1)

where ξ is a random variable uniformally distributed on the open interval (0, 1)

$$p(\xi) = 1, 0 < \xi < 1$$
.
= 0 otherwise (8.2)

Various numerical techniques are available for randomly selecting discrete values of ξ from this distribution. A function subprogram RANNO is used in FASTER to obtain these discrete values of ξ .

The procedure for randomly selecting discrete values of $\,\times\,$ then reduces to solving the equation:

$$\int_{-\infty}^{x} \int_{0}^{x} (x^{i}) dx^{i} = \int_{0}^{\xi} p(\xi^{i}) d\xi^{i} = \xi$$
(8.3)

Caution is exercised, therefore, to ensure that such a solution can be obtained with relative ease.



The form of $p^{*}(x)$ frequently used in the FASTER program for one-dimensional sampling functions involves an exponential function. The probability density function for x is than written, for x on the internal (a, b) as $p^{*}(x; a, b, a, x_{o})$ with the following special cases:

a)
$$p^{*}(x) = \delta(x - \alpha)$$
 if $\alpha = b$
b) $p^{*}(x) = \frac{1}{b-\alpha}$ if $\alpha < b$ and $\alpha = 0$
c) $p^{*}(x) = \frac{\alpha}{c} \exp \left[\alpha | x - x_{0} | \right]$ if $\alpha < b$ and $\alpha \neq 0$ (8.4)

where, for α≠0

x_ is the preferred value of x,

$$\sigma \leq x_{o} \leq b$$

$$C = A + B$$

$$A = \sigma \int_{\sigma}^{X_{o}} \exp \left[\alpha \left| x - x_{o} \right| \right] dx = \exp \left[\alpha \left| \sigma - x_{o} \right| \right] - 1$$

$$B = \sigma \int_{x_{o}}^{b} \exp \left[\alpha \left| x - x_{o} \right| \right] dx = \exp \left[\alpha \left| b - x_{o} \right| \right] - 1$$
(8.5)

The parameter a is usually defined from a specification of the relative importance, P, of x_a as compared to the point, a or b, farthest away from x_a .

$$P = 1/\exp\left[\alpha (x_{0} - \alpha)\right] \quad P = 1/\exp\left[\alpha (b - x_{0})\right], \text{ i.e.},$$

$$\alpha = -\frac{(np)}{\max(x_{0} - \alpha, b - x_{0})} \quad (3.6)$$

The point x_{o} is "least perferred" if P is less than unity.

This probability density function is sampled using the function subprogram SAMPLE in the following manner:

a)
$$\frac{\text{if } \alpha = b}{\text{set } x = \alpha}$$

$$\text{set } p^{*}(x) = 1.0 \quad [\alpha \text{ctually equal to } \delta(x - \alpha)] \qquad (8.7)$$
b)
$$\frac{\text{if } \alpha < b \text{ and } \alpha \equiv 0}{\text{obtain } \xi \text{ from RANNO}}$$

$$\text{solve equation 8.3,}$$

$$\xi = \int_{\alpha}^{x} \frac{dx^{*}}{b - \alpha} = \frac{x - \alpha}{b - \alpha}$$

$$i. e., x = \alpha + \xi(b - \alpha)$$

$$p^{*}(x) = 1/(b - \alpha)$$

$$p^{*}(x) = 1/(b - \alpha)$$

$$(8.8)$$
c)
$$\frac{\text{if } \alpha < b \text{ and } \alpha \neq 0}{p^{*}(x) = 1/(b - \alpha)}$$

$$\text{obtain } \xi \text{ from RANNO}$$

$$\text{solve equation 8.3,}$$

$$i. e., \xi = \frac{\alpha}{c} \int_{\alpha}^{x} \exp \left[\alpha | x - x_{\alpha}|\right] dx$$
1)
$$\text{if } \xi < A/C, \text{ then } x < x_{\alpha}$$

$$\text{and } \xi = \frac{1}{c} \left\{ A - \alpha \int_{x}^{x} \exp \left[\alpha | x^{*} - x_{\alpha}|\right] dx^{*} \right\}$$

$$\text{or } \xi C - A = -\left\{ \exp \left[\alpha (x - x_{\alpha})\right] - 1 \right\}$$
2)
$$\text{if } \xi > A/C, \text{ then } x > x_{\alpha}$$

$$\text{and } \xi = \frac{1}{c} \left\{ A + \alpha \int_{x_{\alpha}}^{x} \exp \left[\alpha | x^{*} - x_{\alpha}|\right] dx^{*} \right\}$$

$$\text{or } \xi C - A = \left\{ \exp \left[\alpha (x - x_{\alpha})\right] - 1 \right\}$$

i.e., let
$$\delta \approx \frac{\xi - A/C}{|\xi - A/C|} \begin{cases} +1 \text{ for case 1 above} \\ -1 \text{ for case 2 above} \end{cases}$$

then $\exp \left[\delta \alpha (x - x_0) \right] = 1 + \delta (\xi C - A)$
let $p = \pi_{a_1} + \delta (\xi C - A)$, $\epsilon_{i_1} = \frac{1}{\alpha} + \delta (\xi C - A)$
then $x' = x_0 + \frac{\delta \ln D}{\alpha}$.
and $p'(x) = \frac{aD}{C}$.
(8.9)

8.2 SPATIAL SAMPLING IN THE FIXED SOURCE COORDINATE SYSTEM

The FASTER program includes both the random selection of initial position vectors in a source centered coordinate system and a sampling procedure utilizing built-in importance functions. However, this latter sampling technique is limited to volume sources. Thus, the first technique is required for problems involving point or line sources. Surface sources can be treated by either technique since they are readily approximated by "thin" volumes.

Random selection of a point in the source coordinate system is performed by subroutine PSTAR. The first step in sampling in the fixed source coordinate system is the random selection of just one of the sources. The following equation defines the total sampling function:

$$P_{o}^{\dagger}(\vec{r}) = \sum_{i=1}^{o} P_{i}^{\dagger} q_{i}^{\dagger}(\vec{r})$$
 (6.10)

where p_i^* is the input relative importance of the <u>ith</u> source

$$\sum_{i=1}^{*} p_{i}^{*} = 1$$
 (8.11)

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The appropriate volume is then selected using a random number ξ from RANNO

$$\xi = \iiint p_{o}^{*}(\vec{r}) dV = \sum_{i=1}^{i-1} p_{ii}^{*} + p_{i}^{*} \iiint_{i} q_{ii}^{*}(\vec{r}) dV$$
(8.13)

where f is some fraction, less than 1.0, of the volume V: Thus, the point $\dot{\vec{r}}$ is in the fixed source volume i for which

$$\sum_{i=1}^{j^{*}-1} P_{i}^{*} < \xi \leq \sum_{i=1}^{j} P_{i}^{*}$$
(8.14)

Having selected the fixed source, then each of the spatial variables v_1 , v_2 , v_3 is obtained using the sampling function SAMPLE, described in Section 8.1

$${}^{*}_{1}(\tilde{r}) dV = \frac{3}{1} P^{*} \left(v_{j} : v_{j}^{\min}, v_{j}^{\max}, v_{j}^{\circ}, \alpha_{j} \right) \frac{dV}{v_{j}^{n}}$$

$$(8.15)$$

where n = 1 and 2 for cylindrical and spherical geometries, respectively

= 0 for rectangular geometries
v min is the minimum value of the ith variable
v max is the maximum value of the ith variable
v j^o is the preferred value of the ith variable

$$a_{1}^{i} = \frac{-\ln P_{1}}{\max \left(v_{1}^{o} - v_{1}^{min}, v_{1}^{max} - v_{1}^{o}\right)}$$
.
 P_{1} is the input relative importance of v_{1}^{o}



The l/v_1^n factor is introduced to simplify the difference in differential volume elements for the different source geometries:

$$\frac{dV}{v_{1,c}^{n}} = \left(v_{1}^{n} dv_{1} dv_{2} dv_{3}\right) / v_{1}^{n} = dv_{1} dv_{2} dv_{3}$$
(8.16)

The rectangular components of \vec{r}_0 are then obtained by the variable transformations discussed in Section 5.0. Since the point \vec{r}_0 defined by (v_1, v_2, v_3) is in the <u>ith</u> volume, the volue of $p_0^+(\vec{r}_0)$ is:

$$p_{o}^{*}(\vec{r}_{o}) = p_{i}^{*}q_{i}^{*}(\vec{r}_{o})$$
 (8.17)

8.3 SOURCE SAMPLING USING A PSEUDO SPHERICAL SOURCE

Another sampling procedure was developed for fixed volume sources and attempts to minimize the variance associated with the source point selection. The function approximates equation 2, 36 by a sampling function with a separable angular and spatial dependence.

$$p_{0}^{*}(\vec{r}) dV = \frac{v^{*}(\vec{\Omega}')v^{*}(r;\vec{\Omega})}{r^{2}} (s^{2} ds d\Omega')$$
(8.18)

where a transformation to a spherical coordinate system about a preferred point $\vec{r}_{p'}$ e.g., a point detector, has been performed. The variables involved in this sampling function are shown in Figure 5. The random selection procedures are incorporated in subroutine SPHERE.

Angular Dependence

The z-axis of the spherical coordinate system is directed towards the center of the sources, i.e., towards \hat{r}_c a point in the center of a sphere, of radius R, which encloses all the fixed sources. The random selection of the direction vector $\hat{\Omega}^1$ in this rotated coordinate system uses the sampling function:

$$\mathbf{v}^{*}(\widehat{\mathbf{\Omega}}^{i})\mathbf{d} \, \Omega^{i} = \mathbf{p}^{*}\left(\boldsymbol{\mu}^{i}; \, \boldsymbol{\mu}^{\min}, \, 1, 1, \boldsymbol{\alpha}_{\mu^{i}}\right) \mathbf{p}^{*}\left(\boldsymbol{\theta}^{i}; -\pi, \, \pi, \, 0, \, \boldsymbol{\alpha}_{\theta^{i}}\right) \mathbf{d} \, \boldsymbol{\mu}^{i} \, \mathbf{d} \, \boldsymbol{\theta}^{i}$$
(8.19)



Figure 5. Optimal Fixed Source Sampling



i.e., discrete values of μ^i and $\;$ are obtained from the function subprogram SAMPLE. The azimuthal angle varies over all possible values. The minimum value of the cosine of the polar angle is defined as:

$$\mu^{\min} = -1 \text{ if } R > R_{o} = \left\{ \vec{r}_{p} - \vec{r}_{c} \right\}$$

$$\cdot = \left[R_{o}^{2} - R^{2} \right]^{1/2} \mathcal{A}_{o}^{\prime} \text{ if } \mathcal{A}_{c}^{\prime} \approx R_{o}^{\prime} \dots \qquad (8.20)$$

i.e., the angular variables are limited to directions which intercept the sphere enclosing the. fixed sources. The parameters a_{μ} , and a_{θ} , are defined from the input relative importances: ρ_{μ} , and ρ_{θ} ;

$$\alpha_{\mu'} = \frac{-\ln \rho_{\mu}}{1 - \mu \min}, \rho_{\mu'} = \frac{importance of \mu' = 1}{importance of = \mu'}$$

$$\alpha_{\theta'} = \frac{-\ln \rho_{\theta'}}{\pi}, \rho_{\theta'} = \frac{importance of \theta' = 0}{importance of \theta' = \pm \pi}$$
(8.21)

The values of μ^{1} and θ^{1} obtained through this sampling procedure define the components of a direction vector in a rotated coordinate system

$$\hat{\vec{n}}' = c_1' \vec{i}' + c_2' \vec{j}' + c_3' \vec{k}' \qquad c_1' = \sqrt{1 - \mu'^2} \cos \theta' c_2' = \sqrt{1 - \mu'^2} \sin \theta' c_3' = \mu'$$
(8.22)

These components are then transformed into equivalent values in the geometry coordinate system;

$$\vec{\Omega} = c_1 \vec{i} + c_2 \vec{i} + c_3 \vec{k} \text{ where } c_1 = \sum_{i=1}^3 c_i^i R_{i,i}^i \quad i = 1, 2, 3$$
(8.23)

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The rotation matrix R_{1,1} is obtained as shown in Figure 4 for the rotation angles:

where $\vec{n}_{0} = c_{1}^{0+1} + c_{2}^{0+1} + c_{3}^{0-1} \vec{k} = (\vec{r}_{0} - \vec{r}_{1})/\vec{k}$, the unit vector directed towards the center of the sphere enclosing the fixed sources.

Spatial Dependence

The spatial sampling function incorporated in subroutine SPHERE is defined for all direction vectors $\hat{\Omega}$ even if no sources lie along $\hat{\tau}_p + s\hat{\Omega}$ for $s \ge 0$. If no source is intercepted along this ray, the outer iteration will yield a zero result. To ensure an adequate number of outer iterations, discrete directions are obtained by random sampling until one of the defined rays intercepts a fixed source. The misses are counted internally and factored into the flux averages; thus if n' is the requested number of iterations, $n \ge n'$ iterations will be performed until non-zero contributions are obtained.

The spatial sampling function is defined as: for s in the ith region along $\,\Omega\,$ as:

$$v^{\star}(s_{j}\overrightarrow{\Omega}) = \frac{A_{j}\exp\left[-\alpha_{j}(s-s_{j})\right]}{\sum_{i}\frac{A_{i}}{\sigma_{i}}\left[1-\exp\left[-\alpha_{i}(s_{i+1}-s_{j})\right]\right]}$$
(8.25)

where $A_i = 0$, if there is no source in the region

$$A_{i}^{\dagger} = I_{i}, P_{i}, \left(\overrightarrow{r}_{p} + (s_{i} + \epsilon)\overrightarrow{\Omega}\right) \exp \left[-\int_{0}^{s} i\sum_{j} \sum_{j=1}^{t} (\overrightarrow{r}_{p} + s^{\dagger}\overrightarrow{\Omega}_{j}) ds^{\dagger}\right]$$
(8.26)

if there is a source, i', in the region

$$\begin{aligned} \alpha_{j} &= \beta_{s} \sum_{l_{0}}^{\dagger} \left(\vec{\tau}_{p} + \vec{s}_{j} \vec{\Omega} \right) + \frac{2}{s_{j+1} \vec{s}_{i}} \quad \ln \left[\frac{\rho_{1}}{\rho_{1}} \left(\frac{\vec{r}_{p} + (s_{j} + \epsilon) \vec{\Omega}}{\rho_{1} \vec{s}_{j} \vec{\Omega}} \right) \right] \\ \vec{s}_{j} &= (s_{j} + s_{j+1}) / 2 \end{aligned}$$
(6.27)

 $\begin{array}{l} {{\rho _{i1}}},\;\left({\stackrel{\bullet }{T}}_{p} + {\left({{s_{i1}} + \epsilon } \right)\overrightarrow \Omega } \right) \text{ is the normalized spatial source density just inside the region,} \\ {{i,e.}\;\;\epsilon = \frac{{{s_{i+1}} - {s_{i1}}}}{{100}}}. \end{array}$

 $p_{i'}(\vec{r}_{p} + \vec{s}_{i} \vec{\Omega})$ is the normalized spatial source density half way through the region

I, is the total source intensity (Mev/sec),

is an average energy group for the sources (described below),

 $\beta_{\rm s}$ is an input adjustment factor for the material attenuation importance, and a two point expanential curve fit of the spatial source density with distance has been used

The average source group index, \hat{f}_{o} , corresponds to an average source energy \bar{E}_{p} computed for the preferred point $\hat{\tau}_{o}$ by subroutine GROUP as:

$$E_{\hat{i}} \rightarrow \overline{E}_{p} \geq E_{\hat{i}} + 1$$
where $\overline{E}_{p} = \frac{\sum_{i}^{c} G_{i} \overline{E}_{i}^{b}}{\sum_{i}^{c} G_{i}}$, $G_{i} = \frac{g_{i} n_{i}^{o} \exp[-\eta_{i}] (1 + b_{i} \eta_{i})}{\sum_{i}^{c} G_{i}}$ (8.28)

where g; is an input group importance e.g., a flux-to-dose conversion tactor

b, is an input linear buildup coefficient,

 $n_{i}^{o}, \ \bar{E}_{0}^{o}$ define the spectrum of the first source encountered on the line from \vec{r}_{c} to \vec{r}_{p} (the source closest to \vec{r}_{c}),

 η_{1} is the number of mean free paths from the edge of this source nearest to the preferred point $\tilde{\tau}_{p,r}^{\nu}$ Σ_{1}^{ν} is the cross section for the region over which the source is superimposed ($\equiv 1.0$ if the region is void).



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then solving the equivalent of equation 8.3.

$$\begin{split} \xi &= \int_{0}^{5} v^{*} \left(s^{i}; \hat{n}\right) ds^{i} \\ &= \underbrace{\sum_{i=1}^{k-1} \frac{A_{i}}{\alpha_{i}} \left[1 - \exp\left[-\alpha_{i}\left(s_{i+1}^{-s_{i}}i\right)\right] + \int_{s_{k}}^{5} A_{k} \exp\left[-\alpha_{k} k^{i} - s_{k}\right]}_{k} ds^{i} \\ &= \underbrace{\sum_{i=1}^{k-1} \frac{A_{i}}{\alpha_{i}} \left[1 - \exp\left[-\alpha_{i}(s_{i+1}^{-s_{i}}i_{j})\right]\right]}_{s_{i}^{i} - \frac{A_{i}}{\alpha_{i}}} \left[1 - \exp\left[-\alpha_{i}(s_{i+1}^{-s_{i}}i_{j})\right]\right] \\ (8.29) \\ s &= s_{k} - \frac{1}{\alpha_{k}} \quad \text{in} \quad \left[1 - \frac{\alpha_{k}}{A_{k}} \quad (\xi A_{>0} - A_{< k})\right] \\ v^{*} \left(s_{i}; \hat{n}\right) &= \left[A_{k} - \alpha_{k} \left(\xi A_{>0} - A_{< k}\right)\right] / A_{>0} \\ v^{\text{where}} &= A_{>0} \quad = \sum_{i} \frac{A_{i}}{\alpha_{i}} \left[1 - \exp\left[-\alpha_{i}(s_{i+1}^{-s_{i}})\right], \text{ the denominator of equation 8.29} \end{split}$$

$$A_{$$

Thus the discrete position reactor is given by-

$$\vec{r}_{o} = \vec{r}_{p} + s\vec{\Omega}$$
with $p_{o}^{*}(\vec{r}_{o}) = \frac{u^{*}(\vec{\Omega}^{*}) v^{*}(s;\vec{\Omega})}{s^{2}}$
(8.31)

8.4 SEPARATION OF VARIABLES FOR SCATTERING POINT SELECTIONS

Application of the procedures discussed in Sections 8.3 and 8.4 reduces the representation of the fixed source(s) to a single point source. The random sampling techniques for selecting the kth scattering point $\vec{\tau}_k$ therefore involve a point angular source at $\vec{\tau}_{k-1}$ and a preferred point at $\vec{\tau}_p$ as shown in Figure 6. For point flux calculations in source and/or scattering volumes, the preferred point $\vec{\tau}_p$ is the detector point $\vec{\tau}$.





Figure 6. Optimal Scattered Source Sampling

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Surface and volume averaged flux calculations utilize the preferred point \vec{r}_{p} to locate in a general manner the area in space where the detectors are located. For these calculations the point \vec{r}_{p} is assumed to be at the center of a sphere of radius R_{p} which contains all the detectors. It is introduced to permit a more comprehensive treatment of the spatial importance of scattering points.

The first technique used in selecting the scattering point is to reduce equation 2.37 to a more simple form by using a representative energy group and by defining the sampling function as a separable function of direction and distance:

$$P_{k}^{*}(\vec{r}') dV = \frac{q^{*}(\vec{\Omega}') v^{*}(x) dV}{x^{2}}$$
 (8.32)

where both $q^{\dagger}(\hat{\Omega}^{\dagger})$ and $u^{\dagger}(x)$ depend on $\hat{\uparrow}$, the index of the energy group corresponding to an average group energy determined from the flux estimation performed for the source point $\hat{\tau}_{l-1}$:

E < > E ≥ E < 1

$$\widetilde{E} = \frac{\sum_{\substack{i \neq b \in ctors}} \sum_{j} \Delta \phi_{i,j,k-1} g_{i} \eta_{j} b_{i} \widetilde{E}_{j}^{2}}{\sum_{\substack{j \in ctors}} \sum_{j} \Delta \phi_{i,j,k-1} g_{j} \eta_{j} b_{j}}$$
(8.33)

The separation of the sampling function into two components permits the selection of a discrete direction vector \overrightarrow{n}^{*} with a cursory treatment of geometric effects. The distance is then selected from the second component using a more detailed treatment of the geometric effects.

It should be noted that the angular integration of the point sources used in obtaining surface and volume averaged fluxes involves a repatitive sampling of the angular part of this sampling function; i.e., discrete directions \hat{n}_{1} are randomly selected from the angular sampling function $q^{*}(\hat{n})$.

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For surface and volume flux colculations the discrete direction and distance defining $\vec{\tau}_k$ are obtained in a spherical coordinate system which is always centered at the source point $\vec{\tau}_{k-1}$ i.e. $dV = t^2 dtd \Omega$. A spherical coordinate system is also used for individual point detectors, except the origin can be located at the detector point $\vec{\tau}_p$ with $dV = s^2 dsd\Omega^2$.

The considerations involved in selecting the origin for point detectors incorporate the fact that there are two singularities in the sampling function, $1/t^2$ from the source point and $1/s^2$ from the detector. Both singularities must be accounted for while also treating material distributions, etc. The singularity at the selected coordinate system origin is removed by the differential volume element. A very simple technique for the second singularity involves the definition:

$$u^{*}(\vec{r}^{*};\Omega)dV = \left\{P_{1}^{*} \quad v_{1}^{*}(\vec{r}^{*}) + P_{2}^{*} \quad v_{2}^{*}(\vec{r}^{*})\right\} dV$$
(8.34)

where

$$u_1^*(\vec{r}) = 0$$
 for points in V_2
 $u_2^*(\vec{r}) = 0$ for points in V_1

V₁ is the volume on the source side of a plane perpendicular to and bisecting the line between the source and detector, and V₂ is the volume on the other side of this plane.

The appropriate volume, and coordinate system origin, is randomly selected using the criterion that the relative importance of scattering in each of the volumes is proportional to the mean free paths encountered in the volumes along the line between the source and detector points:

$$\begin{array}{rcl} \mathbf{P}_1^{*} &=& \eta_1/\eta &, \mbox{ the assumed importance of volume } V_1 \\ \mathbf{P}_2^{*} &=& \eta_2/\eta &, \mbox{ the assumed importance of volume } V_2^{-1} \\ \eta &=& \eta_1 + \eta_2 \end{array}$$

where
$$\eta_1 = \int_{0}^{h/2} \sum_{\hat{1}}^{t} (\vec{r}_{p-1} + i \cdot \hat{n}_{1}) dt^1$$
, on average number of mean free paths in volume V_1
 $\eta_2 = \int_{0}^{h/2} \sum_{\hat{1}}^{t} (\vec{r}_{p} - s^* \hat{n}_{1}) ds^4$, on average number of mean free paths in volume V_2 (8.35)

The appropriate volume is selected using a random number ξ on (0, 1).

$$\forall_{j} \text{ if } \xi = \iiint p_{k}^{*} (t_{i}^{*}) \text{ d} \forall = f \cdot P_{j}^{*} \text{ i.e. } \xi < P_{j}^{*}$$

$$V_2$$
 if $\xi = P_1^* + f'P_2^*$ i.e. $\xi > P_1^*$ (8.36)

where f and f' are fractions. If P_1^* is zero, the point \vec{r}_p^* is automatically selected as the origin and the definition of the u_2^* (\vec{r}') is extended over all space. Similarly if P_2^* is zero, the point \vec{r}_{k-1}^* is selected as an origin with the definition of u_1^* (\vec{r}') being extended to all space points.

This procedure does not eliminate the consideration of the second singularity. It does, however, restrict it to values greater than $4/1 \vec{r}_{k-1} \vec{r}_{p}^{2}$, which is sufficient to remove the major difficulty.

8.5 DIRECTION TO SCATTERING POINT

Direction Vector Sampling-Source Coordinate System

There is a special form of $q^*(\vec{\Omega}')$ available for the case of k = 1; i.e. when \vec{r}_{k-1} is the original point in the fixed source. Since the capability of specifying angular sources is still permitted, these directions may require random sampling in the source coordinate system. In particular, a monodirectional source will always teauire this procedure.

The spatial part of the sampling function is then defined for all space, the source point is the origin, and the direction vector in the rotated <u>source</u> coordinate system is obtained by subroutine QSTAR using SAMPLE.

$$q^{*}(\vec{\Omega}') d\Omega' = \prod_{j=4}^{5} p^{*}(v_{j}; v_{j}^{min}, v_{j}^{max}, v_{j}^{o}, a_{j}) dv_{j}$$
(8.37)

where v_4 is the azimuthal angle, v_5 is the cosine of the polar angle, and the other quantities have the same meaning as in equation 8, 15. This is analogous to the procedure used for spatial sampling in the source coordinate system as discussed in Section 8.2. The selected variables v_4 and v_5 define the direction vector through a rotation procedure similar to that used in previous discussions.

Direction Vector Selection - General

The general procedure for selecting discrete directions attempts to include the importance of the scattered direction, as measured from the direction before scattering, and as measured from the unit vector towards the preferred point.

The unnormalized angular dependence for the scattering angle incorporates an assumed exponential variation with the cosine of the scattering angle:

$$\begin{split} & f_{\alpha}\left(\widehat{n} & \widehat{n}_{k-1}\right) = f_{\alpha}(\mu) = \exp\left[\alpha_{s}^{-}\overline{\alpha}_{s}^{+}\mu\right] \\ & \text{where} \quad \overline{\alpha}_{s} = \left(\rho^{h} \cdot \frac{h}{r_{1}^{h}} \circ \frac{h}{r_{1}^{h}} - \sum_{j=1}^{h} \frac{H}{r_{1}^{h}}\right) / \left(\rho^{h} \cdot \frac{h}{r_{1}^{h}} + \sum_{j=1}^{l}\right) \text{ in subroutine SOBER} \\ & \overline{\alpha}_{s} = \left(\eta^{h} \cdot \frac{h}{\alpha_{1}^{h}} - (\eta - \eta^{h}) \frac{H}{\alpha_{1}^{h}}\right) / \eta \quad \text{in subroutine SOLVER} \\ & \eta^{h} \quad \text{ is the number of mean free paths in hydrogen between } \widetilde{r}_{k-1} \text{ and } \overrightarrow{r}_{p} \\ & \rho^{h} \quad \text{ is the local hydrogen density} \\ & \sigma^{h}_{p} \quad \text{ is the total microscopic hydrogen cross section for group } \widehat{i} \end{split}$$

$\sum_{i=1}^{f}$ is the total cross section-except hydrogen-for group \hat{i} $\alpha_{i}^{h} = -\frac{1}{2} \ln \rho_{i}^{h}$

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is an input relative importance of forward-to-backward scattering for the general group for hydrogen

$$a_{j}^{H} = -\frac{1}{2} \ln \rho_{j}^{H}$$

is the forward-to-backward scatter importance for heavy elements

 $\boldsymbol{\alpha}_{g}$ is an input parameter used to increase or decrease this angular effect.

The unnormalized angular dependence with respect to the preferred point--the effect of the material attenuation--is also assumed to vary exponentially.

$$f_{p}(\vec{\Omega} \cdot \vec{\Omega}_{p}) = \exp(\alpha_{p} \vec{\alpha}_{p} \vec{\Omega} \cdot \vec{\Omega}_{p})$$
 (8.39)

where-

 $\alpha_p = is$ an input adjustment factor, $\overline{\alpha}_n = is$ an internally computed number

The latter number $\ddot{\sigma}_p$ is obtained from a one velocity approximation of the scattering point importance which by neglecting unimportant constants has the forms:

$$f_{p}(\mu) = \int_{0}^{s} \max_{\substack{z \neq z \\ s \neq t}} \frac{\exp\left[-\overline{\Sigma}(s+t)\right]}{s^{2}ds} = s^{2}ds \qquad (8,40)$$

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where

$$\begin{split} \Sigma &= \eta/h \quad \eta = \eta_1 + \eta_2 \\ s_{max} &= h/2\mu, \ \mu > 0 \\ &= \infty, \ \mu \leq 0 \quad \cdot \\ h &= i \stackrel{-}{\tau_{p-1}} i \\ \end{split}$$
Thus
$$f_p(\mu) \bigg|_{\mu = \frac{1}{2}} = \int_0^{h/2} \frac{\exp\left[-\sum h\right]}{(h - s)^2} \ ds = \frac{e^{-\frac{\tau}{2}h}}{h} = \frac{e^{-\frac{\tau}{2}}}{h} \end{split}$$

and
$$f_{p}(\mu)\Big|_{\mu=-1} = \int_{0}^{\infty} \frac{\exp\left[-\overline{\Sigma}h-2\overline{\Sigma}s\right]}{(h-s)^{2}} ds \leq \frac{e^{-\eta}}{h} \left[12\eta\right]^{-1/2}$$

where Schwarz' inequality was used.

Letting
$$f_{\rho}(1)/f_{\rho}(-1) = \exp 2 \overline{\alpha}_{\rho}$$

Then $\exp \left[2 \overline{\alpha}_{\rho}\right] \ge \sqrt{127}$ or $\overline{\alpha}_{\rho} \ge \frac{1}{4}$ in (127) (8.41)

The equality is used in the FASTER program.

The effect of this parameter has been examined for $\mu = 1$ by computing:

$$\frac{\partial f(\mu)}{\partial \mu}\Big|_{\mu=1} = \left[\frac{\partial}{\partial \mu} \int_{0}^{h/2\mu} \frac{\exp\left[-\overline{\Sigma}(s+t)\right]}{t^{2}} ds \Big|_{\mu=1} = \frac{e^{-\eta}}{h} \left(\frac{\eta}{2} - \frac{1}{3}\right)$$

where Leibnitz' rule was applied, μ was then set equal to 1, and then the integration performed. If the true behavior at μ = 1 was exponential, then

$$\bar{a}_{p} = \frac{\eta}{2} - \frac{1}{3}$$
 (8.42)

It is noted that for large values of η , this is a stronger angular dependence than that given by equation 8.41.

The total angular dependence of the sampling function is approximated by various combinations of the above functions. The angular variables are obtained using the function subprogram SAMPLE.

a) Towards Detector Most Important

$$q^{*}(\widehat{\Omega}') = P^{*}(\mu'; -1, 1, -1, \alpha_{p}\overline{\alpha}_{p})$$

$$p^{*}(p' - \theta_{p} - \pi, \pi, 0, -\sigma_{s}\overline{\sigma}_{s} = \sqrt{1 - \mu'^{2}} \sqrt{1 - \widehat{n}_{k-1} \cdot \widehat{n}_{p}^{2}})$$
(8.43)

where
$$\vec{n}_r = \vec{n}_p$$

 $\mu' = \vec{n}' \cdot \vec{n}_r$

and θ_0 is the azimuthal angle between the $\hat{\vec{r}}'$ axis and the projection of $\hat{\vec{n}}_{k-1}$ in the x' - y' plane and where the rotated coordinate system has $\vec{k}' = \vec{n}_p$.

b) Original Direction Most Important

$$q^{*}(\vec{\hat{\Omega}})^{*} = p^{*}(\mu^{*}; -1, 1, -1, \alpha_{s} \vec{\alpha}_{s})$$

$$p^{*}\left(\theta^{*} - \theta_{s}^{*} - \pi, \pi, \theta, -\alpha_{p} \vec{\alpha}_{p} \sqrt{1 - \mu^{*2}} \sqrt{1 - \hat{\vec{\Omega}}_{k-1} \cdot \hat{\vec{\Omega}}_{p}^{2}}\right) \quad (8.44)$$

where

 θ_{p} is the azimuthal angle between the $\hat{\vec{i}}'$ oxis and the projection of $\hat{\Omega}_{p}$ in the x'-y' plane, and where the rotated coordinate system has $\hat{\vec{k}}' = \hat{\Omega}_{k-1}$.



Only the latter technique, equation 8.44, is generally applicable to individual point detectors since the cosine of the polar angle μ^{-1} used in the first technique, equation 8.43, applies only if the source point \vec{r}_{k-1} is selected as the coordinate system origin. As a matter of fact, both of these techniques neglect the effect of the scattering angle of \vec{r}^{-1} , the next scattering point being selected.

The effects of the scattering angle $\cos^{-1}\mu^{\prime\prime}$ at the next scattering point involves the use of the unnormalized approximation:

$$f(\mu^{n})\Big|_{\mu=1} = \int_{0}^{h/2\mu} \frac{\exp\left[\alpha_{s}\overline{\alpha}_{s}\mu^{n}\right]}{t^{2}} ds \Big|_{\mu=1} = \frac{\exp\left[\alpha_{s}\overline{\alpha}_{s}\right]}{h}$$

$$f(\mu^{n})\Big|_{\mu=-1} = \int_{0}^{\infty} \frac{\exp\left[\alpha_{s}\overline{\alpha}_{s}\mu^{n}\right]}{t^{2}} ds \Big|_{\mu=-1} = \frac{\exp\left[-\alpha_{s}\overline{\alpha}_{s}\right]}{h}$$

Assuming on exponential variation exp $[\tilde{\alpha}\mu]$ for intermediate angles μ implies $\overline{\alpha} = \overline{\alpha}_s$ (8.45)

This parameter can be scaled through the input number a.,

Combining this variation with that for material attenuation effects, equation 8.41 or 8.42 yields a third technique for selecting the direction vector with more orless equal applicability to either selected origin in point flux calculations:

c) Combination
$$q_{i}^{*}(\widehat{\Omega}) = p^{*}(\mu'; -1, 1, -1, q_{0}^{*} - q_{0}^{*}) p^{*}(\theta', -\pi, \pi, 0, 0)$$
 (8.46)

where $\hat{\Omega}_{r} = \hat{\Omega}_{0}$

$$\mu' = \hat{\Omega}' \cdot \hat{\Omega}_{\rho}$$

θ' is a uniformly distributed azimuthal angle

All of the above angular sampling techniques, equations 8.43, 8.44, and 8.46, yield polar angle cosines, μ^{+} , and azimuthal angles θ^{+} in a rotated coordinate system. They require application of a rotation to be reduced to equivalent values in the geometry coordinate system. The z⁺ – axis of the rotated coordinate system is Ω_{-} as indicated above. The rotations are performed by previously described techniques.

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8.6 DISTANCE-TO-SCATTERING POINT SELECTION

The spatial sampling function can contain a more detailed treatment of the effects of material distributions since it is defined for a fixed direction. For this discussion, the following notation will be adopted:

> \vec{r}_{a} is the position vector of the selected origin, either \vec{r}_{k-1} or \vec{r}_{p} \vec{r}_{b} is the position vector of the other discrete point h is the distance from \vec{r}_{a} to $\vec{r}_{b} = |\vec{r}_{b} - \vec{r}_{a}|$ $\vec{\Omega}$ is the unit direction vector from \vec{r}_{a} to \vec{r}_{b} $= (\vec{r}_{b} - \vec{r}_{a})/h$ $\vec{\Omega}'$ is the direction vector selected from the ongular sampling function. μ_{o} is the cosine of the angle between $\vec{\Omega}$ and $\vec{\Omega}'$ $= \vec{\Omega} \cdot \vec{\Omega}'$ is the distance from \vec{r}_{a} along $\vec{\Omega}'$ to the outer boundary of the geometry, s_{m} is the maximum distance along $\vec{\Omega}'$ which can be considered for a scattering point.

$$s_m = \min(s_{t'} h/2\mu_o)$$
 if sampling is restricted to the half space around \vec{r}_a and if $\mu_o > 0$



- $$\begin{split} \Sigma^{*}_{\Lambda}(s) & \text{ is the total cross section at a distance } s & \text{ from } \stackrel{\bullet}{r_{\alpha}} & \text{ for the energy} \\ group & \uparrow_{r} & \text{ also denoted by } & \Sigma^{*}_{\Lambda, \ \mu}, & \text{ where } & i' & \text{ indicates the composite} \\ \text{material located at this distance.} \end{split}$$
- is an adjustment factor for material attenuation importance along the first α leg of the scattering triangle (from \vec{r}_{a}).

 β is a similar adjustment factor for the second leg of this triangle (from \vec{r}_{μ}).

Exponential Transformation

There are two techniques available in subroutine USTAR for selecting the distance to the scattering point. The first is the "exponential transformation". There is no essential difficulty with using this technique for point detectors since the singularity is removed by the procedures used in selecting the half space.

The exponential transformation is written in the form:

$$\int_{\alpha}^{s} (s) = \frac{-\frac{d}{ds} \exp \left[-\int_{0}^{s} \Sigma_{\widehat{\Gamma}}^{\vee}(s^{i}) \left[\alpha - \beta \mu(s^{i}) \right] ds^{i} \right]}{1 - \exp \left[-\int_{0}^{s} m - \Sigma_{\widehat{\Gamma}}^{\vee}(s^{i}) \left[\alpha - \beta \mu(s^{i}) \right] ds^{i} \right]}$$
(8.47)

where

 $\mu(s)$ is the cosine of the scattering angle to \overrightarrow{r}_b at a distance s from

$$\vec{r}_{r}$$
, i.e., or $\vec{r}' = \vec{r}_{r}' \cdot s\vec{\Omega}'$

$$\mu(s) = \frac{\mu_{0}h-s}{t}$$
t is the length of the second leg of the scattering tri

iongle

$$= \sqrt[4]{h^2 + s^2 - 2\mu_0 sh}$$

The extent to which this sampling function approximates equation 2,37 for the fixed direction $\vec{\Omega}'$ can be determined by performing the differentiation

$$v^{*}(s) = \frac{1}{C} \sum_{i=1}^{V} (s) \left[\alpha - \beta \mu(s) \right] \exp \left[-\int_{0}^{s} \sum_{i=1}^{V} (s^{*}) \left[\alpha - \beta \mu(s^{*}) \right] ds^{*} \right] \qquad (8.48)$$

where C is the denominator of equation 8.47. The coefficient in front of the exponential should be approximating a term $t^{-2} d\overline{\Sigma} [s, \mu(s)]/d\Omega$ except for a normalizing constant. Its actual form is:

$$\begin{split} \Sigma_{\widehat{\uparrow}}^{\vee}(s) \left[\alpha - \beta \mu(s)\right] &= \sum_{\widehat{\uparrow}}^{\vee} \left(s\right) \left(\alpha - \beta \frac{\mu_{o}^{h-s}}{t}\right) \\ &= \sum_{\widehat{\uparrow}}^{\vee} \left(s\right) \frac{\left[\left(\alpha t + \beta s\right) - \beta \mu_{o}^{h}\right]}{t} \end{split} \tag{8.49}$$

which is not very close to the desired representation. It does include an approximation of the scattering cross section by the total cross section, however.

The exponential term can be examined best by performing the integration of the argument;

$$\int_0^{s} \sum_{i} \sum_{j=1}^{v} (s) \left(\alpha - \beta \mu(s) \right) ds = \alpha \sum_{i} \Delta s_i \sum_{j=1}^{v} \sum_{i=1}^{v} \beta \sum_{j=1}^{v} \sum_{j=1}^{v} \sum_{i=1}^{s+1} \mu(s) ds$$

$$= \alpha \sum_{i} \Delta s_{i} \Sigma \widehat{j}_{i} i^{+} \beta \sum_{i} \Delta t_{i} \Sigma \widehat{j}_{i} i \qquad (8.50)$$

where

 Δs_{i} is the incremental distance in the $i\underline{t}\underline{h}$ region along $\vec{\Omega}$

= s_{i+1} - s_i

 Δt_{i} is the change in distance on the other leg of the scattering triangle corresponding to $\Delta s_{i},~i,e_{*},$

$$\Delta t_{j} = -\int_{s_{j}}^{s_{j+1}} \mu(s) ds = t(s) \Big|_{s_{j}}^{s_{j+1}} = t_{j} - t_{j+j}$$

The first term in this expression properly occounts for attenuation along the first leg of the scattering triangle. The second term accounts for the relative effect of the change in attenuation along the second leg with an implicit assumption of material distributions being spherically symmetric about $\vec{\tau}_b$. This assumption is as good as any since a detailed ireatment of the second leg of the triangle is prohibitive.

Thus, this sampling function approximates to some degree the desired effects. It is sampled by obtaining a random number & from RANNO and solving the equivalent of equation 8.3:

$$\begin{split} \xi &= \frac{1}{C} \left[1 - \exp\left(-\int_0^s \sum_{i=1}^{N} (s^i) \left(\alpha - \beta \mu \left(s^i \right) \right) ds^i \right) \right] \\ \text{i.e.} \quad \exp\left[-\int_0^s \sum_{i=1}^{N} (s^i) \left(\alpha - \beta \mu \left(s^i \right) \right) ds^i \right] = 1 - \xi C \\ \text{or} \left[\alpha \left(s - s_i \right) + \beta \left(1 - 1_j \right) \right] \sum_{i=1}^{N} \frac{1}{2} \sum_{i=1}^{N} \sum_{i=1}^{N} \frac{1}{2} \sum_{i=1}^{N} \frac{1}{2} \alpha \Delta s_i - \beta \Delta 1_i \right] = -\ln \left(1 - \xi C \right) \end{split}$$

This equation can be written in the form

t = As + B

where

.

$$A = -\frac{\alpha}{\beta}$$

$$B = -\frac{1}{\beta} \left\{ \alpha s_{j} + \beta t_{j} - \frac{1}{\sum_{i,j} i^{i}} \left[\ln (1 - \xi C) + \sum_{j=1}^{j-1} \sum_{i,j}^{V} \alpha \Delta s_{j} + \beta \Delta t_{j} \right] \right\}$$

But
$$t^2 = s^2 + h^2 - 2\mu_0 sh = A^2 s + 2 ABs + B^2$$

or $A^* s^2 + 2B^* s + C^* = 0$ $A^* = A^2 - 1$
 $B^* = AB + \mu_0 h$
 $C^* = B^2 - h^2$
Thus
 $s = \frac{-B^* + \sqrt{B^* - A^* C^*}}{A^*}$ (8.51)
 $p^*(s) = \sum_{i=1}^{N} \frac{c}{A} (s) \left(\alpha - \beta \frac{\mu_0 h + s}{A s + B} \right) \left(1 - \xi C \right)$

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Curve Fit of Spatial Dependence (1/t²)

The second technique used for selecting the distance to the scattering point is similar in some respects to the above function. In an unnormalized form, it attempts to approximate equation 2.37 by

$$\left[-\int_{0}^{s} \Sigma \stackrel{\vee}{\uparrow} (\mathfrak{s}) \Delta \Omega (\mathfrak{s}) \exp \left[-\int_{0}^{s} \Sigma \stackrel{\vee}{\uparrow} (\mathfrak{s}') [\alpha - \beta \mu (\mathfrak{s}')] d\mathfrak{s}' \right]$$
(9.52)

where $\Delta \Omega(s)$ is the $1/t^2$ factor for point detector calculations, and is a fractional solid angle for surface and volume detector calculations.

This function is curve-fit from boundary to boundary of the regions traversed by:

$$\begin{split} u^{*}(s) &= A_{i} \exp \left[-\alpha_{i} (s-s_{i})\right] \quad \text{for } s_{i} < s < s_{i+1} \quad (8.53) \\ u^{*}(s_{i}) &= \Sigma^{V}_{i} \cdot i_{i} \quad \Delta \Omega (s_{i}) \exp \left[-\int_{0}^{s} s^{i} \Sigma^{V}_{j} \cdot (s^{i}) \left[\alpha - \beta \mu(s^{i})\right] ds^{i}\right] \end{split}$$

where

$$\begin{split} \mathbf{v}^{*}(\mathbf{s}_{i}) &= \Sigma_{i}^{\vee} \mathbf{x}_{i} \wedge \Delta \Omega \left(\mathbf{s}_{i} \right) \exp \left[\int_{0}^{s} \int_{0}^{s} \Sigma_{i}^{\vee} \left(\mathbf{s}_{i}^{\vee} \right) \left[\alpha - \beta \mu(\mathbf{s}_{i}^{\vee}) \right] d \mathbf{s}_{i}^{\vee} \right] \\ \mathbf{v}^{*}(\mathbf{s}_{i+1}^{\vee}) &= \Sigma_{i}^{\vee} \mathbf{x}_{i}^{\vee} \wedge \Omega \left(\mathbf{s}_{i+1}^{\vee} \right) \exp \left[\int_{0}^{s} \int_{0}^{s} \left[\sum_{i=1}^{v} (\mathbf{s}_{i}^{\vee}) \left[\alpha - \beta \mu(\mathbf{s}_{i}^{\vee}) \right] d \mathbf{s}_{i}^{\vee} \right] \right] \end{split}$$



i.e.,
$$A_{i} = u^{*}(s_{i})$$
$$\alpha_{i} = -\frac{1}{s_{i+1}-s_{i}} \quad \ln \left[u^{*}(s_{i+1})/u^{*}(s_{i}) \right]$$
$$= \alpha \sum_{j=1}^{v} -\frac{1}{s_{i+1}-s_{i}} \left[\ln \frac{\Delta \Omega(s_{i+1})}{\Delta \Omega(s_{i})} - \beta \sum_{j=1}^{v} (t_{i+1}-t_{i}) \right]$$
(8.54)

The fractional solid angle is computed for the detector sphere in surface and volume flux calculations as:

$$\Delta \Omega\left(t_{i}\right) = 1 \text{ if } t_{i} < \mathbb{R}_{p}$$

$$= \frac{1}{4} \left(\frac{\mathbb{R}_{p}}{t_{i}}\right)^{2} \left[1 + \frac{1}{4} \left(\frac{\mathbb{R}_{p}}{t_{i}}\right)^{2}\right] \text{ if } t_{i} > \mathbb{R}_{p}$$

$$(8.55)$$

This is a second order Taylor series exponsion and is sufficiently accurate considering the other approximations.

This function is sampled by the transformation equivalent to equation 8.3 using a random number ξ from RANNO:

-

$$\begin{split} \xi &= -\frac{\int_{0}^{1} v^{*}(s^{i}) ds^{i}}{\int_{0}^{1} s^{m} v^{*}(s^{i}) ds^{i}} = -\frac{1}{C} \left\{ \sum_{j=1}^{1-1} -\frac{A_{j}}{\alpha_{j}} - \left[1 - \exp\left[-\alpha_{j} \Delta s_{j}\right] \right] \right\} \\ &+ \int_{s_{1}}^{s} A_{j} \left[\exp\left[-\alpha_{j} \left(s^{j} - s_{j}\right)\right] ds^{j} \right\} \\ &- \int_{s_{1}}^{s} A_{j} \left[\exp\left[-\alpha_{j} \left(s^{j} - s_{j}\right)\right] ds^{j} \right\} \\ \\ \text{or} \quad A_{j} \exp\left[-\alpha_{j} \left(s - s_{j}\right)\right] = A_{j} - \alpha_{j} \left\{ \xi C - \sum_{j=1}^{1-1} -\frac{A_{j}}{\alpha_{j}} - \left[1 - \exp(-\alpha_{j} \Delta s_{j}) \right] \right\} = D \end{split}$$

where D is the right side of the above equation and C is the denominator of the original. Thus $u^*(s) = D/C$

and
$$s = s_i - \frac{1}{\alpha_i} \ln (D/A_i)$$
 (8.56)

SECTION

9.0 DATA INPUT INSTRUCTIONS

9.1 GENERAL INPUT PROCEDURES

Input Formats

The FASTER program utilizes standard Fortran input statements, Reference 16 page 19. A variety of formats are used. Each format utilizes various combinations of the following data fields

hollerith information: A4 field (4 columns)

integer data: 13 field (3 columns)

floating point data: E9.0 field (9 columns)

Note that for floating point data entered without a decimal point, the decimal point is assumed to be to the right of the data field.

In preparing data, it should be remembered that all blanks in integer or floating point fields are interpreted as zeros. Therefore, all integers (including exponents of floating point numbers) must be right adjusted.

Cord Input and Output

Each physical data card is written on the output file as soon as it is read from the input file. The resulting printout includes the information in card columns (cc) 73 through 80 of the data cards. Since the present version of FASTER does not print details of problem data except for the input cards, prolific use of card labeling is desirable. A note of warning: in obtaining the card identification from cc 73-80, all unused data fields in cc 1-72 are interpreted as data and these unused fields should be blank or contain valid data punches.

Input Data Sections

Date input to FASTER is divided into six sections to simplify the description of multiple change cases. The first data card of each input section is the minimum input requirements. The six sections of data input are:

- 1) title cards, limits, and options
- 2) surfaces and regions
- 3) fixed sources
- cross sections
- · 5) flux groups, response functions and detectors
 - 6) sampling parameters

Detailed input instructions are given below. To simplify the setup of a problem, it is probably best to start with geometric input data and come back to the data input for section 1 later. This simplifies the necessity of specifying maximum array dimensions before the arrays can be used.

Input Control Procedure

The first data card of each input-section contains integer constants controlling the input of the remainder of the data in the section. The general procedure is

- input control constant ≤ 0 , no input
- input control constant >0, input

When input is present, the control constant may serve a dual purpose by also denoting the quantity of input. As an example, the first input-control constant (IN1) for each data section pertains to hollerith or comment cards. If non-positive (IN1 \leq 0), no comment cards should be supplied. If desired, any number of comment cards (up to 999) may be inserted immediately after the input control card for each section. The value of the first input-control constant is then set equal to the number of these comment cards, i.e. IN1 = total number of comment cards.



9.2 SECTION 1 DATA; TITLE CARDS, LIMITS AND OPTIONS

CARD 1-0, Input Controls for Section 1 Data

NOTE: This card is always required.

Column	Format	Symbol	Definition
1-3	13	INI	input control for card 1–1 (descriptive cards) omit card 1–1 if $ N \le 0$ supply $ N $ physical cards if $ N \ge 1$
4-6	13	1N2	input control for cord 1-2 (first title cord) omit card 1-2 if $1N2 \leq 0$ supply card 1-2 if $1N2 \geq 1$
7-9	13	iN3	input control for card 1–3 (second title card) omit card 1–3 if 1N3 ≤ 0 supply card 1–3 if 1N3 ≥ 1
10-12	ł3	1114	input control for card 1–4 (geometric limits) omit card 1–4 if 1N4 ≤ 0 supply card 1–4 if 1N4 ≥ 1
13-15	13	IN5	input control for cord 1–5 (fixed source limits) omit cord 1–5 if IN5 ≤ 0 supply cord 1–5 if IN5 ≥ 1
16-18	13	1N6	input control for card 1–6 (cross section limits) omit card 1–6 if 1N6 ≤ 0 supply card 1–6 if 1N6 ≥ 1
19-21	13	IN7	input control for card 1–7 (neutron scattering limits omit card 1–7 if INZ \leq 0 supply card 1–7 if INZ \geq 1
22-24	13	1N8	input control for card 1–8'(flux limits) omit card 1–8 if INB ≤ 0 supply card 1–8 if INB ≥ 1
25-27	13	1119	input control for cord 1-9 (sampling options) omit cord 1-9 if $ N 9 \leq 0$ supply cord 1-9 if $ N 9 \geq 1$

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Column	Format	Symbol	Definition	CARD 1-4,	Geometric Limi	<u>t</u>			
28-30	13	1110	, input control for card 1−10 (iteration limits) omit card 1−10 if IN10 ≤ 0 supply card 1−10 if IN10 ≥ 1	N	OTE: a) Omit b) Supply	this card if IN4 • this card if IN	≤ 0 14 ≥ 1		
	. 13	15133	estateut esstral for storges man printaut	Column	Format	Symbol	Definition		
31-33	15	INIT	no printout of storage map if IN11 ≤ 0 printout of storage map if IN11 ≥ 1	1-3	13	NSMAX	total number of surfaces required for the geometry description		
34-72	1313		these columns are not used and should be left blank	4-6	13	NAMAX	maximum number of coefficients required to		
73-80	2A4		any desired information for cord identification				e.g. NAMAX = 6 for geometries involving any cones or spheres		
CARD 1-1	, Descriptive h	nformation for	Section 1 Data	7-9	13	NRMAX	total number of regions required to describe the material distribution including voids		
I	b) Sup	aly IN1 physi	cal cords if $ N \ge 1$	10-12	13	NBMAX	maximum number of surfaces bounding a region		
1-72	[8A4		any desired information	13-15	13	NŠTMAX	maximum number of regions which can be		
73-80	73–80 2A4 any desired informatio		any desired information for cord identification				theoretical limit is 2·NSMAX ~ (number of plane surfaces + 1)		
CARD 1-2	2, First Titlè Co	rd for Labelir	ng the Printout	16-72	19/3		these columns are not used and should be left		
N.	iOTE: a) Omit b) Supp	this card if I y this card if	N2≦0 IN2≧1				blank		
1-72	1844		any desired information for identification of	73-80	2A4		any desired information for card identification		
			the problem; this will then appear on the first `line of each printout page	CARD 1-5,	Fixed Source L	mits			
73 - 80	2A4		any desired information for card identification	1	NOTE: a) Omi b) Supp	t this card if it bly this card if	45 <u>≤</u> 0 IN5 <u>></u> 1		
CARD 1-3	, Second Title	Card for Labe	ling the Printout	1-3	13	NEMAX	number of energy groups used in this problem		
	NOTE: 0) Omi b) Sup	t this card if ply this card i	IN3 ≦ 0 IF IN3 ≥ 1				for source spectra and cross sections; source spectra may be described in a different group structure and are regrouped as noted later		
1-72	18A4		any desired information for identification of the problem; this will appear on the second line of each printout page						
73-80	2A4		any desired information for card identification						

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Column	Format	Symbol	Definition	Column	Format	Symbol	Definition
4-6	13	NVMAX	total number of fixed sources	16-72	1913		These columns are not used and should be left blank.
7-9	13	NXMAX	maximum number of points used to tabulate each spatial or angular source distribution	73-80	2A4		Any desired information for card identification.
10-12	13	NXEMAX	maximum number of energy points required to tabulate the differential source spectrum; if any source spectra are described by group integrated values, 2 energy points will be generated for each of these groups before the spectrum is integrated into the group structure for the problem.	<u>CARD 1-7, N</u> NOTE:	a) Omit thi b) Supply th c) For phot	ing Limits s card if IN7 his card if IN7 on problems, d	 Q. ≥ 1. fine each variable on this card as zero. Maximum number of elastic scattering transfer
13-72	2013		these columns are not used and should be left blank	1-5	10	HORDER	natrices for all elements. 1 for P ₀ (transport approximation) (see notes after card 4-5 for internal cross section juggling)
73-80	2A4		ony desired information for card identification				2 for P ₁ , 3 for P ₂ , etc. Negative fluxes can, and will, occur for NORDER > 1 and deep penetrations.
CARD 1-6	, Basic Cross Sect	ion Limits and	Options	4~6	13	NDOWN	Maximum group-to-group transfer for elastic
NOTE: a) Omit this card if $IN6 \leq 0$ b) Supply this card if $IN6 \geq 1$.							scattering for all elements. 1 for in group only, 2 for down 1, etc.
1-3	13	NXSECT	particle type option. O for photons, 1 for neutrons	7-9	13	INELAS	Maximum number of groups for which non-elastic transfer can be initiated for all elements.
4-6'	13	NUNITŖ	composition units option. 0 for 10^{24} atoms/cm ³				included in the P transfer.
· 7-9	13	NUNITX	microscopic cross sections units option. O for barns/atom. 1 for cm²/gm	10-12	13	NDOWN	Maximum group-to-group transfer for non- elastic scattering for all elements. 1 for in group only, 2 for down 1, etc.
10-12	13	NIMAX	total number of different elements or isotopes	13-72	2013		These columns are not used and should be left
13-15	13	NMMAX	total number of composite materials; hydrogen densities can be entered by region thus reducing the total number of different compositions, e.g. pure hydrogen compositions need not be defined	73-80	2A4		Any desired information for card identification.



~				CARD 1-9,	Random Sampli	ng Options		
<u>CARD 1-8,</u> N	<u>Flux Limits</u> IOTE: a) Omit b) Supp	this card if IN ly this card if I	18≦ 0. N8> 1.		NOTE: a) Or b) Su c) Th	nit this card if I oply this card if e preferred valu	N9 \leq 0. IN9 \geq 1. c of each number on this card is 1.	
Column	Format	Symbol		Column	Format	Symbol	Definition	
1-3	13 .	NGMAX	Number of flux groups; less than or equal to the number of groups used for source spectra and cross sections.	1-3	13	NPOINT	0, calculate fluxes for all detectors simultaneously; the preferred point is defined by input, point detectors must be in void regions. 1, calculate fluxes for each point detector individually; the preferred point(s) is the point detector - surface	
4-6	13	NFMAX	Total number of response functions such as flux-				and volume detectors are ignored.	
			response functions.	4-6	13	MODELP	0, randomly select the fixed source and then	
7-9	13	NVMOD	Total number of fixed sources for which separate flux contributions are desired. 0 indicates none.				randomly select the spatial source variables in the source coordinate system. 1, randomly select the spatial source variables in a spherical	
10-12	13	NCMAX	Number of separate contributions to the flux by order-of-scatter 0 - none, 1 - uncollided flux, 2- uncollided flux and single scattered flux, etc.				coordinate system centered at the presence pointy all sources must be volumetric; source volumes must completely cover one or more regions.	
13-15	13	NLMAX	Number of Legendre moments of the angular flux 0, P_0 moment (always obtained, Ξ scalar flux). 1, P_0 and P_1 moments, etc.	7-9	13	MODELQ	0, randomly select angular source variables in the source coordinate system. 1, randomly select angular source variables like MODELV below, with the direction-before-scattering defined as the source for the set of the source to the	
16-18	13	NTMAX	Number of length-of-flight moments of the flux. 0, zeroth moment (always obtained, Ξ scalar flux) 1, zeroth and first moments, etc.	a unit vector i selected sourc angular or isa		selected source point; all sources must be angular or isotropic.		
10-21	13	NDMAX	Total number of detectors of all types	10-12	13	MODELU	Distance between scatters random selection option.	
17 21	10						optimum function (difficulties may be encountered	
22-24	13	NSRMAX	Number of regions for which separate scattering 'contributions are desired.	g for large vol boundary to		for large volumes since the curve tit is from boundary to boundary).		
25-72	1613		These columns are not used and should be left blank.	13-15	. 13	MODELV	Direction vector random selection option. 0, polar angle measured from direction before scattering; azimuthal angle measured from a unit	
73-80 .	2A4		Any desired information for card identification.				direction vector towards the preferred point. 1, opposite of the obove. 2 and 3, polar angle measured from unit vector towards preferred point with combined importance parameters from equations 7.42 and 7.45, or 7.41 and 7.45 respectively; azimuthal angles equiprobable.	

Column	Format	Symbol	Definition							
16-72	1913		These columns are not used and should be left blank.							
73-80	2A4		Any desired information for card identification.							
CARD 1-10, Ite	CARD 1-10, Iteration Limits									
NOTE:	NOTE: a) Omit this card if $IN10 \leq 0$. b) Supply this card if $IN10 \geq 1$.									
1-3	13 ′	NPRINT	Total number of printouts during the flux calculations; yields a convergence history and protects against complete loss if the problem is terminated.							
4-6	13	NUNITS	Number of outer iterations between printouts, i.e., the number of packets of particles.							
7-9	13 <u>.</u> .	N UMBER	Number of discrete directions obtained by random sampling used in integrating the angular point sources to obtain surface and volume averaged fluxes; not used if NPOINT = 1, or if all detectors are points.							
10-12	13	KALIDE	Maximum number of inner iterations per outer iteration, i.e. the number collisions per packet.							
13-72	2013		These columns are not used and should be left blank.							
73-78	2A4	~~~	Any desired information for card identification.							



9.3 SECTION 2 DATA; SURFACES AND REGIONS

CARD 2-0, Input Controls for Section 2 Data

NOTE: a) This card is always required.

Column	Format	Symbol	Definition
1-3	13	INT	Input control for Card 2–1 (descriptive cards). Omit Card 2–1 if IN1 \leq 0, Supply IN1 physical cards if IN1 \geq 1.
4-6	13	IN2	Input control for Card 2-2 (surfaces). Omit Card 2-2 if IN2 \leq 0. Supply IN2 physical cards if IN2 \geq 1, i.e. IN2 surfaces will be described.
7-9	13	IN3 ,	Input control for Card 2-3 (regions) Omit Card 2-3 if IN3 ≤0, Supply IN3 physical cards if IN3 ≥ 1, i.e, IN3 regions will be described.
10-12	13	1N4 ⁽¹⁾	Ambiguity index calculation option. 0, do not calculate ambiguity indices. 1, calculate ambiguity indices. Use IN4 = 1 on the first problem.
13-15	13	IN5 ⁽¹⁾	Geometry consistency check option. 0, do not check geometry. 1, check geometry. Use INS = 1 on the first problem.
16-72	- 1913		These columns are not used and should be left blank.
73-80	2A4		Any desired information for card identification.

(1) IN4 = IN5 = 0 permits the redefinition of regions by surface description changes only. Externe caution should be used to ensure that the ambiguity indices, calculated in previous problems, are still correct.

CARD 2-1, D	Description of S	ection 2 Data	<u>_</u>		
NOI	TE: a) Omit th b) Supply	nis card if iN INI physical	$1 \leq 0$. cards if $ N \geq 1$.		
Column	Format	Symbol	Definition		
1-72	18A5		Any desired information for description of the input data.		کر د ۰ ۰ ۰ ۰ ۳ ۳
73-80	2A4	'	Any desired information for card identification.		
CARD 2-2,	Surface Descrip	tion			Iten 1 (in 1 (in 3 3
NOTE:	a) Omit this b) Supply IN	card if IN2 N2 physical c	\leq 0. ards if IN2 \geq 1.	SNO	. o
1-3	13	· 1	Index of the surface being described.	DUAT	z + a9.
4-6	13	NTP(I)	Index (j) of the last non-zero coefficient if the surface is in the expanded form; calculated internally for all other surfaces.	TABLE 1 JRFACE EC	ation 2 + a _y xy + a ₈ y
7-9	13	NEX	Form (n_) of the surface as input. 0, already in expanded form. 1, \leq NEX \leq 13, special form as indicated in figures 7, 8, and 9 and table 1.	SPECIAL SU	Surface Equ +a ₅ y ² +a ₆ z
10-18	E9.0	AA(1)	First parameter defining the surface.		+° ⁴ × ²
19-27	E9.0 ·	AA(2)	Second parameter defining the surface.		zeo+
64-72	E9.0	AÅ(7)	Seventh parameter defining the surface.		x+a2)
73-80	2A4		* Any desired information for card identification.		

The requisite parameters are listed in the last column of table 1 and are . input in the order shown. If the surface is in the expanded form and rotational terms are involved, supply these on Card 2-2' before supplying Card 2-2 for the next input surface.



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Figure 9. Elliptical Cylinders and Ellipsoids

CARD 2-2', Rotated Surface Equation Terms

NC	OTE: a) Supply omit of	this card as rea herwise.	quired to finish the description of a surface,
Column	Format	Symbol	Definition
1-9	E9.0	A(7, 1)	Coefficient of xy in the general surface equation.
10-18	E9.0	A(8, I)	Coefficient of yz in the general surface equation.
19-27	E9.0	A(9, 1)	Coefficient of zx in the general surface ` equation.
28~72	5E9.0		These columns are not used and should be left blank.
73-80	2A4	'	Any desired information for card identification.
CARD 2-3,	Region Descript	ion	
N	DTE: a) Omit t b) Supply	his card if IN3 IN3 physical c	≤ 0. ands if IN3≥ 1.
1-3	13	I	Index of the region being described.
4-6	13	ISV(I) .	Index of the volume source superimposed over this region. 0, indicates none. Required if and only if MODELP = 1. May also be input or changed on Card 3-6.
7-9	13	MTL(I)	> 0, index of the composition for the region. =0, the region contains hydrogen only. <0, the region is void. This index can be input or changed on Card 4–8.
10-12	13	NS(1, 1)	First boundary surface index.
13-15	13	NS(2, I)	Second boundary surface index. 0 or blank if all boundaries have been listed.





Column	Format	Symbol	Definition
	13	NS(J, I)	<u>Jth</u> boundary surface index, 0 or blank if all boundaries have been listed.
34-36	13	N\$(9, I)	> 0, ninth boundary surface index if the region has exactly nine boundaries. 0, or blank if all boundaries have been listed (less than nine boundaries)1, if the region has more than nine boundaries; the ninth and remaining boundaries are listed on Card 2-3'.
37-45	E9.0	RHO(I)	Hydrogen density in the region apart from that specified for the composite material in the region; units according to NUNITD, may be input or changed on Card 4–9.
46-54	E9.0	XR(1, I)	×-coordinate of any point in the region (cm).
55-63	E9.0	×R(2, I)	y-coordinate of the point in the region (cm).
64-72	E9.0	×R(3, I)	z-coordinate of the point in the region (cm).
73-80	2A4		Any desired information for card identification.

CARD 2-3', Additional Region Boundaries

2413

- NOTE: a) Supply this card(s) for each region having more than nine boundaries, immediately behind Card 2-3 for the region; omit otherwise.
 - b) This card contains data up to and including the maximum number of boundaries (more than 1 physical card if NBMAX > 32). NS(9, 1) Ninth boundary surface index.

1-72

NS(10, 1) Tenth boundary surface index.

- NS(11, 1) Eleventh boundary surface index. 0 or blank if all boundaries are listed.
 - :

	Column	Format	Symbol	Definition						
			NS(NBMAX, I)	Maximum boundary surface index. O or blank if all boundaries are listed.						
	73-80	2A4		Any desired information for card identification.						
	9.4 . ,	SECTION 3 DAT	A; SOURCE DISI	RIBUTIONS						
•	CARD 3-0, Input Controls for Section 3 Data									
		NOTE: a) This	card is always re	quired.						
	1-3	13	İNI	Input control for Card 3–1 (descriptive cards). Omit Card 3–1 if IN1 \leq 0. Supply IN1 physical card if IN1 \geq 1.						
	4-6	13	IN2	Input control for Cord 3-2 (energy levels), Omit Card 3-2 if $IN2 \leq 0$. Supply Card 3-2 if $IN2 \geq 1$.						
	7-9	13	IN3	Input control for fixed sources, omit Cards 3-3 through 3-5 if IN3 \leq 0. Supply Cards 3-3, 3-4 and 3-5 as required for 1N3 fixed sources if IN3 \geq 1.						
	10-12	13	' IN4	Input control for Card 3-6 (source-in-region). Omit Card 3-6 if IN4 ≤ 0 . Supply source in region indices on Card 3-6 for IN4 regions if IN4 ≥ 1 .						
	13-72	2013		These columns are not used and should be left blank.						
	73-80	2A4		Any desired information for card identification.						
	CARD 3-	1, Description of	f Section 3 Data							
		NOTE: a) Omi b) Supp	t this card if IN bly INI physical	$1 \leq 0.$ cords if $1N1 \geq 1.$						
	1-72	18A4		Any desired information for describing the input data						
	73-80	2A4	·	Any desired information for card description.						



CARD 3-2	, Energy Levels	for Sources an	d Cross-Sections	Column	Format	Symbol	Definition		
Column	mn Format Symbol Definition			16-18	13	NPC(4, I)	Azimuthal part of angula	r distribution option	
ı	NOTE: a) Om	it this card if I	N2·≦0.				(fourth source variable.	(See notes below.)	
	b) Sup	ply this card(s)	If $1N2 \ge 1$.	19-21	13	NPC(5, I)	Polar part of the angular	distribution, option	
	c) Sou	urce spectra ca	n be input in any desired group structure and				(fifth source variable).	(See notes below.)	
	wil	l be regrouped	to this set of groups.	N	OTES: The sou	urce variables a	re shown in Figure 10 and a	re ordered as:	
1-72	8E9.0	ELL(1)	Upper energy boundary of the first energy group (Mev).			Rectangula	ar Cylindrical	Spherical	
		E1.L(2)	Lower energy boundary of the first energy group		J≖l	× (cm)	r (cm)	ρ (cm)	
		(-)	and upper boundary of the second group		J = 2	y (cm)	θ (radians)	θ (radians)	
		•			J = 3	z (cm)	z (cm)	۲	
		:	,		J == 4	0' (radia	ıns) θ' (radians)	θ' (radians)	
		ELL(NEMAX	+1) Lower energy boundary of the last energy group;		J = 5	μ'	μ'	μ'	
			diso defines the energy cororr point.		Azimutha	angles are in t	he range − π≤θ, θ'≤ π		
72-80	2A4		Any desired information for card identification.		Cosines of	i polar angles a	e in the range –1 \leq µ, µ' \leq	1	
Card 3-3,	Fixed Source C	Constants and Ir	nput Options	If NPC $(J, i) > 0$, this is the number of tabulation points required to describe the Jth distribution using Card 3-4. If NPC $(J, i) < 0$, the distribution for variable J of source I' = -NPC (J, i) is used and Card 3-4 is not required.					
N	OTE: a) Omit	this card if IN	3≤ 0.						
	b) Suppl	ly this card, an	d Cards 3-4 and 3-5 as required, for IN3 sources					1	
	if IN	3 <u>2</u> 1.	,	22-24	13	MAX	> 0, number of energy p	oints or energy groups	
1-3	13	I	Index of source being described.				 required to describe the source spectrum 0, use the source spectrum for source number 		
4-6	13	N5G(I)	Source geometry type.				1-1000.		
			0, rectangular	25-27	13	NORM	Spectrum normalization	option (the total source	
			2, spherical				of the strength is carried in the of normalize to total sources	spectrum). urce in particles/sec;	
7-9	13	NPC(1 I)	First enotial variable distribution appian				1, normalize to total so	arce in Mev/sec;	
	15		(See notes below.)				2, multiply spectrum by MAX < 0, remember that	the spectrum for source	
10-12	13	NPC(2,)	Second spatial variable distribution option. (See notes below.)				I ¹ = -MAX has been normalized to the total source strength).		
13-15	13	NPC(3, 1)	Third spatial variable distribution option. (See notes below.)						

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Figure 10. Source Distribution Variables

Column	Format	Symbol	Definition
28-30	13	ISP	Input spectrum units option if MAX > 0 0, differential number spectrum at energy points; 1, differential energy spectrum at energy points; 2, groupwise number spectrum (particles in group); 3, groupwise energy spectrum (energy in group).
31-33	13	IAL	Spectrum format option if MAX > 0 0, alternating values of energy points and spectrum 1, spectrum input only using energy points pre- viously input for this case 2, energy point input followed by spectrum input on separate card
34-36	13		These columns are not used and should be left blank.
37-45	E9.0	TOT	Source normalization constant, particles/sec if NORM = 0, Mev/sec if NORM = 1, multiplying constant if NORM = 2.
46-54	E9.0	XTR(1, 1)	x component of the translation of the source coordinate system origin from the geometry coordinate system origin (cm).
55-63	E9.0	XTR(2, 1)	y component of the source translation (cm).
64-72	E9.0	XTR(3, 1)	z component of the source translation (cm).
73-80	2A4		Any desired information for card identification.
Card 3-4, So	urce Variable Di	stributions	

- NOTE: a) Supply these cards immediately behind Card 3-3 for the source to which they apply. Input for each variable in the order J = 1, 2, 3, 4, 5, starting a new physical card for each variable.
 - b) Omit for any variable for which $NPC(J, I) \leq 0$.
 - c) This distribution is normalized and interpolated linearly.
 - d) Histogram data can be used (points can coincide).





Column	Format	Symbol	Definition						
1-72	8E9.0	VEE(1, J, I)	Minimum value of the J $\frac{h}{10}$ variable; if NPC(J, I) = 1, this is the only value of the variable,	Column	Format	Symbol	Definition		
				1-72	8E9.0		See notes below.		
		VAL(1, J, I) VEE(K, J, I) VAL(K, J, I) VEE(L, J, I)	Relative value of the distribution function for the Jth variable at its minimum value (not used if the variable is discrete, NPC(J, I) = 1) Kth value of the Jth variable. Relative value of the distribution function corresponding to VEE(K, J, I).	73-80 NOTES	2A4 : A. If ISP <_: where E(1) is th • E(MAX) EN(K) is point E(t) Mev if IS A. 1 If IAL = and spec A. 2 If IAL =	, the different the maximum sput the differentic (). The units of SP = 1. O, the input or trum E(1), EN(1. the energy (Any desired information for card identification. tial spectrum is tobulated at discrete energy points actral energy (Mev) a spectral energy al spectrum corresponding to the Kth energy al spectrum		
73~80	2A4		corresponding to VEE(L, J, I).		case (they will not be available from a previous case). The input consists of the relative spectrum at these points EN(1), EN(2), , EN(MAX)				
<u>CARD 3-</u>	NOTE: To avoid the minim In particu 3.1416 () significan 5, Source Spectru NOTE: a) Supply immed	numerical diffii um value and i lar, for a unif > n for mrather t figures than a <u>m</u> t this card(s) if iately after the	soulties, it is sometimes necessary to decrement norm azimuthal distribution angular limits use than 3.14159 (<m) computer="" more<br="" since="" the="" uses="">on be input. and <u>only</u> if MAX > 0. It should be placed source variable distributions, if any.</m)>	 A.3 If IAL = 2, the energy points are defined first E(1), E(2), , E(MAX) and then followed by another card with the corresponding spectrum EN(1), EN(2), , EN(MAX) B. If ISP 22, a groupwise integrated spectrum is tobulated by group where EBG(1) is the upper energy boundary of group 1 EBG(MAX+1) is the lower energy boundary of the last spectrum group ENG(K) is the integrat spectrum for the Kith group with units of particles 					





Column Format Syn	abol Distribution	9.3	SECTION 4 DATA	A, MICROSC	OPIC CROSS SECTIONS		
B.] If IAL = 0, the in	uput on Card 3-5 consists of alternating values of energy	CARD 4–0, Input Controls for Section 4 Data					
group boundaries EBG(1), ENG(and group spectrum. 1), EBG(2), ENG(2), , EBG(MAX), ENG(MAX,	NOTE: a) This cord is always required.					
EBG(MAX+1)	Column	Format	Symbol	Definition			
B. 2 If IAL = 1, the energy wise spectrum is supp ENG(1),	yy group boundaries are already defined and the group- olied on Card 3-5 , ENG(2), , ENG(MAX)	1-3	13	IN1	Input control for Card 4−1 (descriptive cards) Omit Card 4−1 if INI ≤ 0, Supply IN1 physical cards if IN1≥1		
B.3 If IAL = 2, the energy EBG(1), and then followed by ENG(1),	y group boundaries are defined first EG(2), , EG(MAX+1) / another card with the groupwise spectrum ENG(2), , ENG(MAX)		13 ·	IN2	Input control for Card 4-2 (neutron scattered energies). Omit Card 4-2 if IN2 ≤0. Supply Card 4-2 if iN2 ≥ 1.		
NOTE: a) Omit this card b) Supply this card c) This data is req d) This data can a	7-9	13	IN3	Input control for microscopic cross sections; Omit Cards 4-3 through 4-7 if $IN3 \leq 0$; Supply Cards 4-3 through 4-7 as required if $IN3 \geq 1$.			
1-72 24(3 (ISV	 First geometric region index (1) Index of source superimposed over Region I (source which completely covers the region), K = 1 	10-12	13 .	IN4	. Input control for Card 4-8 (material-in-region) Omit Card 4-8 If IN4 \leq 0, Supply Card 4-8 with IN4 material-in-region indices if IN4 \geq 1.		
l ISV	0 denotes nane	13-15	13	in5	Input control for Card 4-9 (hydrogen in region) Omit Card 4-9 if IN5 ≤0. Supply Card 4-9 with IN5 hydrogen~in-region deputive if IN5 >1		
	Region I (source splet introduce over the region)	16-18	13	in6	Cross section output option (used only if $NN \ge 1$), no output if $NN \le 0$. If $1N \le 21$, total cross sections are printed by group (neutrant) or level (photons) and by material. Heating responses are printed by energy level for each element in (Mex/atom/unit number flux) x 10^{24} and then for each composite material in (Mex/cm ³ /unit number flux).		
/ /S∨ 73-80	(I) Index of source superimposed over Region I (source which completely covers the region) Any desired information for and identification						
Column	Format	Symbol	Definition	Column	Format	Symbol	Definition .
-------------	--------------------------------------------------	-----------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------------------------------------------------------------	--------------	-------------------	-----------------------------------------------------------------------------------------------------------------------------
19-72	1813		These columns are not used and should be left blank.	1-72	8E9.0	ATW	Atomic weight of the element in atomic mass units.
73-80	2A4		Any desired information for card identification.			ZEE	Atomic number of the element.
CARD 4-1, D	escriptive Inf	ormation for	Section 4 Data			ATD(1)	Density of the element in composite material1,
NOT	E: a) Omittl b) Supply	nis card if IN INI physical	1 ≤0. cards If IN1 ≥1.			ATD(2)	Density of the element in composite material 2.
1-72	18A4		Any desired information for description of the input data.			•	
73-80	2A4	`	Any desired information for card identification.			•	
CARD 4-2, A	verage Neutr	on Energies A	fter Scatter		-	ATD(NMMAX)	Density of the element in the last composite material.
NOT	E: a) Omit ti b) Supply	nis card if IN this card (s) i	2 ≤ 0. [f IN2 ≥ 1.	73-80	2A4		Any desired Information for card identification.
	c) This da	ta is required	if and only if NXSECT=1 (neutron problem)	CARD 4-4, M	icroscopic T	otal Cross Sectio	ns '
1-72	8E9. 0	ESB(1)	Average neutron energy for group 1 (Mev)	NOTE- a) Supply this card immediately after Card 4-3 for each element.			
		ES B(2)	Average neutron energy for group 2	1-72	Β̀Ε9.0	XST(1)	Total microscopic cross section for energy level 1 (photons) or energy group 1 (neutrons), units according to NUNITX.
		•				XST(2)	Total microscopic cross section for energy level 2 or energy group 2,
		ESB(NEM	AX) Average neutron energy for the last energy group.			•	0,0 1
73-80	2A4		Any desired information for cord identification.			•	
CARD 4-3, C	omposition Ve	ctor for Elem	<u>ent</u>			XST(NEMA)	K)Total microscopic cross section for next-to-last photon energy level or last neutron energy group.
NOTE	e: a) Omit C b) Supply all date through	ards 4-3 thro Cards 4-3 thr for the first the data for	ugh 4-7 ff IN3 ≤0. oough 4-7 as required in sets for each element, i.e. element, oll data for tha second element, etc., element number NIMAX if IN3≥1.			XST(NEMA)	K+1) Total microscopic photon cross section for the last energy level. Do not input a number for neutrons.
	c) The first	t element mu	st diways be hydrogen.	73-80	2A4		Any desired information for card identification.



CARD 4-5, 1	Neutron Transfe	Cross Section	n Array Limits	Column	Format	Symbol	Definition			
NOI	 E: a) Omit thi b) Omit thi problem c) Supply the of neutron 	s card for pho s card for the s. his card after on problems.	iton problems. first element (always hydrogen) of neutron Cord 4–4, for oll elements except the first	73-80	2A4	кмх(ЈМАХ)	Maximum non-elastic group-to-group transfer for the last possible initial group, = 1 for in group only, etc.			
Column	Format	Symbol	<u>Definition</u>				·			
1-72	2413	LMAX	LMAX , number of elastic scattering transfer matrices.		NORD	ER = 1, LMAX using	= -2, Code transport corrects P _o elastic transfer P ₁ transfer			
) for P only	Υ.	NORD	NORDER = 1, LMAX = +2, Code transport corrects P elastic transfer and calculates transport cross sections using P1 transfer.				
			LMAX <0, indicates total cross sections are transport corrected. (See notes below.)		NORDER \geq 2, LMAX = -2, Code colculates total cross section using P_1 transfer.					
		NDSM	Maximum group-to-group transfer for elastic scattering			$x = \pm 1$, Cross sections used as input. $x \ge 2$, Cross sections used as input.				
			1 for in-group only	CARD 4-6, 1	Neutron Elastic	Transfer Coef	ficients			
			2 for down 1, etc.	NOTE: a) Supply this cord for all elements except the first of neutron problems						
		JMAX	Maximum number of groups for which non-elastic transfer can be initiated." 0, none	1-72	8E9.0	σ i≁k	(1) <u>1th</u> Legendre moment of the transfer			
		KMX(1)	Maximum non-elastic group-to-group transfer for initial group 1, = 1 for in group only, etc.			XSE(J, K, L)	cross section from group j to k including (21 + 1) coefficient, e.g., GAM-1, GAM-2 rinted autout			
		KMX(2)	Maximum non-elastic group-to-group transfer for initial group 2, = 1 for in group only, etc.	73-80	2A4		Any desired information for card identification.			
					·					

(1) Start a card with P_0 in-group transfer for all energy groups $e^{0}_{i \rightarrow i'} i = 1, 2, ..., NEMAX$



Start a new card with P_0 down 1 transfer for all groups except the last $\sigma_{j \leftarrow i+1}^{\circ}$, i = 1, 2, ..., NEMAX - 1 Start a new card with P_0 down (NDSM-1) transfer $\sigma_{j \leftarrow i}^{\circ}$ + NDSM - 1 , i = 1, 2, ..., NEMAX - (NDSM-1) Start a new card with P_1 in group transfer $\sigma_{j \leftarrow i}^{1}$, i = 1, 2, ..., NEMAX Start a new card with $P_{[LMAX]}$ -1 down (NDSM-1) transfer $\sigma_{j \leftarrow i}^{[LMAX]}$ -1 $\sigma_{j \leftarrow i}^{[LMAX]}$ -1 i = 1, 2, ..., NEMAX - (NDSM-1)

CARD 4-7, Neutron Non-Elastic Transfer Coefficients

 NOTE: a) Supply this card for all elements--except the first--of neutron problems immediately after Card 4-6,
 b) Omit if JMAX = 0.

Column	Format	Symbol	Definition
1-72	8E9.0	_o ne i+⊨i+k−1	⁽¹⁾ Non-elastic transfer coefficient from
		X\$I(K, J) ⁻	group į to group į + k - 1
			$= \sigma \frac{\text{inelastic}}{ \mathbf{p}-\mathbf{j} + \mathbf{K} - 1} + 2 \sigma \frac{n-2n}{ \mathbf{p}-\mathbf{j} + \mathbf{K} - 1} + \dots$
73-80	2A4		Any desired information for card identification.

(1) Start the first card with non-elastic transfer from group 1

Start a new card with non-elastic transfer from group 2

 $^{ne}_{2+2} + K - 1$, K = 1, 2, ..., KMX(2)Start a new card with non-elastic transfer from group JMAX

. CARD 4-8, Material-In-Region Indices

Column

1-72

NOTE: a) Omit this card if IN4 < 0. b) Supply this card if IN4 ≥ 1 with material indices for IN4 regions. c) These indices can also be input on Card 2-3.

F	ormat	Symbol	Definition	
:	2413	I	First region index	٦
		MTL(1)	>0, index of material in this region	
			= 0, region contains hydrogen only	- N=1
			< 0, region is void]
		1	Second region index	7
		MTL(I)	Material index for region	K=2
		•		•
		•		:
		I	Last region index	1
		MTL(I)	Material Index for region	

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Column	Format	Symbol	Definition	
73-80	2A4		Any desired information for card i	dentification,
CARD 4-9, Hyd	drogen Densit	y in Region		
NOTE:	a) Omit thi b) Supply th c) These de	s card if IN5 his card if IN5 nsities can als	<0. 5≥1 with densities for 1N5 regions. so be entered on Card 2-3.	
1-72	6(13, E9, 0)	I	First Region Index	٦
		RHO(1)	Hydrogen density in region I units occording to NUNITD	к=1
		I	Second region index	L _{K=2}
		RHO(I)	Hydrogen density in region I	·]
		•		:
		•		•
		l	Last region index	
		RHO(I)	Hydrogen density in region l	
73-80	2A4		Any desired information for card i	dentification.

9.6 SECTION 5 DATA; DETECTORS AND FLUX CONVERSIONS

CARD 5-0, Input Controls for Section 5 Data

NOTE: a) This card is always required.

1-3	13	111	Input control for Card 5-1 (descriptive cards) Omit Card 5-1 if IN1≤0. Supply IN1 physical cards if IN1≥1.
·4-6. ·	13	1N2	Input control for Cărd 5-2 (flux groups) Omit card 5-2 if IN2≦0. Supply Card 5-2 if IN2≥1.

Column	Format	Symbol	Definition
7-9	13	IN3	Input control for Card 5-3 (response functions) Omit Card 5-3 if IN3 ≤0, -Supply IN3 response functions if IN3 ≥1.
10-12	13	IN4	Input control for Card 5-4 (detectors) Omit Card 5-4 if IN4 ≤0. Supply IN4 detectos if IN4 ≥ 1.
13-15	13	IN5	Input control for Card 5-5 (∆total flux sources) Omit Card 5-5 if IN5≤0. Supply Card 5-5 if IN5≥1.
16-18	13	1146	Input control for Card 5-6 (scottered flux regions) Omit Card 5–6 if 1N6≤0 Supply Card 5–6 if 1N6≥1
19-72	1813		These columns are not used and should be left blank.
73-80	2A4		Any desired information for card identification,
CARD 5-1,	Descriptive Info	armation for !	Section 5 Data
NO	TE: a) Omit th b) Supply	is card if IN IN1 physical	$1 \leq 0$. cards if IN1 ≥ 1 .
1-72	18A4 `		 Any desired information for describing the input data,
73-80	2A4		Any desired information for card identification.
CARD 5-2,	Flux Groups		
NC	DTE: a) Omit t b) Supply c) This co the nu	his card if IN this card if Ind is require Ther of group	↓2≤0. 1N2≥1. d if the number of flux groups (NGMAX) is less than ∞ (NEMAX) used to run the problem.
1-72	2413	NTG(1)	Index of flux group corresponding to first source and cross section group = 1.





Column	Format	Symbol NTG(2)	Definition Index of flux group corresponding to the second source and cross section group.	<u>Column</u> 63-72	<u>Format</u> E9. 0	Symbol RSP(5, 1)	$\label{eq:constraint} \begin{array}{c} \underline{\text{Definition}} \\ Response function for the upper boundary of the 5th flux group (lower boundary of the 4th flux group). Continue on card 5-3' if more than 4 flux groups and NTP \geq 0. Leave blank if NTP< 0.$	
		• NTG(NEMAX)	Index of flux group corresponding to the last source and cross section group,= NGMAX.	73-80	2A4		Any desired information for card identification.	
73~80	2A4		Any desired information for card identification,	<u>CARD 3-3 , 1</u>	NOTE: S	upply this card han 4 flux group	immediately behind Card 5-3 if there are more p_{s} and if NTP ≥ 0 .	
CARD 5-3, K	NOTE:	a) Omit this car b) Supply this c	rd if IN3 \leq 0. ard for IN3 response functions if IN3 \geq 1.	1-72	8E9. Û	RSP(6, I)	Response function for the lower boundary of the 5th flux group (upper boundary of the 6th group).	
1-3	13	1	Index of the response function.		RSP	(NGMAX+1, I)	Response function for the lower boundary of the last flux aroup.	
4-6	13 NTP Response function type, 0, number two response input by flux group boundary with units (response/ particle cm ⁻² sec ⁻¹).	73-80	2A4		Any desired information for card identification,			
			 energy flux response input by flux group boundary with units (response/Mev cm⁻² sec⁻¹) 	CARD 5-4, D	etectors			
			<0, energy deposition response function for region l' = -NTP with units (Mev cm ⁻³ sec ⁻¹ /		NOTE: a) Omit this card if IN4 ≤ 0. b) Supply IN4 physical cards if IN4 ≥ 1.			
			particle an 2 sec ⁻¹). NTP <0 requires input of microscopic cross sections in Section 4 data for	1-3	13	1	index of the detector being described.	
			this problem. (Requires no other input after Column 27 of this card. The response function will appear on the printout immediately below the data on	4-6	13	IDR(I)	0, for point dector ≫, region index for a surface or volume detector.	
			this cord.)	7-9	13	IDS(I)	0 for a point detector.	
7-18	3A4		Any desired description of the response function used in labeling the output.				u for a volume detector. >0, surface index for a surface detector (the detector is that part of surface IDS(1) which	
19-27	E9. 0	FST	Response function scaling factor, this multiplica- tive factor can be used to convert the response units to more useful units. Do not use FST = 0.0.	10-18	E9.0	VOL(!)	bounds region IDK(1)). Not used for point detector, region volume (cm^3) for volume detector; detector area (cm^{2}) for sur-	
28-36	E9.0	0 RSP(1, 1)	Response function for upper boundary of the first flux group. Leave blank if NTP <0.				face detector (1.0 yields surface or volume inte- grated fluxes).	
		•						

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Column	Format	 Symbol 	Definition	Column	Format	Symbol	Definition			
19-27	E9. 0	CDT(1, I)	Relative direction cosine with respect to the $x - \alpha xis$ of the unit direction vector used in obtaining Legendre moments of the angular flux (not used for surface detectors, angular moments	1-72	2413	ISR(1)	Index of the first non-void region from which the individual scattered scalar flux contribution is required.			
		•	are obtained with respect to the surface normal).			•				
28-36	E9.0	CDT(2, I)	Relative direction cosine with respect to the			ISR(NSRMAX)	Index of the last non-void region from which the scattered flux contribution is required.			
37-45	E9.0	CDT(3, I)	Relative direction cosine with respect to the	73-80	2A4		Any desired information for card identification.			
			z – axis, the 3 direction cosines are normalized by the program.	9.7	9.7 SECTION 6 DATA; RANDOM SAMPLING PARAMETERS					
46-54	E9.0	XDT(1, I)	x coordinate if a point detector (cm).	CARD 6-0	, Input Cont	rols for Section 6	Date			
55-63	E9. 0	XDT(2, I)	y coordinate if a point detector (cm).		NOTE:	This card is alw	ays required.			
64-72	E9.0	XDT(3, I)	z coordinate if a point detector (cm).	1-3	13	INI .	Input control for Card 6-1 (descriptive cards) Omit Card 6-1 if IN1 < 0.			
73-80	2A4		Any desired information for card identification.				Supply, IN1 physical cards if $IN1 \ge 1$.			
CARD 5-5	, Flux Contribu	tion Sources		4-6	13	IN2	Input control for Card 6-2 (spherical source and detector).			
	NOTE: a) b)	Omit this card Supply this car	ÍF IN5 ≤ 0. rd if IN5 ≥ 1.				Omit Card 6-2 if $1N2 \leq 0$. Supply Card 6-2 if $1N2 \geq 1$.			
1-72	2413	IS∨(1)	Index of first source for which the individual scalar flux contribution is required,	7-9	13	IN3	Input cantrol for Card 6-3 (source importance). Omit Card 6-3 if $1N2 \leq 0$. Supply Card 6-3 if $1N2 \geq 1$			
		:								
		ISV(NVMOD)	Index of the last source for which the individual scalar flux contribution is required.	10-12	13	114	Input control for Card 6-4 (source variable importance). Omit Card 6-4 if IN4 ≤ 0. Supply Card 6-4 if IN4 ≥ 1.			
73-80	2A4		Any desired information for card identification.	13-15	13	; IN5	Input control for Card 6-5 (aroup importance).			
CARD 5-6,	Scattered Flux	by Scattering	Region .				Omit Card 6-5 if $1N5 \leq 0$. Supply Card 6-5 if $1N5 \geq 1$.			
	NOTE: a) · b)	Omit this car Supply this c	and if IN6 ≤ 0 and if IN6 ≥ 1	16-18	13	1116	Input control for Card 6-6 (linear buildup). Omit Card 6-6 if IN6 ≤ 0. Supply Card 6-6 if IN6 ≥ 1.			

Column	Format	Symbol	Definition	~ '	F	C	Definition	
19-21	13	IN7	Input control for Card 6–7 (heavy element scatter). Omit Card 6–7 if IN7 \leq 0. Supply Card 6–7 if IN7 \geq 1.	46-54	E9, 0	BDC(1)	x - coordinate of the center of the detector sphere (cm).	
22-24	13	IN8	Input control for Card 6-8 (hydrogen scatter). Omit Card 6-8 if IN8 ≤ 0,	55-63	E9.0	BDC(2)	y – coordinate of the center of the detector sphere (cm).	
			Supply Card 6-7 if IN7 \geq 1.	64-72	E9.0	BDC(3)	z - coordinate of the center of the detector	
25-27	13	IN9	Input control for Card 6-8 (scaling factors) Omit Card 6-9 if IN9 ≤ 0. Supply Card 6-9 if IN9 ≥ 1.	73-80	2A4		sphere (cm). Any desired information for card identification.	
28-72	1513		These columns are not used and should be left blank,	CARD 6-3, R	elative Sourc	e Importances		
73-80	2A4		Any desired information for card identification.		NOTE: a) b)	Omit this ca Supply this c	rd if $1N3 \leq 0$. ard if $1N3 \geq 1$.	
CARD 6-1, 1	Descriptive In	formation for S	Section 6 Data		c)	and more than one source is present.		
	NOTE; a) b)	Omit this ca Supply IN1 p	rd if $1N1 \leq 0$. shysical cards if $1N1 \geq 1$.	1-72	8E9. 0	R\$1(1)	Relative importance of fixed source number 1, (use intuitive knowledge or, better yet, a point	
1-72	I8A4		Any desired information for describing Section 6 data.				kernel calculation of fractional contributions from each source).	
73~80	2A4		Any desired information for card identification,			:		
CARD 6-2, 5	Spherical Pseu	do-Source and	d Detector			RSI(NVMAX)	Relative importance of the last fixed source (these importances are normalized in the program).	
	NOTE: a) . b)	Omit this co Supply this c	rd if $1N2 \leq 0$. ard if $1N2 \geq 1$.	73-80	2 A4		Any desired information for card identification.	
1-9	E9 0	RADIUS	Radius of a pseudo spherical source which encloses	CARD 6-4, S	iource Variab	le Sompling (p	preferred values)	
10-18	E9. 0	XCT(1)	x - coordinate of the center of the sphere (cm).		NOTE: a) b) c)	Omit this ca Supply this c The first thre	rd if IN4 \leq 0. card and Card 6-4' for all sources if IN4 \geq 1. se pieces of data on this card are required if	
19-27	E9, 0	XCT(2)	y - coordinate of the center of the sphere (cm).		,- d	MODELP = 0), pieces of data are required if MODELQ = 0.	
28-36	E9. 0	XCT(3)	z - coordinate of the center of the sphere (cm).	1-9	E9.0	VMD(1, 1)	Preferred value of the first source variable of the	
37-45	E9.0	DELTA	Radius of a pseudo spherical detector which covers the area in space where fluxes are being calculated; the center of this sphere is the "preferred point" for surface and volume flux calculations (not used if NPOINT = 1).				Ith source, must be in the range of the variable including the minimum and maximum values.	





<u>Column</u> 46-72 · · · 73-80	<u>Format</u> 3E9.0 2A4	Symbol	<u>Definition</u> These columns are not used and should be left blank. Any desired information for card identification.	CARD 6-5, Gro	note: a) NOTE: b)	Omit this car Supply this c	i if IN5 < 0. ard if IN5 ≥ 1.
CARD 6-4'.	Source Variabl	le Sampling (re	lative importance)	Column	Format	Symbol	Definition
	NQTE; a) b	Omit this car) Supply this c source if IN-	rd if 1114 ≤ 0. sard immediate∫y behind Card 6-4 for the same 4 > 1, i.e.	1-72	859.0	GIM(1)	Relative importance of particles in the first source and cross section group; e.g., an average flux-to- dose conversion factor for the first group.
		Card 6-4 Card 6-4' }	Source 1			GIM(NEMAX)	Relative importance of particles in the last source and cross section group; e.g., an average flux-to- dose conversion factor for the last group.
		Cara ó-4 }	Last Source	73-80	2A4		Any desired information for card identification.
	c) All numbers	on this card must be greater than 0,0,	CARD 6-6, Lin	war Building	Coefficients	
1-9	E9.0	ALP(1, 1)	Relative importance of the preferred value of the first source variable for the <u>lth</u> source, expressed		NOTE: 0) Omit this ca) Supply this c	rd if IN6 ≤ 0. card if IN6 <u>≥</u> 1.
			as a ratio to the importance of the value of the variable furthest away (either the minimum or maximum value of the variable).	1-72	8E9.0	AIM(1)	Linear buildup coefficient for group 1 used to estimate the importance of future collisions, this number, when multiplied by the mean free paths
			> 1.0, the preferred point is more important.				to a detector, is used to approximate the future
			0.0 < ALP(1, 1) < 1.0 the preferred point is less important.				scattered contributions.
			= 1.0, all points are equally important (this number must be > 0.0 since its logarithm is computed).				cross section group.
		•	• • •	73-80	2A4		Any desired information for card identification.
37-45	E9.0	ALP(5, I)	Relative importance of the preferred value of the fifth source variable of the <u>lth</u> source.	CARD 6-7, He	eavy Element	Scattering Imp	portance
46-72	3E9.0		These columns are not used and should be left blank.		NOTE: d	 Omit this co Supply this 	and if $1N7 \leq 0$. card if $1N7 \geq 0$.
73-80	2A4		Any desired information for card identification.			c) All numbers	on this card must be greater than U.U.
				1-72	869.0	ALM(1)	Ratio of forward-to-backward scattering importance for heavy elements for the first energy group. (See note below.)
						:	







	Column	Format	Symbol	Definition	CARD 6-9, So	mpling Parame	eter Scaling	Factors
	•	AL	M(NEMAX)	Similar ratio for the last energy group.		NOTE: a)	Omit this a	card if $ N ^{2} \leq 0$.
'	73-80	2A4		Any desired information for card identification.		5)	Supply Inc	
		NOTES: '	For neutrons, for photons,	a ratio of 10.0 for each group has worked well; the ratio	<u>Column</u> 1-9	Format E9.0	<u>Symbol</u> ATA	<u>Definition</u> Spherical pseudo source sampling, polar angle importance adjustment.
			$\frac{d\Sigma}{d\Omega}$ (0° scatt	er) x energy after scatter (0°)				1.0, all angles equally important,
			$\frac{d\Sigma}{d\Omega}$ (180° sc	atter) × energy after scatter (180°)				>1.0, shifts importance towards small angles, <1.0, shifts importance towards large angles, >1.0, shifts importance towards large angles,
			using the Kle has yielded a	sin-Nishina formula for an average group energy pood results.				(This number must be greater than 0.0.)
	CARD 6-8, Hyd	rogen Scatte	ring Importanc	<u></u>	10-18	E9.0	ATB	Spherical pseudo source sampling, azimuthal anglé important adjustment,
		NOTE: o) b) c)	Omit this car Supply this ca All numbers c	d if IN8 < 0. ard if IN8 ≥ 1. an this card must be greater than 0.0.				1.0, all angles equally important, >1.0, shifts importance towards 0°, <1.0, shifts importance away from 0°. This angle is measured in a rotated coordinate
	1-72	8E9.0	ALH(1)	Ratio of forward-to-backward scattering Importance for hydrogen for the first energy group. (See notes below,)				system and a little difficult to relate to the true coordinate system. The usual procedure is to use ATB = 1.0 (this number must be greater than 0.0).
		AL	.H(NEMAX)	Ratio of forward-to-backward scottering importance far hydrogen for the last energy group.	19-27	E9.0	ATC	Spherical pseudo-source sampling, spatial importance adjustment. 1.0, uses built-in estimate of spatial importance
	73-80	2A4		Any desired information for card identification.				>1.0, shifts importance to lower source energies (source points closer to the detector).
		NOTES:	For neutrons, there is no back scattering from hydrogen; large ratios, e.g., 10 ³ for each group have worked well. For photons, numbers identical to those on Card 6-7 have been used.					<1.0, shifts importance to higher source energies (source points further away), General use of numbers 0.7 <atc<1.3 good<br="" yield="">results.</atc<1.3>
			These numbers are applied only to the hydrogen density specified for the region, they are not applied to the hydrogen part, if any, of material compositions. Therefore, it is essential in neutron problems, that the hydrogen densities be specified by region to				(The program can be tricked for leakage-type surface and volume detector calculations by putting the preferred detector in the center of the source and using ATC \approx -1.0.)	
			property app ing from hydi	oxinare ine ungular aependence or neurron scotter-	28-36	E9.0	ATD	Flux contribution importance used in cutoff con- siderctions; if all contributions to all detector groups on 2 successive inner iterations of a given outer iteration are less than ATD times the flux already obtained in this outer iteration, then the

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inner iterations are terminated.

Column	Format	Symbol	Definition
37-45	E9.0	AT	Scaling factor for the spatial importance on the first leg of the scattering triangle 1.0 uses built- in parameters. .<1.0, shifts importance to higher energies >1.0, shifts importance to lower energies General use of numbers $0.6 < AT < 1.2$ yields good results (must be greater than 0.0).
46-54	E9.0	BT	Scaling factor for the spatial importance on the second leg of the scattering triangle; should approximate higher order scattering effects, so it is generally less than AT. If MODELU = 0, it must be less than AT in abso- tute magnitude, i.e., $ BT < AT$. Numbers on the order of 0.4 < BT < 0.9 yield good results. (If the trick mentioned in discussing ATC is used, it should also be used here; i.e., $-0.9 < BT < -0.4$.) This number cannot = 0.0.
55-63	E9.0	AS	Scaling factor for preferred direction (towards detector) importance 1.0 uses built-in parameter >1.0 forces even more <1.0 forces less, 0.0 yields no effect, (0.0 forces away and should be used when ATC and BT are <0.0.) Use of 1.0 yields good results for point detectors.
64-72	E9.0	85	Scaling factor for scattered direction importance 1.0, usbs group averaged parameter, >1.0 forces ven more <1.0, forces less, 0.0, no effect from scattered direction, Use of 1.0 yields good results.
73-80	2A4		Any desired information for card identification.



SECTION

10.0 SAMPLE PROBLEM

Numerical results obtained from the FASTER program for typical nuclear reactors are reported in References 17 and 18. The input data used in calculations for a large NERVAtype nuclear reactor are reproduced in the classified appendix, Reference 19.

Problem Description

A sample problem of moderate complexity is discussed below. Included in this discussion is a description of the printout obtained from running the FASTER program.

The sample problem involves the configuration used in a Lockheed study reported in Reference 20. Data taken directly from this study include: the geometrical model--shown in Figure 11, material compositions spatial source distributions; and the differential photon spectrum. The specific problem is a dose rate colculation at a point detector above a partially empty liquid hydrogen propellant tank. The problem was run for both photons and neutrons in a single computer run using the "change case" capability of the FASTER program. This problem was run for doub cuter iterations for both photons and neutrons and required less than 4 minutes on the CDC 6600 computer. '

Input Data

The complete printout for this problem is shown in Table 2. The data cards for the problems are not shown since they appear on the printout in almost the same form. The major difference is that the card identification from columns 73-80 appears on the left side of the printout. The card identification (if any) is normally followed by 3 periods (...) after which the data from columns 1 – 72 is printed. However, the printout for this problem has had the card number entered above the 3 periods to simplify the examination of data on particular cards.

The listing of the data cards for each section is preceded by a line indicating the appropriate input section. Section 1 data are first and the printout of input data continues





THE SAMPLE PROBLEM PRINTOUT IS PRESENTED ON PAGES 154 THROUGH 169



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TITLEB	13.						•••	MPT	PROPI	ELL	ANT	TANX	, RE	FERE	NCE E	8-6	536	(LOC	NHE B	50 51	0011		~~~~		
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11-51 4-4	1 7700E-01	1.88006-01	1.00005-01	2 14005-01	2 33005-01	3 41004-01	3	3.47045-01
11-51 4:4	2.8800E=01	4.42005-01	A. 7600E-01	5.15006-01	5 4500E-01	4.356 .5-01	7 000000000	S. 08008-01
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Pun 64+3	1 20105+01	6.00005+00	1 20005+00	1 70005+00	1.30000-000	110400004400	1,14302-40	100005-00
C ASECTER	2 86005=01	4-05005-01	A. 2400E-00	A 5300E-01	1.200000-00	5 3844E-41	4 44445-441	7 08005-01
C AVSECTA-V	7.82005+01	B- 84005-01	9.54005-01	1.03205+00	1 00005400	1.26705400	1 41005-00	1 40805+00
C	1 00005400	2.12005-00	2 44005400	2 09005+00	1.0000000000	3 37005-00	3 84005 400	1.000000000
	5 58475401	2.60005+00	1 10005-00	-0	3414002400	3.31002100	3.04002-00	4.3000E+00
EC-VERCTU-D	3 72005400	2 73005.00	2 74005400	3 74005-00		2.00002.000	3.00002-00	1420002+00
FF-YSECTH-U	3 60005+00	3.03005+00	A 1900E400	A A000EA00	4 95005+00	5 52005400	A 1400E400	3.340000000
FR-REFERRE	8 53045400	0.950000.000	1 38005401	3 17205-01	4.4500E-00	3.32001-00	3.710001-00	7.00002.00
PMR (12366-7	3 35045+03	9.20005401	2.00005=01	3.17202.01	2.03405.401	1.03302-02	3451005-05	1.33305.05
IL _VECTU-D	2.33042402	1 95405401	1 88405401	1 84945-41	-0.	1 16	***	TEGATION
L _verette	70705+01	1.01305-01	1.00405401	1.8.000000000	1.77102.001	1.10302-01	1,73702.01	1.10005.01
U VASECTUR	1.79202-01	1.705000001	1.40402-01	C+1000E+01	2.41002.01	2.99302-01	3.76002-01	3.3000E+01
o wallery	1.02302.02		SECTIONS OF	7573202702	1.14002-03	3.000000003	4.46305443	2.03032.04
*********		ARCREACED TA	TADIT SECT	NON B. DETEC.	UP 10590 AV	AILABLE LVCA	TIUNSCORPORT	
TUDNITE 65:0		1 0 1		104 31 06160	-0 -0 -0		-4 -0	
ADDUDE 122						-0 -0 -0		
DECODUCE.	1 1 1	DENANOUR	1 00005400	1 01005-05	~	2 100 4 - 0	10 10 11	1 11
BEROOMER S-3		3 38045-04	1.000002-00	1.07002-03	A.15005-00	1.10005-00	5.33006-06	2*81005=00
057567005-#	2.300000-00	-0.	1.57001-08	-0	3.71000-07	2.300000-07	2.01005-81	1 73440.03
VEIECI UNIT					1.00000000000	5+20005-05	-v.	1.12406403
			INDUT SECT	13 14 15	10 040467			
6-0		0 1 1			LING PARAMET	Chatter		
CONNENTAGE .	1 1 0			AMETERS	-0 -0 -0	-0 -0 -0	-0 -0 -0	-0 -0 -0
677	7 00005 401			A 45005-01	- 4		- •	
G0000-14605	1.100000-005	0.60000-04	8 40005-04	1 4000E-01			-0.	
GDOUR-THATS	2 50005-05	3.10005-06	2 80005-06	2 40005-06	0.00000000	34000E-06		
GROUP-THETS	3.50005-08	A- 80000 -07	2 40004 -07	1 30005-07	2.10000-00	1410002-06	1.40000-00	1400005-00
6.6	7.00005-01	2.00005-01	2.00006-01	2 00005-01	2.000000001	2 00005-07	1.0000000000	2
2.2	2 00005-01	2.00000-01	2 00005-01	2 000000000	2+000000-01	2.000000-01	2.000002-01	2.000002401
6-6	2.000000001	2.00005-01	2 00005-01	2.000000-01	2.00001-01	2 00001-01	2.000000001	C.0000E-01
SPATHDATLY 7	4 40000004001	2.50001+07	1 800000-01	1 000000000	2.000000001	2.0000E-01	2.000000-01	3 00000.03
5047-0474-7	**************************************	1 500000000	1 12005402	B 3000E+03	1.000000-03	1.0000E+02	SUGGE-02	2.0000E+05
3CA1-141997	C.00000E*02	1+34005+05	1.15005-05	0.2000E+01	0.0000E*01	uv00L+01	<. (000E+01	1+/000E+01

SCATHHATCEL	1.00001+01	0.00001000	4.00002-00	5 1000L-00	2.300000.000	2.0000E-00	1.10005-00	
SCAT-RAT6.	4-0000E+03	2.50002+03	1.8000E+03	1.4000E+03	1.00002+03	7.0000E+02	4.5000E+92	3.00002+02
SCAT-RATES	2.0000E+02	1.5000E+02	1.1200E+02	8.2000E+01	6.0000E-01	4.0000E*01	2.7000E+01	1.7000E+01
SCAT-RATES	1.00002+01	6.0000E+00	4.0000E+00	2.7000E+00	2.5000E+00	2.00002.00	1.7000E+00	
HATIOS 617	1,0000E+00	1.0000E+00	5.0000E-01	-1.0000E-03	7.0000E-01	5.0000E-01	0.	1.00002.00
***********		**********	ATA INPUT AN	D PREPARATIO	N COMPLETED*		***********	**********
+60+60+60+60	•60+60+60+60	+60+60+60+60	°60°00°60°60	*60*60*60*60	+G0+60+60+60	*60*60*60*60	+60+60+80*60	*60*60*60*

SAMPL	PROPEL	EN 1. PHOTON LANT TANK. P	N DOSE RATE A	AT POINT DETA 8236 (LOCKH	ECTOR ABOVE	PARTIALLY R NASA=HSFC1	SESSET AND JO	STER CODE	**CASE 1
		*********		ES FOR DETEN	108 1 AFT		********		
		CALCULATED	AVERAGE	NUMBER FLUX	ENERGY FLUX	NUNBER FLUX	ENERGY FLUX	NUMBER FLUX	ENERGY FLUX
		PRECISION	ENERGY-MEY	THIS GROUP	THIS GROUP	DERIVATIVE	DERIVATIVE	CUNULATIVE	CUMULATIVE
GROUP	1	0.	0,	٥.	0,	0.	٥.	0.	••
GROUP	2	7.03976-02	6.7364E+00	1.2661E+07	6,5291E+07	6.3307E+06	4.2046E.07	1+2661E+07	8.5291E+07
OROUP	3	1-2-216-01	4.70452400	6.4996E-07	3-0518E+08	3.2448E+07	1.5289E*08	7.765TE+07	1.9107E+08
GROUP		1.50246-01	3.12316-00	1.80405400	3.97722+00	B. 49538 +07	5.02125.08	2.0304E+UB	. ************
00000		2.00230-01	1 48205400	1 44555400	3.30032.00	2.12002.00	4.40040-00	. 3.04046400	1411000-009
GROUP	7	2.60057=01	9.66565-01	2.8191E+08	2.7194F+08	4.76525+08	6.0430F+08	7.93176+08	1.40795+09
GROUP	8	3.13365-01	5.5938E-01	5.5496E+0R	1.1043E+08	1.38745+09	7.76085+08	1.34816+09	1.91845+09
SROUP	9	3.30688-01	2.82895-01	1.60132.08	4-5300E+07	0.0065E+08	2.2650E+08	1.50828+09	1.96376+09
GROUP	10	6.0923E-01	1.1708E+01	1.1227E.09	1.3145E+08	9.3555E+09	1.09541.09	2.6309E+09	2.09518+09
GROUP	11	6.0018E+01	0.3239E-02	7.5916E+07	4.8008E+06	1,5183E+09	9.6017E+07	2.7068E+09	2.099995+09
******		***********	NUMBER FLUX	RESPONSES FC	A DETECTOR	1 AFTER	NOO PACKETSH	***********	
00000		REM/HOUR							
60002		0.00535403							
6POUP		3 497925+01							
GROUP		5-6571F+02							
GROUP	5	6.2991F+02							
6ROUP	6	3.80362+02							
GROUP	7	5.19418.02							
GROUP	8	6.2366E+02							
GROUP	9	8.8876E+01							
GROUP	10	2.29568+02							
GROUP	11	1.3865E+01							
TOTALS	******	3.44016+03							
MAY ED		9.8/630-02							
			ONINSES BUILD	MONENTS FOR	OF TECTOR			******	******
		TTERANT 1	REGION 1	REGION 2	REGION 3	SEGION A	REGION S	REGION 6	NEGTON T
GROUP	1	0.	٥.	0.	0.	0.	0.	0.	0.
GROUP	2	1.26618.07	8.09012.04	۰.	7.05861+03	0.	ò.	1.07656+05	4.2188E+05
GROUP	3	6+4996E+07	1.0890E+06	o.	1.32362+05	3.82692+05	0.	2.2475E+06	1.0407E+07
GROUP	A	1.2743E+08	3.1946E+06	0.	1.3947E+06	1.4615E+06	0.	8,92742+06	2.1597E+07
GROUP	5	1.5960E+08	1.8013E+06	0.	4.8757E+06	1.7619E+06	Q.	4.6404E+06	1.7124E+07
GROUP		1.4055E+08	7.4252E+05	0.	5.2407E+06	1.34492+06	0.	3.0568E+06	0.0527E+06
GROUP		2.81V3E+08	1.7002E+05	·	0.38522+06	3.40502+05	0.	1.5097E.06	1.05286+06
OHOUP		2+3440E+08	0+5011F+03	0 .	3*0A21E+60	Z.3049E+06	Q.	8,2937E+04	5.0YD0E+05

ELPTY	PAGPEL	LANT TANK.	EFERENCE ER-	8236 (LOCKHE	ED STUDY FOR	NASA-MSFC)	****T.#* JOF	DAN . WANL	APAGE 6
GROUP	9	1.60138*08	4.3394E+01	٥.	2.5557E+05	1.4762E+05	٥.	2.6323E+93	5.03106+93
GROUP	10	1.1227E+09	8.8622E-05	3.00882+55	8.8383E+03	7.1608E+03	0.	3.2657E-01	1.80B6E+00
GROUP	11	7.5916E+07	6.9577E+33	9.0566-150	5.0195E+03	7.9767E+05	ò.	4.1301E-11	8.0481E-11
R	EM/HOUR	3.4401E+03	2.9566E+01	6.1523E+62	5-2891E+01	2.1716E+01	0 .	8.0144E+01	2.36546+02
			.NUMBER FLUX	MOMENTS FOR	DETECTOR	1 AFTER 40	O PACKETSees		*********
		REGION 8	REGION 12	REGION 13	REGION 14	REGION 15	REGION 16	SCATTER 0	SCATTER 1
GROUP	1	0.	0.	0.	0,	0.	٥.	٥.	0.
GROUP	2	0.	0.	0.	Q.	2.1977E+05	6,6297E+05	1.1161E.07	1.5002E+06
GROUP	3	1.4729E+06	0.	0.	0,	4.1814E+06	7.4966E+06	3.7586E+07	2.36762+07
GROUP	4	9,3473E+06	0.	0.	D.	6.1216E+06	3,5461E+07	3.9924E+U7	6.6118L+07
BROUP	5	7.0088E*00	0.	1.4469E+05	0.	2+6314E+06	1.0826E+08	1.1348E+U7	7.9286E+07
GROUP	6	6.520RE+06	0.	6.7360E+06	٥.	2.15082+06	1.12342+08	2.36286+06	6.2395E+07
GROUP	7	3.05462+06	9+1398E+03	3.9501E+07	6.3105E+07	4,9943E+06	1.6150E+08	3.1205E+05	8.6505E+07
GROUP	8	4.5719E-05	8.53412+02	1.6128E+07	8.8349E+07	2717E+05	4,4273E+08	9.5295E+03	8.7282E+07
GROUP	9	1.5765E+04	1+6136E+03	1.3250E.07	3.3616E.07	3.02196+04	1.1281E+08	1.2035E+01	9,95428+05
GROUP	10	6.1644E+02	3.9678E+00	2.6209E+06	4.4848E+07	4.5514E+03	1.0752E.09	2.2818E-99	7.8979E+02
GROUP	11	9,1599E-02	2.1657E-02	5.7032E+01	1.4080E+06	3.7175E-01	7.4503E+07	0.1	0.
RE	H/ROUR	9,6652E-01	1.8694F-02	1.1675E+02	2.4363E+02	7,7941E+01	1,9497E+03	5.34572+02	1.13026+03
*****		*********	WUHBER FLUX	NUMENTS FOR	DETECTOR	1 AFTER 40	0 PACKETS+++	***********	*******
		SCATTER 5 2	SCATTER 3	SCATTER 4	SCATTER 5	SCATTER 6	SCATTER 7	ANGULAR 1	SPATIAL 1
GROUP	1	0.	Q.	0.	o.	٥.	0.	0.	0.
GROUP	2	0.	0.	o.	0.	0.	۰.	1.2504E*07	1.2367E+07
GBOAD	3	3,7332E+06	-0,	٥.	۰.	۰.	0.	6.4155E+07	6.3482E+07
GROUP	4	2,1388E+07	0.	0.	0.	۰.	۰.	1,2545E+08	1.5440E+08
GROUP	5	5.6404E 07	1.2561E+07	0.	٥.	٥.	0.	1,5761E+08	1.6027E+08
BROUP	6	3.83455407	3+5533F+02	1,12136+07	0.	٥.	٥.	1.4306E+98	1.4781E+08
GROUP	7	1.27865.08	3.39862.07	3+2193E+07	1.0838E+96	٥.	0.	2,5806E+90	3.05632+08
GROUP	8	1.30702.08	1.9135E+08	8.7381E+07	5.8241E+07	0.	0.	5,0989E+08	0+0829E+08
GROUP	9	8.0511E.06	2.9793E.07	6.0951£+07	5.1079E+07	9.16942+06	8,90851.04	1.4082E*V8	1.7970E+08
BROUP	10	1.9769E+07	2.4815E.07	2.6005E+07	3.4453E+07	1.0725E+08	1.4140£*08	9.7146E*08	1+3502E+09
GROUP	11	6,9574E433	6.4315E+02	1.6224E+04	2.1545E+05	4,9278E+05	2.0099E+07	7,2435E+07	9+6058E+07

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SAMPLE PRORLEM 1. PHOTON DOSE RATE AT POINT DETECTOR ABOVE PARTIALLY *****THE FASTER CODE*****CASE EMPTY PROPELLANT TANK. REFERENCE ER=8236 (LOCKMEED STUDY FOR NASA=#SFC) ****T.M.JORDAN,MANL******** ļ
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SAMPLE PROBLEM 1. PHOTON DOSE MATE AT POINT DETECTOR ABOVE PARTIALLY *****THE FASTER CODE*****CASE EMPly propellant tank. Reference ER=8236 (LOCKNEED STUDY FOR MASA=MSFC) *****T,M-JORDAN,WANL******************* 2

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SAMPLE PROBLEM 2. NEUTR Empty propellant tank.	ION DOSE RATE AT POINT Reference er+8236 (LO	DETECTOR ABOV	E PARTIALLY Or NASA-#SFCI	*****THE FE	STER CODE	eeocase 2 Peopage 2
L16+P100#+6 6.1810E-01	5.6190E-01 3.2930E 5.4800E-01 4.2560E	00 1.1360E+0	4.3010E-01 1 -2.4200E-01	-1,19602-01	4,29302-91	-1.6830E-01
LIG+P102 +1.4180E=01 LIG+P102 +1.4180E=01 LIG+P102 +5.3780E=01	-7.0700E-01 -3.1890E -7.0700E-02 -2.9330E -8.4150E-01 -7.7700E	01 +7.8220E+0	l o.	-2.3230E-01	+7,2880E-01	-2.37802-01
L16-P103.T. 0.	01.0790E	•01 0.	0.	+6.54D0E+02	۰.	۰.
RHO LITER 7.01608-00 LITEST 4.4 4.1700E-01	3.0000E+00 =0. 6.2950E+01 1.1620E 2.4110F+00 3.1150E	-0. 00 1.4270E+0	+0. 1.4210E+00	-0. 1.2290E-00	"0. 1.1850E+90	3.85002-01 1.1890E-00
L17-LD1 4.5 -2 4 0 L17-P0D04-6 0.6200E-01 L17-P0D04-6 4.9650E-01	-0 -0 -0 -0 -0 9.5670E-01 1.3550E 2.6720E-01 2.1850E	00 8,8360E-0	-0 -0 -0 6.4150E-01 1.0040E+00	-0 9.5710E+01	3.4340E-91	2.8870E-01
LIT-PODI-: 3.2540E+01	6.0440E=01 5.7990E	01 7.6050E=01 00 3.9840E=01	1.14905+00	3,38402-01	5.6900E=01	9.1590E+01
L17-POD2- 8.56008-02	7.4900E-03 2.0620E	01 4.2620E-01	i o. <u>.</u>	1.31702-01	3.9000E-01	2.5000E-02
LI7-P0D3 0.	0. 1.2400E-	02 0.	۰.	7,5500E-03	٥.	o.
LI7-P100 2.2400E-00	2.4380E+00 3.0300E	00 2.0960E-00	1.48405-00	9,8980E-01	7.4550E+01	6.1560E-01
LI7-P101. 4.6270E-01	3,9960E=01 2,8920E	01 5.7140E-01	-3.7310E-01	+1,4570E-01	2.8630E-01	-4.29002-91
L17+P101+++ -3-3720E+01 L17+P102+++ -1-3160E+01	-1.1200E+00 -1.3840E -2.0300E-02 -3,1320E	00 -2.0000E-01 01 -7.3810E-01	o.	-2.0850E-01	-6.0110E-01	-6.8000E-0Z
L17-P103. 0.	0, -3,1600E-	02 0.	۰.	-1.8300E-02	٥.	-0.
HD C4-2 1-2010E+01 ST C 4-4 0-9573E=01	4.000DE+00 1.3000E+ 9.3957E+01 1.3793E+ 3.3957E+01 1.3793E+	00 1.7000E+00 00 1.9536E+00	1.2000E+00	*0. 1.8946E*00	*0. 2.4107E+00	*0. 2,6626E+00
LDI+C 4+5 -2 3 3 \$5 C 4+6 5.7010E-01 55 C 4+6 2.7010E-01	12 5 11 +0 +0 4.8204E+01 9.7411E+ 1.5810F+00 2.8307F	-0 -0 -0 -0 01 8.21082-01 00 2.81965-00	+0 +0 +0 6.3918E+01	-0 1.5851E+00	1.20366+40	1.3299E+90
D1 C 3.1784E-01 D1 C 9.7611E-01	3.9527E+01 5.1330E+ 2.1491E+00 1.1557E	01 1.0514E.00 00 1.4172E.00	1.0206E+00	5.2091E-01	1.4747E-90	1.70052.00
D2 C 3.9040E-02 D2 C 5.6530E-02	0. 1.0868E-	01 1.4551E-01	0.	3.3419E=02	8.7174E-02	۰.
AS0 C 1.3672E.00	1.04948-00 1.48958	00 1.8481E+00	1.1781E+00	1.1128E+00	2,0312E+90	2.1942E+00
ANI C 4-4 4-9294E-02	-3.7204E-01 -4.4736E	01 =1.2681E+00	-1.1126E+00	-2.9932E-01	-7.4989E+01	-1.09892-00

RHO FE4-2	5.58478+01	2.6000E+01	1.1000E-01	-0.	-0.	2.00002-00	7.00001-90	1-50005-00
ST FF H.H	1.7609E+00	1.8463E+00	2.23692+00	2.09682+00	2.2055E+00	2.0395E+00	1.9117E+00	2.1432£+00
ST FF H-H	3.1222E+00	2.58402-00	2.7164E+00	3.7268E+00	6.5578E+00			
Intere w. c		13 12 11	10 9 8	7 =0 =0	-0 -0 -0	-0		
	1 00415400	2.23425400	2 39725+00	1.94055+00	1.00865400	1.97295+00	2-1071E+00	2.27576+00
23 FE 2	3 37425400	2.61785400	2 73605400	3.44506400	A.7542F+00			
35	3433422-00	7 04035-03	0 50575-03	1 84425-01	01005-01	7 17105-02	2 2935Fe01	2.82545-01
01 12.4	5.32000-02	1.20030-02	7.070/2-02	1.00422401	1.441345-01	1.11110-02		
D1 PE+4+	5+43046-01	3+53472-01	1	C*IBOILONI				1 81478-00
ADO PEIGO	2.03245.00	344113E-00	0071E-00	3.23742.000	2.30305-00	1+0>1500	2.17945.44	11310EC-40
ASO FE.	1.73432+00	1+1784E+00	0.3131E-01	0.98585-01	6.2845F-01			-7 67005-01
A51 FE-8.	2.9669E-02	3-56106-05	**,97201-02	-1-1010E-01	*1+7556E*91	+0*0010r+05	-5-06000-41	-2.5/005-01
ASI FER-6	-2.3173E-01	-2.9987E-01	-1.1980E-01	+2.1540E+01				
T 61 FE4+7	9.7803E-03	4-19742-02	2.1761E-01	1,6833E=01	1.8104E=01	4.4147E-01	8.9481E-V2	4.41252-02
T 61 FF4+7	7.4024E+02	1.95136-02	2.0594E-02	8.1905E+03	5.06702-03			
T 02 FE	1.6918E=02	1.7455E-01	1.5576E=01	1.8152E-01	4.8606E=01	1,0593E=01	7,7610E+92	9.1646E+02
T 02 FF.	2.4610F-02	2.6250F+02	1.0549E+02	6.5790E=03				
T 03 FF.1.	8.7458F+02	1.4874E=01	1.8457E-01	5.3999E=01	1.2549E+01	9.38296-02	1.13148+01	3.0911E-02
T 03 FF	3. 33035-02	1.3512F=02	8.4920E=03					
T 64 FF.	0.	2-4084F=01	3.2113E+01	5-5709F-02	4.5313F#02	1.41778-01	4.4860E-02	7.4787E=02'
	3. 304 35-03	3.44925-02						
	3117030-02	8.14555-01	•	A 18335-03	3 54845-47	7.15485-01	6.3636Fe03	7.07685-03
1 05 75.44	0.07078-03	AN1422E-01	**	0030316-03	CODUCT-OF	101000-00		
1 05 15 9	9.01020-03					4 38005-03	<u>.</u> .	S OBDOT-OA
1 00 PE.1.	1411545-01	D*8203E=05		1.80125-01	4.00/0E-V2	0.3099E-02		3743405468
1 07 FE	0.				0.42435-03	A"20AIL-OX	0.1343E-AK	- 4
RHO U2354-3	2.3204E+05	9.2000Z+01	5.0000E+01	-0,	-0.	-0.	-0.	••••
ST U5 4+#	2.5055E+00	3.04925.00	*.1328E.00	4.7243E+00	5,16262+00	5.15298+00	5.12716-00	2*55A4E+00 .
ST. US 4+4	5.9259E+00	7.0168E+Q0	8,0903E+00	9.7811E+00	1.45592+01			
LD1=U5 4-5	-2 2 13	13 12 11	10 9 8	765	4 3 2	1		
\$\$ U54-2	2.93652+00	.3+7367E+00	5,2109E+00	4.9526E+00	4.3373E+00	3.6614E+00	3,8616E+00	4.1047E+00
55 U54-4	4.9039E+00	'5.8900E+00	7.0164E+00	6.4298E+00	1.0221E+01			
D1 U54 - 4	1.3391E-02	1.3309E=02	2,3410E-02	4.7280E-02	6.2644E+02	3.2946E-02	8.8340E+92	9.5222E-02
D1 U54-4	6-76555-02	1.59892-01	9.6470E-02	1.41145-01				

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EMPTY	PROPEL	EM 2º NEUTR Lant Tank.	ON DOSE RATE Reference er	AT POINT OF	TECTOR ABOVE EED STUDY FO	PARTIALLY R NASA-MSFC1	T.R.JO	STER CODE+4+++	PASE 2
******		***********	FLU	XES FOR DETR		ER 400 PAC	ETS#########	**********	*********
		CALCULATED	AVERAGE	NUMBER FLUX	ENERGY FLUX	NUMBER FLUX	ENFROY FLUX	NUMBER FLUX F	NEDGY ELLIN
		PRECISION	ENERGY-KEV	THIS GROUP	THIS GROUP	DERIVATIVE.	DERIVATIVE	CUMULATIVE	CUBUL ATTYF
GROUP	ه و مذ	1.2053E-01	8.61852+00	2.1542E+06	1.8566E+07	9.73865+05	8.3937E+06	2.1942E+96	1.45665.07
GROUP	2	4.2116E-01	6.9695E+00	9.37316+06	6.5326E+07	5.44008+06	3.7914E+07	1.1527E+07	8. 38916407
690UP	3	3.85126-01	4.7162E+00	4.0302E-97	1.90076+08	1.6891E+07	7.96606+07	5.1829E+07	2.73945.08
GROUP	4	3.8927E-01	3.2740E+00	2.0397E+07	6.6780E+07	2.5057E+07	8.2039E+07	7.2226E+\$7	3.40745+08
38006		5.4402E-01	2.5479E+00	3,9871E+07	1.0159E+08	6.2888E+07	1.6023E+08	1.1210E+98	4.42335+08
3ROUP	6	6.13076-01	1.4163E+00	3.6454E+08	5.1630E+08	3.0972E+08	4,3866E+08	4.7464E+98	9.5863E+08
BROUP	7	5.8004E=01	9.3843E+01	3.9628E+07	3.71882+07	1.7008E+08	1.59616*08	5.1624E+08	9.95816+08
39006	8	6+1600E-01	7.0991E-01	7.9277E+07	5.6279E+07	4.35592+08	3.0923E+08	5.9554E+08	1.0521E+09
JROUP	9	6+0213E=01	5.28256-01	8.3204E+07	4,3953E+07	3.3149E+08	1.75115.08	6.7875E+98	1.096DE-09
JROUP	10	8.3453E=01	3.7470E-01	8.2904E+07	3,1004E+07	9.64002+08	3.6121E+08	7.4265E+08	1.12716+09
ROUP	11	5+6267E*01	2.4982E-01	2.8943E-07	7,2303E+06	2.43216+08	6.0759E+07	7.9059E+08	1.1343E+09
ноон	15	6.0460E-01	1.6553E-01	1.72526-07	2.05576+06	2.39616+08	3,9662E+07	8.0784E+08	1.1372E+09
1HOUH	13	9.1825E-01	6.1254E-02	8.0437E+07	4,9271E+06	7.96402+08	4.8783E407	8.8828E+98	1.14216+09
	*****	*********	NUMBER FLUX	RESPONSES PO	R DETECTOR	1 AFTER 4	OO PACKETS-		*********
	. '	ADITISTAN	RADIETH) /HR	REM/HOUR					
RUUP	1	3.0//52-01	3.8103E+01	5.41135.05					
NOUP	2	1.02046-02	2.35265+02	1.04232.03					
POUP	3	0.31395.02	0.42106.02	4.38062-03					
ROUP	2	2.93886.02	4.1310E+02	2.09141-03					
PAUP	2	3 43805407	4 44915407	3,10116+03					
		3. 33305+03	4 00710-03	3.35702-04					
BOUB		3013202-02	7 44395 402	3.25202-03					
		A. 30186402	A 00105402	5443102-V3					
DOUD		4.15736402	5 03985402	A 30775+03					
ROUP	11	1.08165402	1-57716+02	1 06805403					
ROUP	12	S.ARROFen1	8.03995.01	E 1000Fe03					
ROUP		1-02057+02	1-46995+02	8.8710F+03					
OTALS.		7-0624F+03	9.80505+03	5-53AUF+0A					
IN ERF	08	3-1490F=01	3-09516-01	3.29715+01					
AX EAF	108	5-8551F-01	5-85576-01	5.97776+01					
		*********	NURBER FLUX	NONENTS FOR	OFTECTOR	-			********
		ITERANT 1	REGION 1	REGION 2	REGION 1	REGION .	REGION &		PERTAN T
ROUP	1	2-1542E+06	1.07016+05	0.	6.7903E+04	1.42935404	8-03045+01	3.44305+04 1	A A A A A A A A A
ROUP	2	9.37312+06	2.3580E+05	ō.	3.12416+05	6.6207F+04	6-1688E402	A. 17ARFaŭa	25485405
ROUP	1	A. 6302Fe07	1.08825+05				10000000		
				~ ~	1.000112900	1.9457/00		2.71767806 4	

SAMPLE Empty	PROPEL	EM 2, NEUTR Lant Tank.	REFERENCE ER-	AT POINT DET 8236 (LOCKHE	ECTOR ABOVE ED STUDY FO	PARTIALLY R NASA-MSFCI	SOUTHE FA	STER CODE	POPAGE 2
GROUP	5	3.98712.07	5.6543E+03	٥.	8.1361E+05	7.4130E+04	1.78726+02	2.1450E+03	3.84182+04
GROUP	6	3.6454E+08	6+3833F+02	0.	7.4154E+05	7.8036E+04	1,3412E+02	3.7668E+02	1.34995+04
GROUP	7	3.9628E+01	3.7502E+00	0 .	3.5543E+04	2.6047E+03	2.00462+01	2.51472+90	3.5218F+02
GROUP	8	7.9277E+01	1.5312E-01	0	9.7181E+03	1.6618E+03	4.1581E+01	1.0079E-01	7.6659E+01
GROUP	9	8.32046+07	4+5115E-04	0.	1.0214E+03	1.9553E+02	1.35928-04	1.9996E-03	1.0399E+01
GROUP	10	8-2904E+07	14+0476F-07	6 .	4.7798E+01	9.3432E400	8.21445-02	1.8024E-05	8.0674E-01
GROUP	11+++	2.8943E+01	5.2645E-10	ō.	3.02062.00	5.7751E-01	1.2243E+02	4.7245E-07	1.96246+02
GROUP	12	1.72522.07	3+1628E=14	0.	7.47032-03	3.3980E+03	1.5861E-05	9.1404E+10	8.8571E-06
GROUP	13	8-0437E+07	1.9565E-27	0.	5.7399E-09	6.9630E-09	3.4901E=11	9.40358-16	5-94956-12
RADIT	15)/HR	7.052+E+03	8.0679E+00	0.	6.1521E+01	7.0189E+00	4.5378E-02	1.8580E+00	2.34872.01
RADIE	TH)/HR	9.8050E+03	1.1645L+01	0.	8.59802+01	9.89442+00	6.3380E-02	2.7294E+00	3.3706E+01
RE	RIGHYM	6.5349E+04	-5+2564E+01	0 .	4.4902E+02	5.0412E+01	3.0959E+01	1.2337E+01	1.54545+02
******			NUNBER FLUX	NONENTS FOR	DETECTOR	1 AFTER 40	O PACKETSee		
		REGION 8	, REGION 12	REGION 13	REGION 14	REGION 15	SCATTER 0	SCATTER 1	SCATTER 2
GROUP	1	1.83816+04	*++7857E+03	1.48492+03	8.0035E+04	6.0340E+05	8.8750E+05	7.3522E+05	3.0527E+05
GROUP	2	2.5377E+04	+5+1326E+03	4.01918+04	1.1077E+06	6.3956E+06	6,1623E+05	4.49502+96	1.5856E+06
GROUP	3	2.8657E+04	3+6268E+03	1.1052E+06	1.21896+07	2.4489E+07	1.1771E+05	1.0966E+07	8.5107E+06
GROUP	4	9.68212+03	.6.3598E+02	1.6573E+06	1.1542E+07	6.2324E+06	1.0200E+04	1.28892+05	1.7964E+06
BROUP	5	7,3100E+03	3.54846.402	4,2268E+06	3.1102E+07	3.5980E+06	2.50051+03	2.6451E+05	1.9476E+06
9UOR0	6	3.94092+03	9.8509E+01	3,0643E+07	1.2204E+08	2.11022.08	1,8643E+02	7,99072+05	3,3742E+06
ROUP	7	1.0734E+02	1.9387E+00	8.6751E+06	2.9411E+07	1.5037E+06	6.1613E-01	3.9155E+04	3.9441E+05
UDDRE	8	2.6538E+01	13.2700E-01	1.0141E+07	2.4345E+07	4.4781E+07	2.0950E-02	2.95792+04	3.09626+05
GROUP	9	3.6849E+00	3.48836-02	1.2925E+07	2,3291E+07	4.6986E+07	5.9251E+05	3,4275E+04	4,3087E+05
3ROUP	10+++	9.4981E+02	+5+3207E=04	6.5236E+06	5.9865E+06	7.03928+07	4.4951E-08	9.4463E+03	1.2820E+05
GROUP	11	4-25012-03	*2.6677E-05	6.3433E+06	6.2469E+06	1.6352E+07	6.0304E-11	1.0569E+04	1.64572+05
GROUP	12	1.0756E-05	5-4496E-08	3.5215E+06	3.1613E+06	1.0569E+07	3.7495E-15	4.2042E+03	6.8539E+04
GROUP	13	7.43046-12	3-0346E-14	2.0265E+06	7.58352+07	2.5753E+06	2.18522-28	2.6535E+V3	5.3467E+04
RADIT	15)/HR	1.50016+00	2.5096E-01	6,6248E+02	2.5970E+03	3+6704E+03	2.8716E+01	2.0214E+02	2.6128E+02
RADIE	TH)/KA	2.1448E.00	- 3+6285E=01	9.2217E+02	3.6095E+03	5.0844E+03	4,2290E+01	3.9418E+02	3.6337E+02
RE	RUOH/N	1.0110E.01	.1.6440E+00	6.3853E+03	2.36932+04	3.4355E+04	1.84682+02	1.8960E+03	1.90945+03
	******	*********	<i>APNUMBER FLUX</i>	HOMENTS FOR	DETECTOR	1 AFTER 40	O PACKETSees	***********	*********
		SCATTER 3	SCATTER 4	SCATTER 5	SCATTER 6	SCATTER 7	SCATTER B	ANGULAR 1	SPATIAL 1
GROUP	1	1.4198E+05	-38.1786E+0A	2.1542E+03	2.5837E+02	1.9107E+01	6.9572E+00	2.1106E+05	2.1267E+06
GROUP	2	1.5214E+06	1.08525+06	3.49132+04	2.0711E+04	3.8854E+03	2.1031E+03	60+3020E+08	9.6004E+06
GROUP	3	9.8302E+06	- 3.7396E+06	1.7153E+06	3.2232E+06	4.6816E+05	1.6814E.06	3.7189E+07	4.3244E+07
BROUP	4	6.4712E.06	1.9331E+06	2.+163E+06	5.32196.06	1.4742E+06	5.0798E+04	1.7676E+97	2.3111E+07
BROUP	5	1.7303E+07	2+2566E+06	8.1941E+05	1-5129E+07	8.6028E+05	2.85326+05	3.3925E+07	4.6546E+07
BROUP	6	5.4909E+07	- 6-5222E+06	2.09242+06	8.3846E+07	5.4673E+06	9.74776+05	3.38446+08	4.1287E+08
GROUP	7	9.6559E+06	,1.3693E+06	4.4096E+05	2.5308E+07	1.7603E+05	1.90396-05	3.4648E+07	4.6638E+07
BOUP		6-36695+06	- 9-8255F+05	2.9981F+05	2.3610F+07	2.10185404	2.50735+08	7 43806407	8.90807+07

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SAMPLE PROBLEM 2. NEUTR EMPTY PROPELLANT TANK.	ON DOSE RATE AT POINT (Reference er-8236 (Loci	DETECTOR ABOVE PARTIALLY CHEED STUDY FOR WASA-MSFC	*****THE FASTER CODE***	**CASE 2 **PAGE 8	(ई)
GROUP 96.1157E*06 GROUP 101.7787E*06 GROUP 112.3623E*06 GROUP 127.0017E*05 GROUP 125.8481E*05 RAD(115)/HR 1.822E*03 RAD(ETH)/HR 1.6421E*03 RAD(ETH)/HR 1.6421E*03 REMOUR 1.032E*04	1.1127E+06 5.2258E+ 3.1580E+05 1.3075E+ 4.0064E+05 1.3888E+ 9.5088E+05 1.3888E+ 5.7373E+07 7.9705E+ 3.0003E+02 1.5776E+ 4.2143E+02 1.5776E+ 2.4640E+03 8.4632E+	05 2,1237E+07 2,7156E+0 05 6+883E+06 7,5750E+0 05 4,1991E+06 1,1307E+0 05 1,4309E+06 2,9012E+0 05 5,4150+06 5,1729E+0 02 1,4504E+03 2,0926E+0 02 1,4574E+04 1,3835E+0	5 3.9784E+05 7.8164E+07 5 1.1898E+05 8.0415E+07 5 5.4586E+05 2.7280E+07 5 5.9487E+06 1.6650E+07 2 2.0903E+05 6.9984E+07 2 4.9203E+01 6.51195+03 6 6.7997E+01 9.0401E+03 3 3.915E+02 6.03355E+04	9.4681E+07 9.1955E+07 3.2738E+07 1.9414E+07 9.9830E+07 7.9730E+03 1.1049E+04 7.3913E+04	Astronuclear Laboratory

EMPTY P	ROPEL	Eñ,	ίt τά	NK.	REF	RENC	E EA	82	36 11	OCKH	ĔĎ	STU	DY F	RNA	SA-HS	rc,	++++++, H. JORDAN, WANL ########	ie i
******				***8	OUN	ARY	SEAR	ж	PARAM	ETER	5.	(នបន	FACE	HOST	PROS	AULI	NEXT REGION)	
REGION	ĩ	1	-3.	2)	۰.		41	ſ	16.	3)								
REGTON	;	-i	-2.	9)	ï	3.	0)	Ē	16.	31								
REATON	- 1	i	-2.	- 91	ċ			ċ	-16.	- 11	. (17	. 10					
REGION	ĭ	i	-4.	- 11	i	5.	5)	i	17.	101								
REGION		i		- 41	i	6.	6)	ė	17.	101								
SFOTON	1	÷	-6-	- 53	i	7.	71	i	17.	101								
REGTON	ž	- 1	-7.	67	i		aí.	ī	17.	101								
REGTON		÷	-8.	75	i	9.	111	- 6	17.	101								
REGION	ä	- 2	-1-	31)	i	2.	01	i	20.	315								
REGION	10	- i	-17.	7)	i	20.	31)	i	•2.	. 95		9	. 11					
REGION	11	i	-9.	101	i	10.	12)	ċ	20.	315								
REGION	12	÷	.10.	111	- 4	11.	15)	i	-21.	01			•					
BEGTON	- 13	i	-10.	60	i	18.	14)	i	21.	161		-22	. 18					
REGION	14	÷	14.	03	i	-18.	17)	i	19.	191	i	-22	. 0		-10.	01		
REGTON	16	- i	-11.	121	i	12.	161	- i	-21.	.131					• · · ·			
REGION	14	- 7	-12.	155	i	13.	171	i	18.	141	- 1	->1	• 13					
REGION	17	i	-13.	16)	i	14.	201	ī	18.	141								
REGION	- 16	- 7	-10.	in	i	19,	191	ċ	22.	135								
REGION	10	i	.19.	- 61	i	20.	313	i	-10.	111		14	. 20					
REATON	26	- 7	-14.		i	15.	311	ċ	20.	311		•						

by section, and terminates at page 4 of case 1 (upper right hand corner of the printout). Every page after the first has the title cords printed at the top of the page.

Flux Output

The next page, (5), of the printout starts the output of the computed fluxes by detector and energy group. The various calculated flux components are separated by lines comtaining asterisks.

The first set of output, lobeled: ** FLUXES FOR DETECTOR XXX AFTER XXX PACKETS **, is always printed first. (The term packet is just another way of describing an outer iteration; i.e., each energy dependent angular point source can be visualized as a packet of particles of different energies.) Each of the columns contains groupwise information as indicated on the left side of the printout. Note: there are less flux groups than were used in running the problem; i.e., 23 groups were collapsed to 11, as shown on Card 5-2. The first column is the coefficient of variation of the scalar flux, expressed as a fraction. The second column is the average energy in Mev. The third column is the number flux in particles/ cm² sec unless the input data were juggled; e.g., using unit areas and volumes for surface and volume detectors. The fourth column contains the energy flux in Mev/cm² sec. The fifth and sixth columns contain the group averaged differential number and energy fluxs, i.e., columns 3 and 4, respectively, divided by the group width. The last two columns are running summations of the fluxes and give the total flux from particles with energies greater than the lower boundary of the group.

The next set of output is labeled ** NUMBER FLUX RESPONSES FOR DETECTOR XXX AFTER XXX PACKETS **. Only one response function was input and its title (entered on Card 5-3) appears over the first column. The response by group is then printed. The last three lines in this column are the total response, the coefficient of variation as if the groupwise responses were obtained independently (labeled MIN ERROR), and the coefficient of variation as if the group wise responses were strictly dependent (labeled MAX ERROR).

This set of response function output would be omitted if no response functions were input. It would be repeated, until all response functions were output, for problems with more than 8 input responses.



- a) total flux by source, labeled SOURCE XXX (not used in this problem since only 1 source was present)
- b) total scattered flux by scattering region, labeled REGION XXX (obtained in this problem for every non-void region)
- c) total flux by order-of-scatter, labeled SCATTER XXX (obtained through the 7th scatter for this problem)
- d) Legendre moments of the angular flux, labeled ANGULAR XXX (the current was obtained for this problem)
- e) length-of-flight moments of the flux, labeled SPATIAL XXX (first moment obtained for this problem)

After printing the contribution by group, each column contains the total contribution to each of the response functions, if any.

The final page of printaut for a problem (page 7 of this printaut) is sometimes helpful in correcting geometric errors. It contains a listing, by region, of the bounding surfaces (with the sign of the ambiguity index affixed) and the region entered the last time a ray crossed these boundaries (most-probable-next-region). Most-probable-next-region indices graater than the total number of regions (greater than 20 for this problem) indicate that there was no next region and should correspond to the outer boundaries of the problem. A zero indicates the boundary was never crossed.

The remainder of this printout, labeled CASE 2, is the neutron problem which was run as a change case immediately behind the first case. Most of the input changes involve





the multigroup scattering cross sections. The flux printout (starting on page 6 of case 2) is interpreted in exactly the some manner as case 1.

The results contained in this printout are summarized in Table 3 along with appropriote results from Reference 20. Since the FASTER calculation was intended as a sample problem, comments on the relative accuracy and computer time requirements of the various calculations are not made.

TABLE 3

SUMMARY OF SAMPLE PROBLEM RESULTS

	FASTER Monte Carlo	18-0 [*] Monte Carlo	Point Kernel
Photons (rad/hr)	$3.4 \times 10^3 \pm 0.34 \times 10^3$	\sim 6, 7 × 10 ³ ± 3.0 × 10 ³	~3.0×10 ³
Neutrons (rad/h r)	$7.1 \times 10^3 \pm 2.7 \times 10^3$	$\sim 2.4 \times 10^4 \pm 1.5 \times 10^4$	~2.0 x 10 ² (14-0, A.W.) ~5.0 x 10 ² (QAD, H ₂ O) ~6.6 x 10 ² (QAD, C)

*Reference 20, Figures 30 and 55

SECTION

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APPENDIX A ALTERNATE MONTE CARLO PROCEDURES

Section 2.0 of this volume pertained to a development of the Monte Carlo method which utilized random sampling for all of the spatial integrations. This method is used in the FASTER program. It is not necessarily the most efficient procedure since there are many alternatives. An alternate technique for integrating the spatial dependence of the distributed fixed source is discussed below. The discussion is limited to 1) a technique which further reduces the integrations performed by random sampling and, 2) the consideration of a single point detector.

Alternate Uncollided Angular Flux Estimator

Equation for the uncollided scalar flux can be manipulated as-

$$\phi_{0}(\vec{r}, E) = \iint_{4\pi} \left\{ \frac{\phi_{0}(\vec{r}, \hat{\Omega}, E)}{q(\hat{\Omega})} \right\} q^{*}(\hat{\Omega}) d\Omega \qquad (A.1)$$

$$\approx \frac{1}{n} \sum_{i=1}^{n} \phi_{0}^{*}(\vec{i},\vec{\Omega}_{i},E)$$
(A.2)

where
$$\phi_{\phi}^{*}(\vec{r}, \hat{\vec{n}}_{1}, E) = \frac{1}{q(\hat{\vec{n}}_{1})} \phi_{\phi}(\vec{r}, \hat{\vec{n}}_{1}, E)$$
 (A.3)

$$\frac{1}{\Omega_1}$$
 selected at random from q^{*} ($\hat{\Omega}$) (A, 4)

$$\begin{array}{l} q^{*}(\vec{\Omega}) \geq 0 \\ q^{*}(\vec{\Omega}) > 0 \quad \text{if} \quad \int_{0}^{\sigma} \phi_{0}(\vec{r}, \vec{\Omega}, E) dE > 0 \\ \iint_{4\pi} q^{*}(\vec{\Omega}) d\vec{n} = 1 \end{array} \right)$$

$$(A.5)$$

Thus the angular flux is approximated for finite n by:

$$\phi_{0}^{*}\left(\widehat{r},\widehat{\Omega},E\right) = \frac{1}{n}\sum_{i=1}^{n} \phi_{0}^{*}\left(\widehat{r},\widehat{\Omega}_{i},E\right) \delta\left(\widehat{\Omega}-\widehat{\Omega}_{i}\right) \qquad (A,\delta)$$

But $\phi_0^*(\vec{r},\vec{\Omega}_1,E)$ is given by a simple line integral, i.e., equation 2.2:

$$\phi_{0}^{*}(\vec{r},\vec{n}_{1},E) = \frac{1}{q(\vec{n}_{1})} \int_{0}^{\infty} \int_{0}^{\infty} (\vec{r} - s \vec{n}_{1},\vec{n}_{1},E) \exp\left[-\int_{0}^{s} \Sigma^{\dagger}(r - s^{\dagger}\vec{n}_{1},E) ds^{\dagger}\right] ds$$
(A.7)

This integration can be performed numerically with extreme accuracy for non-void source regions with slowly varying source distributions by using the transformation:

$$\dot{d}_{U} = \exp \left[-\int_{0}^{5} \Sigma^{\dagger} \left(\hat{\vec{r}} - s^{\dagger} \hat{\vec{\Omega}}_{\gamma} \vec{E} \right) ds^{\dagger} \right] ds \qquad (A, 8)$$

i.e., the discrete values of s corresponding to discrete values of u will be exponentially distributed with approximately equal contributions to the integration. Note: the transformation is performed for some average energy \tilde{E} thus yielding the same "source" points for all energies. Solving A.8 for ds and substituting into A.7 gives the transformed equation:

$$\phi^{*}_{0}(\vec{r},\vec{\Omega}_{1},E) = \frac{1}{q(\vec{\Omega}_{1})} \int_{U} S_{0}(\vec{r}-s(u)\vec{\Omega}_{1},\vec{\Omega}_{1},E) \exp\left[\Delta \int_{0}^{s(u)} \Sigma^{\dagger}(\vec{r}-s'\vec{\Omega}_{1},\vec{E}) - \Sigma^{\dagger}(\vec{r}-s'\vec{\Omega}_{1},\vec{E}) \right] ds' \right] du$$

$$(A, 9)$$

where s(u) is the solution for s of

$$u = \int_{0}^{s(u)} \exp \left[- \int_{0}^{s} \Sigma^{\dagger} \left(\overline{r} - s^{t} \widehat{\Omega}_{t}, \overline{E} \right) ds^{t} \right] ds \qquad (A. 10)$$

This procedure can also be generalized to include the effects of the source distribution in the transformation. All of these considerations have been incorporated into the sampling function described in Section 8.3, which approximates equation 2.36. The only difference is: random



discrete values of s (or u) are obtained for performing the numerical integration.

Another procedure for computing the uncollided angular flux, is to perform all integrations numerically. When an angular integration is included in a rotated spherical coordinate system centered at the detector paint, smaller computer times are expended than on most point kernel calculations. This is a result of the many "point sources" having the same "line-of-sight" to the detector; i.e., the geometric calculations are significantly reduced.

Alternate Single Scattered Flux Estimator

The use of the above technique does not yield a single point source which can be used to calculate the point representation of the scattered source at the first scattering point. However, the same technique can be applied at the first scattering point. The procedure, again, is to write the equation for the single scattered scalar flux. (This formalism isn't really necessary but it provides a convenient and consistent basis for the application of random sampling techniques. It is useful in inferring the form of optional sampling functions.)

$$\phi_{1}(\vec{r},E) = \iiint \left\{ \frac{ \sum_{i} \left[\vec{r}_{i}, \vec{n}, E \right] \exp \left[- \sum_{i}^{\infty} \sum_{i}^{t} \left(\vec{r}_{i} - s^{i} \vec{n}, E \right) ds^{i} \right] }{ p_{1}(\vec{r}^{i}) s^{2}} \right\} p_{1}^{*}(\vec{r}^{i}) dV \qquad (A.11)^{2}$$

which yields a point, single-scattered source

$$W_{1}^{s}(\widehat{\Omega}, E) = \frac{1}{p_{1}(\widehat{r}_{1})} - S_{1}(\widehat{r}_{1}, \widehat{\Omega}, E)$$
 (A.12)

where \vec{r}_1 is selected at random from $p_1^*(\vec{r})$ as shown in Section 2.4.

In Section 2, 4 it was assumed that there was an energy dependent angular point source, $W_q(\hat{\Omega}, E)$, at $\hat{\tau}_q$ which finally yielded $W_1^s(\hat{\Omega}, E)$. The point source $W_q(\hat{\Omega}, E)$ con be obtained at this point in the calculation although another technique is used for the uncollidea rlux. Nevertheless, other techniques can also be used. In particular, the technique discussed for the uncollided scalar flux can also be used for the single scattered source.

$$W_{1}^{\dagger}(\widehat{\overline{\Omega}}, E) = \frac{1}{p_{1}(\widehat{\Gamma}_{1})} \iint_{4\pi} \left\{ \frac{\int_{0}^{\infty} \phi_{0}(\widehat{\Gamma}_{1}, \widehat{\overline{\Omega}}', E) \frac{d^{2}\Sigma^{5}}{d\Omega dE}(\widehat{\Gamma}_{1}; \widehat{\overline{\Omega}}', E' + \widehat{\overline{\Omega}}, E) dE'}{q^{\dagger}(\widehat{\Omega}')} \right\} q^{\dagger}(\widehat{\overline{\Omega}}') d\Omega' \qquad (A.13)$$

$$= \frac{1}{\rho_1(\tilde{r}_1)} \frac{1}{q^*(\tilde{n}_1)} \int_0^{\infty} \phi_0(\tilde{r}_1, \tilde{n}_1, E^i) \frac{d^2 z^5}{d\Omega dE} (\tilde{r}_1, \tilde{n}_1, E^i \rightarrow \tilde{n}, E) dE^i$$
(A.14)

where the equality holds in the sense of the expected value. Multiple scattered flux contributions can be obtained using the remainder of the techniques described in Section 2.4.

There is an implicit assumption in the concept of using a line integral along a fixed direction vector that the angular variations can be approximated with facility in $q^*(\vec{\alpha})$, intuitively, this appears correct since the angular flux at a point detector usually varies slowly within the solid angle cone subtended by the source. Especially, fluxes at a point detector in the most intense portion of a source could be computed with accuracy using only a few discrete directions.

The amount of detail which can be built into sampling functions internal to a computer program is limited and is usually based on line-of-sight observations between source or scattering points and the detector point. For more difficult problems, where line-of-sight estimates are not strictly correct, i.e., where short circuiting around a shield actually yields the major component of the flux, the effects can be approximated by using several alternate definitions of $\rho_1(\hat{\tau}^i)$, where $\rho_1(\hat{\tau}^i)$ is used in randomly selecting the first-scatter points. This same capability is not usually warnated for multiple scattering events since the effect is harder to predict and control.



APPENDIX B

ANGULAR AND SPATIAL FLUX MOMENTS

Legendre moments of the angular flux are obtained by an integration of the individual flux contributions over solid angle. Using the notation of Section 7.0, the angular dependence of the flux contributions is denoted by:

$$\Delta \phi_{i,j,k}^{*}(\vec{\Omega}) = \Delta \phi_{i,j,k} \quad s(\vec{\Omega} - \vec{\Omega})$$

where $\Delta \phi_{i,j,k}$ is the flux contribution to the <u>ith</u> energy group from the <u>kth</u> inner iteration of the <u>ith</u> outer iteration and is obtained for the fixed direction $\hat{\overline{\Omega}}_{0}$.

The angular moments are averaged over the azimuthal angle and obtained with respect to a preferred direction \hat{a}_{i} :

$$\phi_{j}^{l} = \frac{1}{n} \sum_{i=1}^{n} \sum_{k=0}^{n} \iint_{A\pi} \Delta \phi_{i, j, k} \delta(\hat{\vec{n}} - \hat{\vec{n}}_{o}) P_{j}(\hat{\vec{n}} \cdot \hat{\vec{n}}_{p}) d\Omega \qquad (B.1)$$

$$= \frac{1}{n} \sum_{i=1}^{n} \sum_{k=0}^{\Delta \phi_{i,j,k}} \Phi_{i,j,k} P_{i} (\tilde{\vec{n}}_{o} \cdot \tilde{\vec{n}}_{p})$$
(B.2)

where
$$P_{0}(\mu) = 1$$

 $P_{1}(\mu) =$
 $P_{1}(\mu) = \frac{1}{T} \left[(21 - 1) \mu P_{1-1}(\mu) - (1-1) P_{1-2}(\mu) \right]$
(B.3)

The preferred direction $\overrightarrow{\Omega}_{p}$ is fixed by input for point and volume detectors. For surface detectors, it is the unit normal to the surface, \overrightarrow{n} , as defined by equation 4. 11. The zeroth moment, l = 0, is the scalar flux as given by equation 7.6 and the first moment, l = 1, is the particle current with respect to \overrightarrow{n}_{p} .



The azimuthally averaged Legendre moments can be used to define azimuthally averaged differential angular fluxes and/or interval integrated values. This is not done by the FASTER program. However, the equations required for external manipulation of these moments are summarized below:

a) differential angular flux

$$\phi_{j}(\mu) = \sum_{||=0} \frac{2l+1}{4\pi} \phi_{j}^{l} P_{j}(\mu)$$
 (B.4)

b) interval integrated flux, $\mu_m \leq \mu \leq \mu_{m+1}$

$$\vec{\phi}_{j,m} = \sum_{i=0}^{\infty} \frac{2i+1}{2} \phi_{j}^{i} \int_{\mu_{m}}^{\mu_{m}+1} P_{j}(\mu) d\mu \qquad (B.5)$$

Using the relationship (Reference 15, page 309):

$$P_{1}(\mu) = \frac{1}{2!+1} \left\{ \frac{dP}{d\mu} + 1^{(\mu)} - \frac{dP}{d\mu} + 1^{(\mu)} \right\}$$
(B.6)

Then

$$\vec{\Phi}_{j,m} = \frac{1}{2} \sum_{l=0} \phi_{j}^{l} \left\{ P_{l+1}(\mu_{m+1}) - P_{l+1}(\mu_{m}) - P_{l-1}(\mu_{m+1}) + P_{l-1}(\mu_{m}) \right\} \quad (8.7)$$

Spatial Moments

Length-of-flight moments of the flux can also be obtained from FASTER. These are normalized to a reference distance t_{a^*} Thus

$$\widetilde{\phi}_{j}^{m} = \frac{1}{n} \sum_{k=0}^{n} \sum_{k=0}^{n} \Delta \phi_{j,j,k} \left(\frac{t_{j,k}}{t_{o}} \right)^{m}$$
(B.8)

$$t_{o} = \max(|\vec{r}_{p} - \vec{r}_{c}|, 100), \vec{r}_{p}, \vec{r}_{c} \text{ ore defined in Section 8.3} (B.9)$$

$$\mathbf{t}_{i,k} = \sum_{k'=0}^{\kappa} \left[\hat{\mathbf{r}}_{i,k'} - \hat{\mathbf{r}}_{i,k'-1} \right] + \Delta \mathbf{t}_{i,k}$$
(B. 10)

where

$$\Delta t_{i,k} = |\vec{r} - \vec{r}_{i,k}| \quad \text{for a point detector}$$

= s, the distance to a surface detector (B.11)

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Moments of the average length-of-flight are obtained for volume detectors.

$$\Delta t_{i,k} = -s + \Delta s/2 \quad \text{if void}$$

$$= s + 1/\Sigma_{i}^{v} - \Delta s/\left[\exp\left(\Sigma_{i}^{v}\Delta s\right) - 1\right] \quad \text{if not void} \quad (B.12)$$

For photons and non-volume detectors, the length-of-flight moments can be related to the time of arrival af the flux

$${}^{t}_{i,k} = {}^{c}_{i,k}, {}^{\tau}_{i,k} = {}^{t}_{i,k} / {}^{c}$$
 (B.13)

where c is the velocity of light and τ is the time. If the source is assumed to have a time dependence $\delta(\tau)$, then, the temporal moments are given by

$$\widehat{\Phi}_{j}^{m} = \frac{1}{n} \sum_{i=1}^{n} \sum_{k=0} \Delta \phi_{i,j,k} \quad \widehat{\tau}_{j,k}^{m}$$

$$= \frac{1}{n} \sum_{i=1}^{n} \sum_{k=0} \Delta \phi_{i,j,k} \quad \left(\frac{t_{i,k}}{c}\right)^{m}$$

$$= \left(\frac{t_{0}}{c}\right)^{m} \quad \overline{\phi}_{j}^{m}$$

$$(B.14)$$

These moments are not processed by the FASTER program but the obvious procedure is to use techniques of the type used for the spatial dependence in the moments^{(O}; e.g., assume a functional form and match moments.

$$\begin{split} \phi_{\mathbf{j}}^{(\tau)} &= \exp\left[-\alpha\left(\tau - \tau_{\mathbf{o}}\right)\right] \sum_{\mathbf{m}' = 0} b_{\mathbf{m}'} \left(\tau - \tau_{\mathbf{o}}\right)^{\mathbf{m}'}, \ \tau \geq \tau_{\mathbf{o}} \\ &= 0, \ \tau < \tau_{\mathbf{o}} \end{split}$$

$$\end{split}$$

$$(8.15)$$

180



where r_{α} is the earliest arrival time, α is an exponential decay constant, and the b_m 's are constants in a polynomial representation of the departure from a true exponential decay.

Then

$$\hat{\mathbf{r}}_{j}^{m} = \int_{\tau_{\alpha}}^{\infty} \phi_{j}(\tau) \ \tau^{m} d\tau$$

$$= \int_{\tau_{\alpha}}^{\infty} \exp\left[-\alpha (\tau - \tau_{\alpha})\right] \sum_{m'=0} b_{m'} (\tau - \tau_{\alpha})^{m'} \tau^{m} d\tau$$

$$= \sum_{m'=0} b_{m'} c_{m,m'}, \ m = 0, \ 1, \ \dots$$
(5.16)

where

$$c_{m_{\mu},m^{i}} = \int_{\tau_{0}}^{\infty} \exp \left[-\alpha \left(\tau - \tau_{0}\right)\right] \tau^{m} \left(\tau - \tau_{0}\right)^{m^{i}} d\tau$$
 (B.17)

Equation 8.16 is solved for the constants b_{m^1} , m^t = 0, 1, . . . and equation 8.15 is used to compute the temporal dependence.



APPENDIX C

PROGRAM LISTING

The FORTRAN IV listing of the FASTER program is given in this appendix. Compatibility with other computer facilities can be obtained by the following changes in the control program on the first page of the listing:

a) Change of input tape logical designation from 5 to 1

- b) Change of output tape logical designation from 6 to j replace M2 = 6 by M2 = j
- c) Change of maximum number of lines per printout page from 43 to k replace LINEX = 43 by LINEX = k
- Change of maximum number of locations for dimensioned arrays from 12000 to 1replace COMMON H(12000) by COMMON H(1)
 - and replace NSTORE = 12001 by NSTORE = 1+1

The listing corresponds to an operational program for the IBM 7094 computer which uses a MAP random number generator as shown on the last page of the listing. For conversion to the CDC 6600 computer, the MAP routine is removed and a card in the control program (first page of listing) is changed:

replace IBMCDC = 0 by IBMCDC = 1

It is assumed that the random number generator, RANF, distributed by the Control Data Corporation is on the library tape and that the calling sequence is:

R = RANF(i), where i > 0, stores i as the generator

R = RANF(0) yields a random number R on (0, 1)

All calls to the random number generator are relayed through the function subprogram RANNO (n) where n is a do-nothing argument—n is not used in the calling subprograms and can be defined arbitrarily in RANNO. Therefore, any other random number generator can be used by FASTER with appropriate changes in RANNO.

FORTRAN IV LISTING IS PRESENTED ON PAGES 184 THROUGH 259.

SINI T	C FASI #947	2.897									
FEAST	TRAF URTRAN-ANAL	11110	SHUTTO							FAS	10001
	CUMMIN	4(125	001		PU-41, E4	OVI 10A-	RANDOM	SAHPLIN	16411	4JF A S	10002
	CUMMON/COCTAN.	/188C D	č,,							FAS	T0003
	FINHDR/TAREID	/41	` µ ?							FAS	0004
	C 19MJN/CASETO	12455	+ TA							FAS	19005
	COMMON /L LATTE	AND CON	INFRGP	10111	+LINEX	*LILE	A(13)	, T I TLE	314	31 F A S	10006
	I	N	F ALERHO	Y,NSMAX	, NA 4A X	* *-{MAX	+N344.4	,NSTMA	x,	FAS	19697
	-	10 17 4	• NV 16 X	NXPAX	+NXE-IA	X,NENOD	+NXSEC	T,NUN11	Ð.	845	Touna
		AGATES	XAPLINEX	* WHAX	+ YORDF	RAUCAN	. INEL 1	S.NTRAN	s.	FAS	tonno
		MAMPA	NGMAX	,NFMAX	+ NVHOD	+NCM4x	NL dAx	NTPAX		FAS	Enol 1
		VOYAX	+ NG400	* NOWEN	1+NU40D	NPD 4A	K NP JMJ	D-NSGMA	x.	FAC	LAOLA
	2	NYOMAS	X MADWCI	9.NPOIN	1,400EU	PINCOL	Q. MODEL	U. MOGEL	v.	645	LOUIS
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		1 X 1 8	+ I SIJV	, EA TN	+ FATW	+LE23	1558	-1000		FAS	10/15
	3	INTG	.IFLF	+ 1 F G w	+1105	-1 tov	.1100	1100	•	FASI	0015
	•	IVUL	1001	. (XOT	1851	161 1	11/10	11105	•	PASI	0017
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		ISPK	. ISPE	ALATO	1250	1 50 1	11160	TVAL	•	PAST	0019
1	ł	1565	NEXT	- 1 XHP	1568	.115	165	11101	•	FASI	0020
	3	150	• IND	. 111	.14		115	1140	•	FAST	0921
ę	}	ENRG	INSC.	1579	1000	LNCO	1121	151		FAST	0022
- I		1 F X I	IFXE	LEYA	7 - 1007	TINCE	* 1 F XP	11 X X 2	,	FAST	0023
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	COMMON/REGSCA/	NSRPAY	TNSP	1 d mars	IN LENO					FAST	0027
	18HCDC = 0									CORR	ECT
	NST088 = 12001									FASI	6200
	M1 = 5									FAST	0029
	N2 = 6									FAST	0030
	LINEX # 43									FAST	1 200
	KASE = 0									FAST	2600
1)	CALL DEEINE									F'AS T	0033
	CALL SOLVIT									FAST	0034
	60 10 10									FAST	0035
	END									FASTO	1036
STRETC	LABLE HOLD	VD 2								FAST	3037
LAGEL	*DUIDUIT BACE S	1 A K 7								FASTO	038
2	FUNCTION LABOR	164610	us ruk i	PRUGRAM	FASTER	*T.H.JO	RDAN+WA	NL+OCT.	1966	FASTO	0039
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	COMMON /CACE TO /S	11	*M2							FASTO	041
	2 TANSI INC.	ASC 1	NPAGE :	LINES	LINEX	TITLEA	18)	TITLEB	(181	+ AS TO	042
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			,							FASTO	044
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IFILINES, LE.LINEXIGG TO 20	FAS10047
1) LINES = L + 3	FAST0048
N-AGE = NPAGE + 1	FAST0049
LAB51 = 1	FAS10050
WRITE (42.2000) TITLEA.KASE.TITLEB.NPAGE	FAST0051
2301 6-03541 (181, 1844, 308+****THE [ASTER CODE******CASE.15/1X, 1844, 308*	*FAST0057
10441.H. 1080AN, WANI ++++++DAG+, 15/14 1	EAST0053
2) RETURN	FAST0054
END :	FASTOOSS
110FTC VECTR 994/2.887	FASTOOSA
CVICTUR WINT VECTOR	FAS10057
FUNCTION VELTCRIX.Y.C)	54513059
$D_{1}H(NSTON \times (1), Y(3), C(3))$	FAST 1059
+ EST = 0.0	EASTDOAN
03.10 1=1.3	CAST00041
$c_{11} = v_{11} = v_{11}$	FAST-0001
(1) = (1) = -(1)	F #510062
dcr = contract	F 1310765
	1 15 1064
	FAS10065
	PAS10065
	FASTOOGF
(13) - 1+0 (1) 10 16	F AS 10169
90 10 27	PA310969
	14510170
$\gamma = \zeta = $	FAS11071
	FAS10072
GURN	FAS10073
FND	FAST 3074
SINFIC LANK M9472, XR7	FASTON75
CZERNUT*ZERO NUT ARRAY	FAST 2076
SUBRIUTINE ZERUUTIMAKINI	FAST0077
DIMENSION N(1)	FAS19078
IF(MAX.LF.C)GO ID 20	FAST0079
DJ 1) [*1,4AX	FAS F0080
1) N(1) = D	FAST0981
2) 4ETURN	F A S TUOR 2
ENO	FAS [0083
·IBETC LOKATE M94/2, XR7	FAS10084
CLUGATE*REGINA INGEX CALCULATION FOR PROGRAM FASTER*T.H.JORDAN*WANL*19	56FAST9985
FUNCTION LUCATE (NNN, XXX)	FAST0986
JIMENSION XXXII)	F & S T 0 0 8 7
- CONFON H111	F 45 T ንባዓ ዓ
CJMMUN/L1MITS/NSTORE,NERPUR,NSMAX ,NAMAX ,NEMAX ,NAMAX ,NSTMAX,	F4510989
1 NEMAX ,NYPAX ,NXPAX ,NXEMAX,NEMOD ,NXSECT,NUNITD,	1 45 10090
7 NUNITX,NIMAX ,NMMAX ,NCRDER,NDDWN ,1%FLAS,NTPANS,	F & S T D D 9 1
3 NNMAX ,NGMAX ,NFMAX ,NVHOD ,NCMAX ,NLMAX ,NTMAX ,	F AS T0092
4 NOMAX ,NGMCU ,MOMENT,NDMUD ,NPDHAX,NPCHEC,NSCMAX,	FAST0093

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NVOPAX, NVOMCC, NPCINT, HODELP, MODELQ, MODELU, MCDELV, NPRINT, NUNITS, NUMRER, KALIDE FAST0094 FAS10095 FAST0096 INTL . 1 7 9 COMMON/INDEXS/INTP +1AZ +11SV , LJSN , LJSX , INSG +I NPC TEL N . 1 4 5 TRF ICEN FAST0098 TATE , LAIN IATW .1854 . ISSH 1 50 V .1105 .161M .1VAL .1101 ž TIOR £ 4510099 TOS +I TOV INTG TELE FASTOIOO IXCT. . IVSD INDL , ICDT , 18SI AT AT P 4 , IA , IKSP , ISGR •1NS •1SGT •1WS IVEE + AST0101 . TALM . LALH FASTOIOZ 1 SP N 111CE ,1SPF , 1A TD ^; 7 151 , IWC £ AST0103 FASTOL04 1FC , INU ,1U14 я £ AST0105 INRP INCP . LEXP IFXS a FAST0106 . 1 F XA IFXT ,IFXE EASTO107 COMMON/DUML CC/NN 11141 FASTOLOS D) 10 I=1+3 X([] = XXX([) NN = NNN FAST0109 FAST0110 FAST0111 2.1 CALL LUCDUM(NAHAX,NBMAX,1,H(INTP),H(IAZ),H(IA),H(INS),H(IND), LOCATE = MM FASTOLIZ 1 FAST0113 FASTOI14 RETURN FASTOI15 END END SIGETC LOCOML M94/2,XR7 CLOCOMM*REGION INCEX CALCULATION FOR PROGRAM FASTER*T.H.JOPDAN*WANL*1966FASTOII7 FASTOL18 FASTOL19 SUBROUTINE LOCOUM(L1,L2,L3,NTP,AZ,A,NS,ND,U) DIMENSION NTP11),A(L1,L3),NS(L2,L3),NO(11,U(1) DIMENSION NIPELLY, AZLLY, AZLLY, AZLLY, AZLLY, AZLY, A FAST0120 FAST0122 CASTOL 24 FAS10125 6 AST0126 FAST0127 6 b NPWIN D0 100 [=1+3 X(1+3) = X(1)*X(1) J = I + 1 - 3*(1/3) 100 X(1+6) = X(1)*X(J) LAST0128 FAST0129 ŝ F4510130 FAST0131 FAST0132 DO 110 I=L+NSHAX 110 ND(1) = 0 DU 200 N=1,2 FAST0133 FAST0134 FAST0135 IFIN.GT.LIGL TO 130 FASTO136 TMIN = NNNFAST0137 IF([]MIN-1)*(NRMAX-[HIN+1].GT.C)GC TO 120 EAST0138 IMIN = NRMAX + 1 FAST0139 GO. TO 200 FAST0140

GO TO 140 130 [MAX = [MIN - 1 141N = 1 140 00 199 [=!MIN,[MAX 00 170]=[,NBMAX 1E(NS1,1),E0,01GG TO 180 FASTOLAL FASTO142 FASTO143 ASTO144 FAST0145 FASTO146 IF(NS(J,1)/1000000 K = NS(J,1)/100000 K = NS(J,1)/1000 - 1000*KP IF(ND(K).GT.0)GO TO 160 FAST0147 FASTO148 FAST0149 TF[NDIK].GI.UUUU UL ... NDIK! = 1 MAX = NTP[K] UIK] = AZ(K) DO 150 L=1.MAX 150 UK] = U(K] + X[]*A(L;K) 160 TF[FL0AT[2*KP -]]*U(K].GT.0.0)GG TO 190 ... CANTING FAST0150 FASTOIST FAST0152 FAST0153 FAST0154 FAST0156 180 NN = I GO TO 210 FAST0157 FAST0158 190 CONTINUE **FAST0159** 200 CONTINUE FAS TO160 NN = 0 FASTOIAT 210 RETURN FAST0162 END FASTO163 SORIGIN FAST0164 ALPHA SORIGUE AND A CONTRACT AND A CONTRAC CORMON V(v(1) COMMON V(1) COMMONY LASS DIVALS + NPAGE LINES LINEX TITLEAI (18) TITLEBIPASTOITO COMMONY LASS DIVAS + NPAGE LINES LINEX TITLEAI (18) TITLEBIPASTOITO COMMONY LINITS/NSTORE.MERROR,NSAAX ,NAMAX ,NAMAX ,NGMAX ,HSTNAX, FASTOITI 1 NHAR ,NVMAX ,NKXAX ,NXEMAX,NEMAD ,NXSECT,NUMITD - FASTOITZ 2 NUMITX/NIMAX ,NMAX ,NKMAX ,NXEMAX,NEMAD ,NXSECT,NUMITD 3 NMHAX ,NGMAX ,NFMAX ,NVMCD ,NYDMAX ,NTEASS ,FASTOITZ 4 NDMAX ,NXGMD , MYDEN, NXMCD ,NYDMAX ,NTEASS ,FASTOITZ 5 NVDAX,NVDFD,NFL (NT,NDCD , MYDEN, NYDMOX ,FASTOITZ 5 NVDMAX,NVDFD,NFL (NT,NDCD , MYDMAX, NYDMOX ,FASTOITZ 5 NVDMAX,NVDFD,NFL (NT,NDCD , MYDMAX , NYDMAX ,FASTOITZ 5 45 6 COMMON/INDEXS/INTP L ELW Z IXTR 3 INTG . IAZ , INTL , I RHO .1XR +1159 . 1 5 9 9 EAST0178 , I J SN FAST0179 .186 ,I NPC ,I ESB ,I IDV 1J5X . ISUV . IATN + ISSH . IATW .IDEN FAST0180 TDS ,110S FASTO181 ٦ . . I VHD IVOL , I COT . LXCT .IRSI .1 ALP ,1G1M FASTO182 FASTO183 5 , INS IVEE . 1A . ISPE IRSP ISGR TOPL , TATD •ISGT .110E .1ES ,ILDI ,IWC FAST0184 ises NEXT FASTO185 .1U TEC . 150 . 7 . . 1 54 TST FASTOIRS я INRG , INSC INRP INCP IFXP IFXS FASTOL87

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I JEXT JEXE JEXA	EAST0188
COMMON/INPUTS/IN1 (INN(23)	FASTOIRS
OTHENSION TOURISAL TYPEIS 61 ADDINITES	FASTOIRO
DATA TOUN/	FASTOIST
1 44(F10.4HRTRA.4HN.(A.4H)NAL.4HYTIC.4H [S1.4HDLUT.4]	HIGN 4H(T)R. FAST0192
2 4HANSP.4HORT .4H(F)0.4HUATT.4HON. (.4HR IAN.4HOUN .4)	ASAND. ANI ING. FASTO193
3 4HMATH, 4HEMAT, 4HICAL, 4H AND, 4H NUR, 4HERIC, 4HAL A.4	HNAL Y. 4HSTS EASTOIRA
4 4HCCMP+4HUTER+4H PRG+4HGRAM+4HHING+4H AND+4H CHE+4	HCKDU.4HT BY/FASTO195
DATA TYPE/	F45T0196
1 4H VAR, 4HIABL, 4HE DI, 4HHENS, 4HIONS,	FASTO197
2 4HSURF.4HACES.4H ANC.4H REG.4HEGNS.	FASTOIS
3 4H IND, 4HEPEA, 4HDENT, 4H SOU, 4HRCES,	FAST0199
4 4HBASI, 4HC CR, 4HCSS , 4HSECT, 4HIONS,	FAST0200
5 4HDETE, 4HCTOR, 4HS + , 4HRESP, 4HUNSE,	FAST0201
6 4H SAM, 4HPLIN, 4HG PA, 4HRAME, 4HTERS/	FAS 10202
1J KASE = KASE + 1	FAST0203
NPAGE = 0	FAST0204
LINES = LINEX	FAS T0 20 5
1F(KASE.GT.1) GO TO 3C	FAS10206
DO 20 J=1,36	FAST0207
20 TITLFA(J) = TDUM(J)	FAST0208
30 CONTINUE	FAST0209
00 700 NNN=1.6	FASTOZLO
TF(LABEL(1).GE.O) WRITE(M2,200G) NNN, (TYPE(1, NNN), 1=1	,5) FAST0211
2000 FORMAT(1x,32(1H+),18HDATA INPUT SECTION,12,2H, ,5A4,3	3(1H+)) FAST0212
CALL READT(24, INL)	FAST0213
	FAST0214
	FAS10215
59 CALL READALIS, AUDAL	FAST0216
69 GU 10 [100;200;300;400;500;600]; NNN	FAS10717
CD TO 300	FASIO218
	FASTUZIA
CALL CONTINUE	FAS10220
	CAST0221
	CAST0222
300 IF = ASICRE - AVENAX	EAST0225
IEN = IE - NYSHAY	EAST0225
LENG = LEN - NXEPAX	FAST0226
IEBG = IENG - NXEMAX	FAST0227
IFLIENG.LT.NEXT) NERROR = NERROR + 1	FAST0228
CALL SOURCEINEMAX, NXHAX, 5, 1, VIIELL), VIIELW, VIIAE), VI	18F) . VI INSG1 . FAST0229
1 V(INPC).V(IJSN).V(IJSX).V(ISUV).V(IXTR).V	[IVEF]. FAST0230
2 V([VAL],V(ISPW),V(ISPE),V(IISV),V(IE),V	(LEN). FAST0231
3 V(1E8G),V(1FAG))	FAST0232
GO TO 700	FAS10233
400 IEAC = NSTOPE - NEHGC+(NIHAX + NHMAX)	FAST0234

[JNX = IEAC - NXSECT*(INELAS + 3)	FAST0235
IXSI = IJMX - NXSECT+INELAS+NTRANS	FAST0236
IXSE = IXSI - NXSECT* NDDWN*NEMAX*MAX0(2+NORDER)	FAST0237
IXST = IXSE - NEMCD	FAST0239
INI = IXST - ISGS	FAS10240
CALL INSECT (NEHOD NOONN NORDER INFLAS NEMAX 1. VITESB) VI	IDEN1. EAST0241
1 VIISSH), VIISGT), VIIIOE), VIIIOI)	GS1. EAST0242
2 V(1MT1), V(1DUD1, V(1YST), V(1ATD), V(1MY1, V))	CE1. EAST0241
3VIIVELVIIENT, VIIENT, NTOANS	EAST0244
	FISTO2/ F
150000 15000 10000	F4310243
CO TO TO	FA51-1246
	FASIU247
JOD CALL KESDLITHERDITLY TINGS WITCH STUTTED STATIS	SPJ, FA510248
	LLI. FAS10249
ZV(IATC),V(IRHO),V(IEAC),NEMOD)	FAST0250
60 10 700	FAST0251
600 CALL RANDOM(V(IRSI),V(IALP),V(IVHD),V(IGIH),V(IAIH),V(IA	LHI FASTO252
LV(IALH),V(INPC),V(IVEE),KXHAX,5)	FAST0253
700 CONTINUE	FAST0254
1F(LABEL(1).GE.0)WRITE(M2,2010)	FAST0255
2010 FORMAT(1X,35(1H*),36HDATA INPUT AND PREPARATION COMPLETE	0,36(1H+))FAST0256
[F(NERROR.EC.0) GO TO 900	FAST0257
IF(LABEL(1).GE.0)%RITE(#2,2020)	FAST0258
2020 FORMAT(1X,42(1H+),23HPROCEEDING TO NEXT CASE,42(1H+))	FAST0259
GO TO 10	FA510260
900 MAX = NSTORE - 1	FAST0261
DO 910 I=NEXT.MAX	FAST0262
910 V(1) = 0.0	FAST0263
IF (1ABEL(1), GF.0) HRITE(H2, 2040)	FASTOZAS
2040 FORMAT(1X+1H+.35(3HGO+))	FAST0265
LINES = LINEX + 1	FAST0266
RETURN	· FAST0267
END	EAST0268
\$1951C \$1005 #94/3- VP7	EAST0240
CONSERVITE INTELEVAL	EDATH 1844 #645 10203
CIDENTITIE CTORES	EACTO271
	FASTOZII
	FASTUZZZ
COMMONT REDSCAT REARING A LINSK	FASIUZIS
	FASTOZIA
COMPONICASETURASE APAGE LINES LINES (INEX (IILEA(IB))	TILLED (LB) FASTU275
COMMUNICIALISTASIOKETACKKUKINSPAA INAMAA INAMAA INBMAA I	HALTAN FASTO276
L ACTAR INVAR INTAR INTARA INTERATION UNIVERSITY	NUNITU, FASTO277
Z NUNISASDINAX SNMMAX SNUDEKSNOUWN SINELASS	NIKANS, FASTO278
> NNMAX INGHAX INFHAX INVHOD INCHAX INLMAX I	NIMAX + FAST0279
4 NURBA TAGHUG THUPENT NORDU THEPHAX, NPOROD,	NSUMAA+ FAST0280
> NVUMAA, NVUMUD, NPUINT, MODELP, MODELQ, MODELU,	MUDELV, FASTO281
6 NPRINI NUNITS NUMBER KALIDE	FASTO282

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	COM		INDEXS	/18	۰.	147		t r'e	υ.			. 1 844		140	۰.					
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	2	-		TYT		1 511		TAT	м !	TAT			•	1000		1334		- 5	ASI	1284
	- 3			INT	č .	TEL		IFC		110		.7 100		1100		1024	•	- 5	ASI	1287
	4		•	1 10		tent		IYn	7 3	7051				1100		103	•	- 5	AST	1280
	Ś.	:		141	ù .	1 41 1		TAT		. 14		INC	•	1100			• •	- 5	ASI	1287
	6			I SP		1500		1 & 1	n .	these		1 601	. 1	1100		TAL	•	-	A5 41	1238
	7			ISG	-	NEVI				tsco		1	- 7	100		101	•	- 5	A510	205
	à ·	:		TEC		TND		10		10		1 1 1	•	103	• •		•		A511	1289
	ē.	· ·	•	INR	в .	INSC		išti		INDO		1 100		151		51	•	- 5	4510	290
	i /	•		TFX	÷ :	LEXE		IFY		• ••••			•	11.44		E NP	•	÷	A510	1291
	COMM	IGN / 1	NPUTS	/181		1N2		INT	۰.	TNA		145		TNA		N 7	• •	- 2	4514	292
	1			INA		ING		INTO		1911		TNN		1110			•	- 5	A510	293
	OTHE	NSTO	N L C P 1	511	. ARR	AY4 7	arL	nri	· • • '				* 3 1					- 21		294
	EQUI	VALE	NCE (00.0	11.1	NTPI			•••									- 21	1010	293
	EQUE	VALE	NCETIC	PLA	91.I	11.4	100	6601		1.0		A 1 1	, 21		0147	• •		- 21	1010	270
	LLCP	(43)	.151.1	LCP	(44)	.1 61	. (1)	CPL	51.	1 73 2	ñ,	DIAK	5.1		1000	471		- 21		291
	2 ILCP	(48)	.L10)	LC	P149	i i	65.	11.0	150	5.71	21		• • •				12311	12		278
	DATA	AR	RAY			/ 3	HNT	. 31	1AZ	. 381	ŝv.	3887		ненл		ο		.5	1010	279
	13HEL	W. 3H	AE .31	IBE .	3HN	56.3	HNP	. 36	1151	311.1	ςΥ.	BHYT	0.3	USIN	- 344		DUATU			201
	23HES	B . 3H	SSH.3H	DEN	3HN	TG . 3	HEL	- 31	FRY	. 3117	ns.	3410		1100	- 3111	nc		12	1310	301
•	33HCD	т, эн	XDT 3H	RSI	3HA	LP.3	HVK	3. 3H	GIN	- 3HA	IR.	3HAL	N. 3	HATH	- 344	0.38		12	1510	202
	43HVE	Е. ЗН	VAL . 3H	ISP#	3HSI	PE.3	HAT		RSP	- 3HS	GT.	3HI0		1111	. 340	c e	20530		1310	305
	53HXM	P, 3H	SGR, 3H	WS .	3HE	5.3	HHC	• 3H	IEC	- 3HN	δ.	380	- 31	HV	3111		HCI		1070	305
	63HST	• 3H	NRG, 3H	NSC	3HS	FP.3	HNR	· 31	NCP	- 3HF	XP.	3 HF X	5.3	IFXT	- 3HE	XE.	LUEYA	16	STA	205
	IF{K	ASE.	GT.11	GO 1	TO 21	D .													IC TO	300
	NERR	OR =	0						· •	ŕ.								- 22	1010	301
	NNNA	X = 1	o '															Ē	ETO	300
	NAX	• NS'	TORE -	1														FI	STO	310
*	00 1	0 1=	1.HAX															F	STO	311
10	N(I)	* 0																÷,	STO	312
	GOT	0 30	•															Ē	STO	313
20	MAXS	* N	SMAX															FI	STO	314
•	AXAH	= N/	XAMA	•														FI	570	315
	MAXR	* NI	RMAX															F.	STO	316
•	NAXB	* NI	BMAX															F.	570	317
	MAXV	* N1	VHAX															FA	STO	318
	MAXX-	** NJ	KRAX															FA	STO	319
	MAXE	* NI	ENAX															FA	STO	320
	MAXH	* 11	XAMP															FA	\$70	321
	MAXI	* NI	EMAX															FA	STO	122
•	MAXE	* 11	MAX															FA	510	123
	RUDG	- 80	SHUD															FA	STO	124
	RUDE	- NE	:400															FA	STO	125
	SUDX,	- N)	SECT															FA	STO	26
	HUDD,	- NC	JRUER															FA	STO	327
	HUDD,	= 80	108N														•	FA	STO	128

	HODI T INELAS	FAST0329
		FAST0330
30	DRAM - MUDRA TELIND AT AL CALL DEADAILD. TITLEAL	EAST0331
	TECINA CT.OJ CALL READATIO.TITEGI	FAST0332
	IF(INA., CT(A) CALL READILY SANAWAY Y	F45T0333
	TECHNS CT.OL CALL REACTING AND AND A	FAST0334
	IF(ING GT-O) (ALL READLY SINESET)	FAST0335
	IF(INT GT-0) CALL READILY A.NORDER)	FAST0336
	IFINA GT.O. CALL REACT A.NGWAY 1	FAST0337
	IEIINB-CT-OJ NSRMAX = NGHDD	FAST0338
	IFLING GT.O. CALL READER S. NPCINT)	FAST0339
	TECINIO.GT.OJ CALL READIS 4.0PRINTS	· FAST0340
	1618ASE-E0-11 GO TO 70	FAST0341
	NARRAY = 51	FAST0342
	IF (NXSECT. FO. MODX) GO TO 40	FAST0343
	NARRAY = 47	FAST0344
	NNMAX = 0	FAST0345
40	MOVE = LOCENARRAY)	FAS10346
	NADVE - NSTORE - NOVE	FAS10347
	DO 50 I=1-NARRAY	- FAST0348
. 50	LCP(I) = LOC(I) + NHOVE	FA5T0349
	1 = NSTORE	FAST0350
	J = NOVE	FAS70351
	NHOVE = HOVE - 1	FAS10352
	DO 60 K=1.NHOVE	FAST0353
	1 = 1 - 1	FAST0354
	Ⅰ = 1 음 L ·	FA570355
60	$N(1) = {}^{3}N(3)$	FAST0356
170	NEMDD # NEMAX + 1	FAST0357
	NGHOD * NGHAX + 1	 FAST0358
	HOHENT, = NVHOD + NCHAX + NLHAX + NTHAX + 1	FAS10359
	HOMENT * NOHENT + NSRHAX	FAST0360
	NDHOD = 1	FAST036L
	IF(NPCINT:EQ.C) NDNOD = NDMAX	FAST0362
	INTP'=1.NSRHAX + 1	• FAST0363
	IAZ 式 INTP + NSMAX	FAS T0364
	'IISV'= IAZ + NSMAX	FA510365
	INTL = IISV + NRMAX	- FAS10366
	IRHO = INTL + NRMAX	FAS10367
	IXR, =, IRHD + NRMAX	FA510369
	IDLE, TYLER + NEARATS	EAST0271
	IELW = IELE + NEADD	FAS10571
	1AC - 1518 T ACAAA	EAST0373
	100 - 100 A NEMAY	EAST0274
	INSU TIBE T NEMAA	EAST0375
	10PL = 1000 + NVHANAC	EAST0374
	100H - 11PL T HTDHATD	



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tjsx ≈	I JSN +	NYMAX
IXTR #	I J SX +	NVHAX
ISUV =	IXTR +	NVHAX#3
IATN =	ISUV +	NAWWX
IATW ×	IATN +	NIMAX
IESB ≖	IATH +	NEMAX
ISSH =	IESB +	NEMAX
(DEN #	15SH +	NEMOD
INTG ×	IDEN +	NHHAX
IELF =	INTG +	NEPAX
IFGW *	IELF +	NGPOD
ITDS ×	IFGW +	NGKAX
IIDV =	ITCS +	NFKAX+3
LIDR =	11DV +	NVHOD
IIDS =	IIDR +	NOMAX
IVOL =	1105 +	NDMAX
1CDT =	140L +	NDNAX
IXOT #	ICDT +	NDMAX#3
IRSI =	IXOT +	NDMAX+3
IALP =	IRSE +	NVHAX
tvmD ≠	IALP +	NVHAX#5
IGIN =	IVHD +	NVHAX*5
IAIM =	1GIM +	NEMAX
IALM =	IAIN +	NEMAX
IALH =	IALH +	NEHAX ,
IA =	TALH +	NEMAX
INS =	IA +	NSMAX*NAMAX
IVEE =	INS +	NKHAX*NBHAX
IVAL =	IVEE +	NVNAX*NXMAX*S
ISPW =	IVAL +	NVMAX*NXMAX*D
ISPE #	ISPW +	NVAAX BEEAX
LAID =	ISPE .+	NYMAX TEMAX
IRSP 1	IAIU +	
1561 =	1850 +	
1100 =	1301 +	NAMAX*REAUU
1101 -		NUMAYATNEI ASANYSECT
1303 -	1505 4	NNNAYANYSECT
IEYA -	NSTOPE	~ NDHODENGRAYENDKENT
TEYE a	IFYA -	NORODENCHAY
IEXT =	1516 -	NOHODANGHAY
IEXS =	IFXT -	NDHOD*NGHAX
IFXP =	IFXS -	NOHOD*NGFAX
INCP =	IFXP -	NSTHAX
INRP =	INCP -	NSTNAX
ISTP =	INRP -	NSTHAX
INSC =	ISTP -	NSTMAX

FASTO	378
FASTO	379
FASTO	380
FASTO	381
FASTO:	382
FASTO	383
FASTO	384
FASTO	385
FASTO	386
FASTO	387
FASTO	368
FASTO	388
FASTO	389
FASTO	390
FASTO	391
FASTO	392
FASTO	393
FASTO:	394
FASTO	395
FASTO	396
FASTO	397
FASTO.	398
FASTO	399
FASTO	400
FASTO	401
PASIU	402
FASIO	403
PASIO	404
FASID	403
FASTO	406
FASTO	101
EASTO	400
EASTO	410
FASTO	411
FASTO	412
FASTO	413
FASTO	414
FASTO	415
FASTO	416
FASTO	417
FASTO	41B
FASTO	419
FASTO	420
FASTO	421
FASTO	42 Z

FAST0377

	INRG = INSC - NSTNAX	FAST0423
	IST = INRG - NSTRAX	FAST0424
	ISI = ISI - NSHAX+2	FAST0425
	IU = ISI - NSHAX	FAST0426
	TV = TH - NSHAX	FAST0427
	TH # TV - NSMAX	FAST0428
	IND = IU = NSNAY	FAST0429
	IEC = IND - NEMAX	FAST0430
	TVC ~ TEC - NEHAY	FAST0431
		FAST0432
		FAST0433
		FAST0434
	TYND & ISCD - NEWAY	FAST0435
		FAST0436
		FAST0437
	P(0, 0, 0, 0) = 100(1)	FAST0438
		FAST0439
		FASTORAD
		FAST0441
		FAST0442
		EASTO443
		EASTOAAA
	K = L(r)	FAST0445
	CALL RESIDENTANTITITITITITITITITITITITI	FAST0446
	00 10 70 01 00 01 00 01 00 00 00 00 00 00 00 00	FAST0447
	DOD FORMATINA 39(100) A3. 25H ARRAY CANNOT BE RESTORED. 40(10*)	EAST0448
		EAST0449
		EAST0450
		FASTOASI
	16(100(1-1),66,10(1)) 60 10 100	FAST0452
•	te (1 A BEI (1) CE (A) UPI TE(N2, 20101A9PAV/1-1)	FAST0453
	THE ADDREET IN ASTINGTAR AND AN AND AN AR DESTROYED INCORDECTIVE 3511	H#1FAST0454
		FASTOASS
		FAST0456
		EAST0457
	CALL BECTOILANAY, NCRAY, 1, NITAS, NAVA, NAVC, 1, NITAS	EAST0458
	CALL ACTION CARAGE AND AT A STATISTIC TA THE ACTION OF THE	FASTOASS
	FALL BECTOR (NUMAY, 5.4VMAY,N(IVEE), MAYY, 5. MAYV,N(13))	FASTOA60
	ALL RESTORINGARY S. NUMAY. NI TVAL 1. MAXX. 5. MAYU.NII 411	EAST0461
	CALL DESTRUCTIONANAY JUNAY J. NOT SOUN MAY 6- NAY V. 1. NOT SI	EAST0462
	CALL RESTOUNEHAX, NVHAX, L.N(ISPE), MAXE, MAXV, L.N(L6))	FAS10463
	CALL DESTCH(ALMAY, ANHAY, L.N. (ATR), MAXI, MAXN, 1.N. (7))	FAST0464
	CALL RESTOWINGHOD, NEPAY, 1-NI IRSPI-MODG-MAXE -1-NII ALL	FAST0465
	IF(NYSECT.NE.MORY) G0 TO 120	FAST0466
	CALL RESTOWINGHED.NEWAX. 1.N(ISCT1.NODE.HAXM.1.N(191)	FAST0467
	TEINSECT. C. OL GC TO 120	FASTOA68
	CALL RESTORTOORN, NORDER, NEWAY, NOTTEL, HODD, HOD, HAXH, NOT 1011	EAST0469

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IF(INELAS.LE.0) GG TC 110	FAST0470
CALL RESTONCINELAS, NHMAX+1, N(I[DI]+HODI, HAXH+1+N(L11))	FAST0471
110 CALL RESTON(NNNAX.). 1. N(ISGS). MAXN.1.1.N(112)]	FAST0472
120 [F(IN11-LF-0) GD TO 130	FAST0473
IF(LABEL(15).GE.0) WRITE(M2,2030)(ARRAY(I), LGC(1), I=1,73)	FAST0474
130 CONTINUE	FAST0475
2030 FORMAT(1X,43(1H*),22HDATA ARRAY STCRAGE MAP,43(1H*)/6(4X,14HARRAY	FAST0476
1LOCATION)/16(6X,A3, [9)]]	FAST0477
RETURN	FAST0478
END	FAST0479
SIBFTC RESTOR M94/2, XR7	FAST0480
CRESTOW+RESTORE MULTIDIMENSIONAL ARRAYS WITH NEW DIMENSIONS+T. H. JORDAN	FAST0481
SUBROUTINE RESTONILA, JA, KA, NA, IB, JA, KB, NB)	FAST0482
DIHENSION NA(IA+JA+KA)+N8(IB+JE+KB)	FAST0483
DD 20 K=1,KA	FAST0484
DD 20 J=1,JA	FAST0485
A1,1=1 01 00	FAST0486
NC = 0	FAST0487
IF(I.GT.18) GO IO 10	FAST0488
[F(J+GT+J8) 60 TO 10	FAST0489
LF(K.GT.KR) GO TO 10	FAST0490
$NC = NR\{I_{+}J_{+}K\}$	FAST0491
IO NA(1,J+K) = NC	FAST0492
29 CONTINUE	FAST0493
RETURN	FAST0494
END	FAST0495
SIBFIC GEUM M94/2,XR7	FAST0496
CGEOMIN*SURFACE AND REGION INPUT FOR PROGRAM FASTER*T.M.JORDAN*WANL*66	FAST0497
SUBROUTINE GEORINILI, L2, L3, NTP, AZ, A, ISV, MTL, NS, RHO, XR)	FAST0498
DIHENSTON AA(7), ADH(9), ICH(12)	FAST0499
EQUIVALENCE (AAII), ADM(1))	FAS10500
DIMENSION NIPILI, AZIII, ALLI, LJI, ISV(I), ATLLII, NS(LZ, LJI, RHO(I),	FAST0501
	FAS10502
COMMON/TAPETC/HI ,H2	FAST0503
CORMON/LIMITS/NSTURE.NERRUK.NSPAX .NAMAX .NRMAX .NBMAX .NSTMAX.	FAS10504
I NEMAX, NYMAX, NXMAX, NXEMAX, NEMOD, NXSECT, NUNITD,	FASTOSUS
Z NUNITX, NIMAX, NMPAX, NURDER, NDUNN, INELAS, NIKANS,	FAS10506
3 NNRAX , NGRAX , NFRAX , NYRUU , NLRAX , NLRAX , NIRAX ,	FAS10507
4 ADAAX (KGADU (ADERI) ADADU (APDAAX, NPONDU, NSDAX,	PASTOSUS
> NYUAAX, NYUAU, NYUAU, NUBER, NUBER, NUBER, NUBELU, NUBELV,	FASTUS09
S REPRINT THE THE THE THE THE THE THE THE THE	FASTUSIU
C OLIMPAC SUPERCES	PAS10511
L VUMURIL JURTRES	PAS10512
	FA510513
00 674 H=14106 CALL DEADCITCH. AA1	FASTUS14
LALL REAVELING ###	FAS10515
te that t	FA510516

		NTP(1) = 10H(2)	FAS10517
		NEX - 108(3)	FASTOSIB
			EACTOSIC
			545 10520
С	EXP	ANDED FORM	FAS10520
		AZ(I) = AA(I)	PAS10521
		HAX = HINO(NBMAX,6)	FAST0522
		DO 220 J=1, MAX	FAST0523
	220	$A(J_{+}I) = AA(J_{+}I)$	FAST0524
		IFINTP([].GT.6)CALL READE(NTP(])-6.A(7.1))	FAST0525
		GD TD 290	FAST0526
	230	NGT = (NEX+2)/3	FAST0527
	200	$N = N = N = 2 \pm (N C T = 1)$	FAST0528
			FAST3529
			EAST0530
	231		64570531
			ELETOFAT
		GO TO(232,233,235,260,2551,NGT	FASTUSSZ
	232	NTP(I) = NEX	PASTUSSS
		AZ(I) = -AA(1)	FAS10534
		A(NEX, 1) = 1.0	FAST0535
		GB TO 290	FAST0536
	233	FST = AA(3) - AA(1)	FAST0537
		D = -1.0	FAST0538
		K = 0 1	FAST0539
		00.334 (=1.3	FAST0540
			EAST0561
		1P(J.EQ.MEA.IGD 10 254	EAST0547
		D = -D	EACTOR/3
		K = K + 1	CARTO544
		ALD 411 = 1	FASTUS44
		$A(J_1) = D + FST/(AA(K+2) - AA(K))$	FASTU545
		AZ[[] = AZ[]] - AA(K)+A(J,[]	FAST0546
	234	CONTINUE	FAST0547
		G0 T0 290	FAST0548
c	CONS	E PARALLEL TO NEX-AXIS	FAST0549
-	235	CONTINUE	FAST0550
		XY = (AA(6) = AA(6))/(AA(5) = AA(3))	FAST0551
		YY = XX = A = A = A = A = A = A = A = A =	FAST0552
			FAST0553
			FASTOSSA
			EACTORES
		A211) = 11++2 - XA+(ARIL)++2 + ARI2)++21	FASTOSS/
		K = 0	FAS10330
		DO 250 J=1,3	FAS10557
		IF(J_NE_NEXIGO TO 240	FAST0558
		$A(J_{\tau}I) = 2 \cdot 0 + Y Y \qquad 1$	FAST0559
		A(j+3,1) = 1.0	FAST0560
		GO TO 250	FAST0561
	240	K = K + 1	FAST0562
		$A(J,I) = 2.0 \times X \times AA(K)$	FAST0563

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$\Delta(1+3,1) = -XX$
250 CONTINUE
60 TO 290
FULTETICAL CALINDER AND FULTESOID
255 NEY = 0
260 CONTINUE
K = -}
00 200 1+1.3
15/1.50.NEVICO TO 200
270 NTP(1) = 1 + 3
2.0 M(F(1) = 3 + 5
* AT 143-11 - 1.0/34(KA114#2
A(1,1) = -2.0#44(K)#A(1+3,1)
$A_{1} = -2.0 - R_{1} + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 +$
290 CONTINUE
DECTON DEETNITIONS
200 16/103 16 0100 10 200
151 - 110 151100110 FO 11551 - 0 6025/1 60707
17(NONTID.EQ.1773) = 0.002771.00177
CALL REAURI LDM; AUNI
-134(1) = 104(2)
KHU(1) * FS1*AUA(1)
00 305 J=1,3
505 XR(J)[] * AUR(J)]]
UU SIZ JELINDHAA
312 NS[31] * 0
NUU = AINU(NBAAX,9)
515 NS(J)[] = 2000+10/(J+5)
1 FINBMAX.LE.93 GU TU 320
IF(10H(12).611) GU 10 320
CALL READILINGMAX-0,NS19,111
DO 318 J=9,NBMAX
318 M313+11 = 1000+M313+11
320 CUNIINUE
330 IFIINA.LE.0368 IU 340
DU 334 L#1,NKMAX
DD 331 J=1,3
ADMEJI = XREJ,ET
ADM(J+3) = ADM(J)++2
K = J + 1 - 3 = (J/3)

331 ADH(J+6) = ADH(J)+XR(K,1)

FAST0564	
FAST0565	
FAST0566	
FAS10567	
FAST0568	
FAST0569	
FAST0570	•
FAST0571	
FAS10572	
FAST0573	
FAST0574	
FAST0575	
FAST0576	
FAST0577	
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FAST0592 FAST0593 FAST0594 FAST0595 FAST0596 FAST0597 FAST0598 FAST0599 FAS 10600 FAS 10601 FAST0602 FASTORDE FAST0604 FAST0605 FASTOGOG FAST0607 FAST0608

FAST0609

FASTORIO

00 333 J=1,NBMAX FASTOFIL DO 333 J-1,08AX IF(HS(J,I).EC.016G TO 334 K = KS(J,I)/1000 K = K - 10004(K/1000) MAX = NTP(K) NS(J,I) = 1000K F3T = A2(K) 32 CF = J-AAN FF(FT,L) = J-AAN FF(FT,L) = J-AAN FF(FT,L) = NS(J,I) = NS(J,I) + 1000000 33 CPUTING FAST0612 **FAST0613** FA5T0614 FAS10615 FAST0616 FAST0617 FAST0618 FAST0619 F45T0620
 333
 CONTINUE
 rasucs.

 334
 CONTINUE
 FASTO622

 340
 FIFINS.LE.0.100 10 370
 FASTO624

 100 360
 1-1,MRMAX
 FASTO624

 NGS = 1
 GONTANCE
 FASTO624

 100 500
 1-1,MRMAX
 FASTO624

 NGS = 1
 GONTANCE
 FASTO624

 200 FORAT LINGS+1,XR(1+11)
 FASTO626

 200 FORAT LIN,21LMB,39HEGONTRY ERROR, THE POINT IN REGION,15.18H ISFASTO629
 FASTO630

 2000 FORAT LIX,22LIM*) SHEGONTRY ERROR, THE POINT IN REGION,15.18H ISFASTO629
 FASTO631

 1 FINDS.01.0 REGION (5,22LIM*))
 FASTO630
 FASTO630

 NEGROR = KERRCR * 1
 FASTO630
 FASTO630

 1 FINDS.01.0 RD 70 350
 FASTO630
 FASTO630
 333 CONTINUE FAST0621 FAST0633 370 RETURN FAST0634 END FASTOG36 SIGFIC SOURSE N94/2;XR7 FASTOG36 CSOURGE+FIXED SOURCE INFUT AND NCRMALIZATICN FOR PROGRAM FASTER+T,JORDANFASTOG37 SUBROUTINE SOURCE(1,1,2,1,3,1,4,ELL,ELM,AE,BE,NSG,NPC,JSM,JSX,SUY, FASTOG36 L XTR,VEE,VAL,SPM,SPC,ISV,E,SCM,EBG,ENGI FASTOG40 DIMENSION ELL(1),ACH(1),BE(1),NG(1),NC(1,5,1),JSM(1),JSX(1),FASTOG41 L SUV(1),XTR(3,1),VEE(12,2,3,4,4),VAL(12,1,3,1,4),SPM(1),JSX(1),FASTOG42 2 SPELL,14),JSV(1),EE(1),EN(1),EBG(1),FAS(1),FASTOG41 ASTOG40 ASTOG END FAS10635 2 SPEILL, 14), ISVII, EII), ENII, EBGIII, ENGII) COMMON/LENEID/MI .X COMMON/LENEID/MI .X COMMON/LENEIS/ENERGE, NSPAX , NAMAX , NAMAX , NSTAX, I NEMAX , NYNAX , NXHAX , NXHAX , NAMAX , NSHAX, NI 2 NUNITX.NIMAX , NAMAX , NXHAX , NHAX, NLELAS, NTFANS, 3 NNMAX , NGMAX , NHAX , NYNDD , NFONAX , NNDAX , NXTAX , 4 NDAX , NGMAX , NGPENI, NGDEL, NGDAUG, NDDAUG, NSDAX, NYOMAX , NUNDEL, NGDEL, NGDEL, NGDAUG, NDDAUG, NSDAX, 6 SMON/INPUTS/NI, NJAI, NJAIMAS, NGDEL, NGDEL, NGDEL, NGDEL, 6 SMON/INPUTS/NI, NJAIMA, NJAIMAS , NGL, NJAIMA, NJAIMA , NJAIAX , NIALAS, NJAIMA 6 SMON/INPUTS/NI, NJAIMAS, NJAIMAS, NGL, NJAIMA, NJAIMA , NJAIMA , NJAIMA 6 SMON/INPUTS/NI, NJAIMAS, NJAIMAS, NGL, NJAIMA, NJAIMA, NJAIMAX , NJAIMAS, NJAIM FAST0644 FAST0645 FAST0646 FAST0647 ٦ FAST0668 FAST0649 5 FAST0650 FAST0651 FAST0652 LUMADA/INPOIS/INL/102/IN3, IF(IN2.LE.O)GO TO 330 CALL READE(NEMAX+1,ELL) DO 10 I=1,NEMAX ELW(I) = ELL(I) - ELL(I+1) FAST0653 FAST0654 FAST0655 FASTOSS AE(1) = 1.0 FAST0657



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	10	BE(1) = 0.0	FAST0658
c	TOT	AL SOURCE, ERRGR CRITERION, TRANSLATION VECTOR	FAST0659
	330	(F(1N3.LE.0)60 TO 505	FAST0660
		DO 430 NNN=1, IN3	FAST0661
		CALL READRIIDH.ADHI	FAST0662
		VOLUME = 1.0	FAST0663
		I = (DM(1))	FAST0664
		NSG(1) = IDP(2)	FAST0665
		N TR NSG(1)	FAST0666
		D0 405 J=1.5	FAST0667
		MAX = IDM(J+2)	FAST0668
		IF(MAX.GT.0) GO TO 299	FAST0669
		K = -HAX	FAST0670
		HAX = NPC(J+K)	FAS10671
		D0 200 L=1, KAX	FAST0672
		VEE(L,J,I) = VEE(L,J,K)	FAST0673
	200	VAL(L,J,I) = VAL(L,J,K)	FAS10674
		NPC(J+1) = MAX	FAST0675
		IF(MAX - 11 405,405,21C	FAST0676
	299	NPC(J+I) = MAX	FAST0677
		CALL READEE(MAX, VEE(1, J, 1), VAL(1, J, 1))	FAST0678
		[F(MAX.LE.1)GD TO 405	FAST0679
		FST = 0.0	FAST0680
Ċ		00 987 K=1, MAX	FA510681
c		$IF(VEE(K,J,{I},EQ.0.0) VEE(K,J,I) = I.0E-30$	FAST0682
С	987	CONTINUE	FAST0683
		QO 395 K=2, MAX	FAST068A
		BB = 0.0	FAST0685
		∠AB ★ 0.0	FAST0686
		[F{VEE[K, J, 1].EC.VEE(K-1, J, 1]} GO TO 395	FAS10687
		$BB \approx \{VAL(K,J,I) = VAL(K-1,J,I)\}/(VEE(K,J,I) = VEE(K-1,J,I)]$	FAST0688
		AB # VAL(K+J,11 - BE#VEE(K,J,1)	FAST0689
	395	FST = FST+AB*(VEE(K,J,[]**(N+1) - VEE(K-1,J,I)**(N+1))/FLOAT(N+1)	FAST0690
	1	+88*(VEE{K,J;[]**{N+2} - VEE(K-1,J,I)**(N+2})/FLUAT(N+2)	FAST0691
		DO 400 K=1, MAX	FAST0692
	400	VAL(K,J,I) = VAL(K,J,I)/FST -	FAST0693
	210	CONTINUE	FAST0694
		$IF(J_LE_3)VOLUME = VOLUME*(VEE(MAX,J_E))**(N+1)-VEE(1,J,E)**(N+1))$	FAST0695
	405	N = 0	FAST0696
		ISP = [DR110]	FAST0697
		HAX = IOH(8)	FAST0698
		1F(MAX.GT.01GO 10 29P	FAST0699
		K = -MAX	FAS10700
		JSN(() = JSN(K)	FAS10701
		P2x(1) = P2x(k)	+ AST0702
		FSI = 0.0	FAS10703
		EST # 0.0 ·	FA510704

	DO 220 J=1,NEMAX	FAS T0705
	SPW(J,[] = SPW(J,K)	FAST0706
	SPE(J,I) = SPE(J,K)	FAST0707
	FST = FST + SPN(J,1)	FAST0708
	220 EST = EST + SPW(J+I)=SPE(J+I)	FAST0709
	GO TO 297	FAST0710
	298 CONTINUE	FAST0711
	IF(ISP.GT.11 GO TO 100 '	FAST0712
С	INPUT SPECTRUM IS DIFFERENTIAL IN PARTICLES OR INTENSITY	FAS10713
	IF(IDM(111.GT.0) GD TO 600	FAST0714
	CALL READEE(MAX, E, EN)	FAST0715
	GO TO 601	FAST0716
	600 IF(IDM(11).EQ.2) CALL READE(MAX.E)	FASTOTLT
	CALL READE(MAX,EN)	FAST0718
	601 CONTINUE	FAST0719
	IF(ISP.LE.0)G0 T0 354	FAST0720
С	DIFFERENTIAL IN INTENSITY	FAST0721
	00 350 J=1,HAX	. FAST0722
	350 EN(J) = EN(J)/E(J)	FAST0723
	GO TO 354	FAST0724
c	INPUT SPECTRUM IS GROUPHISE INTEGRATED, MAX = NC. GROUPS	FAS10725
	100 IF(IBM(11).EQ.0) G0 10 351	FAST0726
	IF(IDA(III.EQ.2) CALL READE(MAX+1,EBG)	FAST0727
	CALL READE(MAX,ENG)	FAST0728
		FAS10729
	351 GALL READEE(MAXY1;EHG;ENG)	FASTUTIO
		FASI0731
-	TELISPIEQUELO DO 333	FASIUTSZ
c	TOTAL DEV IN UNDERT DIVIDE OF AVERAGE ENERGY	FAS10733
	DU 322 J-1+08A	FAS10134
c .	TOTAL DABLELES IN COMPANY LEDGED - CIVIDE BY COMPANY	EAS10733
۰.	ISE V = A	EAST0737
		54CT0738
	$FSI \approx ENG(J)/(EBG(J) - EBG(J+1))$	FASTO739
	00 353 1 = 1 - 2	FAST0760
		F4510761
	M = j + L - 1	FAST0742
	E(K) = EBG(M)	FAS 10743
	353 ENIKI = FST	FAST0744
	MAX = K	FAST0745
	354 FST ≈ 0.0 .	FAST0746
	EST = 0.0	FAST0747
	JSN(1) = NEMAX	FAST0748
	JSX(1) = 1	FAST0749
	DO 415 J=1,NEMAX	FAST0750
	SPW(J,1) = 0.0	FAST0751

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;

		-	
		SP[[],1] = 0.0	FAST0752
		DO 410 K=2,MAX	FAS10753
		EMax = AMINIIELL[J], E[K-1])	FAST0754
		EMIN = AMAX1(ELL[J+1])E[K])	FAST0755
		IF(EMIN.GE.EMAX)GC TO 410	FAST0756
		BB = (EN(K-1) - EN(K))/(E(K-1) - E(K))	FAST0757
		AA = EN(K) - BB + E(K)	FAS10758
		DEL = (FHAX*+? - [HIN*+2]/7.0	FAST0759
		SPW(J,1) = SPW(J,1) + AA+(EMAX - EMIN) + BB+DEL	FAST0760
		SPE(J,1) ≈ SPE(J,1) + AA+DEL + BB+(EMAX++3 - EMIN++3)/3.0	FAST0761
	410	CONTINUE	FAST0762
		IF(SPW(J,1).EC.0.0)GC TO 415	FAST0763
		$(L_{1}) = (L_{1}) + (L_{1}) + (L_{1})$	FAST0764
		$(L_{1}) = (1) \times 2L$	FAST0765
		$FST = FST + SPW(J_1)$	FAST0766
		EST = EST + SPE(J,1)	FA5T0767
		SPE(J,1) = SPE(J,[}/SPW(J,1)	FAST0768
	415	CONTINUE	FAST0769
	797	CONTINUE	FAST0770
		D0 420 J=1,3	FAST0771
	420	XTR[J, } = ADH[J+1]	FAST0772
		EAVE = EST/FSJ	FAST0773
		[F([DH(9] - 1) 421,422,423	FAST0774
С	NDA	MALIZE TO TOTAL PARTICLES	FAST0775
	421	FST = ACH(1)/FST	FASI0776
		SUV(I) = ADH(1)*EAVE	FAST0777
		GQ TO 424	FAST0778
С	NOR	HALIZE TO TOTAL NEV	FAST0779
	422	FST = ADM(1)/EST	FAST0780
		SUV(T) = ADP(1)	FAST0781
		GO 10 424	FAST0782
С	SCA	LE INPUT SPECTRUM	FAST0783
	423	FST = ADH(1)	FAST0784
		SUV(I) = ADM(1)*EST	FNST0785
	424	CONTINUE	F4ST0786
		DU 425 J=L.NENAX	FAST0787
	425	SPR(J,I) = FST*SPR(J,I)	FAST0788
	430	LUNIINUE	FAST0789
	505	IP(IN4.GI.D)CALL READISTIN4,ISVI	FAST0790
		UU 510 1ª I, NKMAX	FAST0791
		$F(1)V(1)$, $G(1)V(A)V(1)V(1) \neq 0$	FA510792
	510	CUNTINUE	FAS10793
		KETOKN	FAS10794
			FAS10795
5	1851	G ASEGI - MY4/21AR/ CTACDOS - SCTIDN ANDUT AND MINING FOR ADARAM SIGTERAT N ADARMAN	FA510796
6	1425	CUPCKUSS SECTION INPUT, AND MEALING FUR PROGRAM PASTER#1.4.30RDAN*66	-FAS10797
		SOBROOTINE INSECTILITESTESTESTESTESTESTESTESTESTESTESTESTEST	FA510798

LSGS, MTL, RHD, XST, ATD, JHX, XSE, XSI, EAC, ELL, L7) LSGS, MTL, RHO, XST, ATD, JNX, XSE, XSI, FAC, ELL, L7)
DIMEMSION ADMEDI
EQUIVALENCE FADMEDI
EQUIVALENCE FADMEDI, SSHI1, SSCI1, SSC FAST0799 FASTOBOO FASTOBOL FASTORDZ FAST0803 FAST0804 FAST0805 FAST0806 FASTOBO7 FASTOBO8 FAST0809 FAST0810 FAST0811 FASTOR12 6 NPRINT,NUNITS,NUMBER,KALIDE COMMON/INPUTS/IN1,IN2,IN3,IN4,IN5,IN6,IN7,IN8,IN9,IN10,INN(14) FASTOB13 FASTOB14 CUMMON/INPUTS/IN.IN., IN2, IN3, IN4, IN5, IN6, IN DIMENSION XSET(2) EQUIVALENCE (XSET11), XMB), (XSET[2], FST) IF(IN2.GT.OICALL REACE(NENAX, ESB) IF(IN3.LE.OIGO ID 210 FAST0815 FAST0816 FAST0818 FAST0817 FAST0818 FAST0819 FAST0820 IFING.LEIGIGL VEALEINENAAFESD IFING.LEIGIG DO 20 NERN = NEHOD - NXSECT 00 10 IFI.KHNAX 05 NI I = 0.0 00 10 J.I.KENIN 10 SUTIJ.II = 0.0 00 20 J-I.KENIN 00 CONITMUE IFINELAS.GT.01 CALL ZEROUT(INELAS*KMHAX.IDI) CALL ZEROUT(INLOS) 50 NUMOO = INI + 1 CALL ZEROUT(NEMOON/NIMAX+MMHAX),EAC) NN = 1 00 20 J-I.KIMAX FAST0821 FASTORZZ FAST0823 FAST0824 FAST0825 FAST0826 FAST0827 FASTOBZE FAST0829 FAST0830 FAST0831 FAST0832 FAST0833 FAST0834 FAST0835 FAST0835 FAST0836 FAST0837 FAST0838 FAST0839 FAST0840 DO 200 1=1, NIMAX MOD = HINO(8,NHHAX+2) CALL READE(NOD,ADN) MO0 = HOD - 2 D0 65 J=1+HOD FASTOB41 D0 65 J=1:HU0 ATOLJ = ADMLJ+21 IF(NUNIAX.GT.6]CALL READE(NHMAX~6,ATD(7)) IF(NUNITD.EQ.0]GO TO 85 FST = 0.6025/ATM FASTOR42 65 FAST0843

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FAST0844 FASTOB45 Astronuclea

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	50 75 / / University	F . F 700//
	DU /S J=LINAPAX	FASTUG40
	75 ATD(J) = FST#ATD(J)	FAST0847
	85 CALL READEINENIN.XST1	FAST0848
	LEININITY EO DIGD TO 105	FASTORAS
		CASTORSO
	F31 < A1870.0023	FASTOBSO
	DO 45 Jal, NEMIN	FASTURST
	95 XST(J) = FST+XST(J)	FASTOR52
	105 IF(NXSECT.GT.0) GO TO 105	FAST0853
C I	COMPTON ENERGY ABSORBIION CREEFICIENT	FA5T0854
	00 104 1-1.5500	EAST0855
		EACTORES
		F#310090
	XAB = 1.0 + 2.0*XAA	FASTURDI
	LU6 EAC(J, I)*ELL(J)*(XST(J)-0.249375*ZEE*(ALOG(XHB)/XHA**3*2.0	1#(1.0+ FASTUR58
	1XMA)*(2,0*XHA**2-XMB)/(XMA*XHB)**2+8.0*XMA**2/(3.0*XHB**3)	FAST0859
	109 IF(I.GT.1) GO TO 125	FAST0860
	DD 115 Jal-NEBIN	FASTORA
	115 554(1) - 757(7)	EASTOR67
		FA310602
	TPENKSECFICC.01 GO TO TOO	FASTURES
	DO 116 J#1,NEMOD -	F4510864
	EAC(J,[] = 0.0	FAST0865
	$IF{J_GT_1} EAC{J_1} = SSH{J-1}$	FASTOB66
	$If(J_LT_NEMOD) = AC(J_I) \approx EAC(J_I) + SSH(J)$	FAST0867
	116 FAC(1-1) * FLL(1)*FAC(1-1)/6-0	FASTORAS
		EACTORNO.
		FR310807
	125 IFINXSECT.EQ.0160 IU 100	FASTURIU
	MOD = MINU(24,INELAS+3)	FAST0871
	CALL READI(MOD_JHX)	FAST0872
	NSIGT = 1	FAST0873-
	IF(JMX(1),GT=0) NS(GT = 0	FAST0874
	1 MAX = 1 ABS(1) MX(1)	FAST0875
		EAST0076
		FASTOSIO
		FASTUBIT
	LFIKHAX-GI-21)CALL READI(KHAX-21, JHX125))	FAST0878
	DO BO L=1+LMAX	FAST0879
	DO 80 K=1,NDSH	FASTOBBO
	BO CALL READE(NEMAX+1-K.XSE(1.K.L))	FAST0881
c	TRANSPORT CORRECTION OF P-ZERO IN GROUP FROM P-ONE SCATTER	EASTOR92
-	XHA = ATW/(1-OP(ATW + 1-O)PA2)	EASTORES
		FAS10083
	IF HORITALGI UJ APA - APA-RIR/U.8023	FA510884
	LRUD # HIND(2,CRAX)	FAST0885
	DO 82 J=1+NEMAX	FASTOB86
	FST = 0.0	FAST0887
	XNB = 0.0	FASTORBB
	NDSHOD = MINO(NDSH, NEHAX+11)	FASTORBO
	00 181 1 -1 -1 #00	ENSTOOD
		LY2108AD
		PASIOBAL
	SI XSEVILI = XSEVILI + XSEVJ,K,L)	FAST0892

		XMUL = FST/(3.0*XMB)	 FAST0893
		XHUC × XHUL**2 - 1.0	FAST0894
		XHUC = (XHUC + XHUL+SORT(ATH++2 + XHUC))/ATH	FAST0895
		FACT I. T XHANYNRAIL.G . YNUCS	EASTORA
		IEIIWAY CT HORDERS YEEII S IS - YEEII S IS - ECT/2 O	EACTORD 7
		f = f = f = f = f = f = f = f = f = f =	FAS10077
			FA310698
	82	CONTINUE	FAS10899
			PASTUGUU
		LMAX = MINU(MUKUEK+LMAA)	FA510901
		KMA = 0.0	FAST0902
		DO 397 J×1, NEMOD	FAST0903
		XHB = 0.0	FAST0904
		IF(J.LT.NEHOD) XHB = EAC(J,I)	FAST0905
		EAC(J,[] = ELL(J)=(XNA + XMB)	FAST0906
	397	XMA = XMB	FAST0907
		IF(KMAX+LE+OIGO TO 398 -	FAST0908
C	INE	LASTIC TRANSFER	FAST0909
		DO 90 K=1,KMAX	FAST0910
	90	CALL READE(JMX(K+3),XSI(1,K))	FAST0911
	398	DO 117 J=1,NEMOD,NEMAX	FAST0912
	117	EAC(J,11 = 2.0*EAC(J,1)	FAST0913
С	CON	BINE MATERIAL TOTALS	FAST0914
	100	DG 190 H=1+NKHAX	FAST0915
		1F(ATD(H), F0.0.0360 T0 190	FASTORIA
		DO 110 Jal AFRIN	EASTON 7
	110	SGT(J.M) a SGT(J.M) + ATC(M)AYST(1)	FASTORIA
	••••	I = NIMAY + N	EASTONIO
		00 111 1x1 NEMOD	FAST0717
	111	EAC(1,1) = EAC(1,1) + ATO(N) = EAC(1,1)	FA310420
		IEINVEET OF ALCO TO 130	FR310921
			F#310922
		00 TO 100	FASTO923
			FAS10924
	150	17(1.61.1)G0 10 130	FAS (0925
			PAS10926
		00 10 140	FAST0927
	130	GST = AID(H)	FAST0928
		IFINUNITA.NE.UIGST # GST#ATE/0.6025	FAST0929
		DU 165 L=1.LMAX	FAST0930
		DO 165 K=1,NDSM	FAST0931
		MM = IDELK,L.MI	FAST0932
		MAX = NEHED - K	FAST0933
		IF (MM.GT.O) GO TC 140	FAST0934
		MK = NN	FAST0935
		NN = NN + MAX	FAST0936
		IDE(K,L,N) = NN	FAST0937
	140	IF((NM + MAX).LE.NNHOD) GD TO 150	FAST0938
		NERROR = NERROR + 1	FAST0939

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		GO FC 165	FA5T0940
	150	DD 160 .1≈1.HAX	E45T0941
	160	\$G\$(1, NM) = \$G\$(1, MH) + G\$T#X\$F{1,K,11	FAST0942
	145		E1510042
	100		FAST0945
		IFIRMAX.CE.UIGU IL 190	FA510944
С	INEL	LASTIC NEXT	FAST0945
		DO 185 X=1+KFAX	FAST0946
		HH1= IDI(K,H)	FAS10947
		(E+X)XHL = XAH	FAST0948
		[F(NN1.GT.0) GD TO 170	F4570949
		HK = NN	FAST0950
		NN = NN + STNDINTRANS_NEHDD-V1	EASTONEL
			FAST0751
			FAST0952
			FA510953
	110	RA = ART/1000	FAS10954
	173	IDI(K, H) = 1000+RM + HAXO(HAX, HH1-1000+HH)	FAST0955
		[F((HM + HAX).LE.NANCO) GO TO 175	FAST0956
		NERROR = NERROR + 1	FAST0957
		60 10 185	FAST0958
	175	DD 180 J=1. MAX	FASTORSO
	180	SGSLL NN) # SGSLL NH) + GSTexSILL K)	FACTOR60
	205		FAST0900
	103	CONTINUE	PASTUADI
	140	CONTINUE	FAS10962
	200	CONTINOF	FAS10963
	390	CONTINUE	FAST0964
		NNMAX = NN ~ 1	FAST0965
		IF(LABEL(1).GE.O) WRITE(M2.200C)NNMAX.IN1	FAST0966
	2000	FORMAT(1X,19(1H+),34HSCATTERING CROSS SECTIONS REQUIRED,16,3H OF,	FAST0967
		116,20H AVAILABLE LOCATIONS,19(1H+1)	FAST0968
		LE(IN6-1E-0) G0 1E 210	EASTINGAG
		DD 510 1=1. NSKAY	EAST0070
			FAST0710
		bo Job J-trentite	FAST0771
		HAA = RINULJ + /,RCHIN/	FA510972
		IFILABEL(1).GE.0) WRITE(#2,300011,(SGT(K,1),K=J,HAX)	FAS10973
	3000	FURMATIIX,6HSIGMAT,15,1PBE12.41	FAST0974
	500	CONTINUE	FAST0975
	510	CONTINUE	FAST0976
		HAXR = NIMAX + ³ NHMAX	FAST0977
		DO 530 1=1.MAXR	FAS10978
		x = [FAST0979
		IF(X.GT.NIRAY) K = K - NIRAY	EASTORRO
		00 520 L=1.KENDD.4	EASTOPAL
		HAY # NISOTI A TAEKODI	FAST0901
		The second of the second second second to the second	LA210A85
		17(LADEL111,GE,U) XKIIE(A2, JULU/K+(EAU(L+1)+L=J+MAX)	FAS10983
	3010	FUXMAI (1X+6HE-DUMP,15+1P8E12+4)	FAST0984
	520	CONTINUE	FAST0985
	530	CONTINUE '	FAS10986

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510 11	LING.GT.OICALL READISTING.NTLI	C
(F	(IN5.LE.0)GD TO 250	FAST0987
16	(NUNITD.E0.0100 TO 210	FAS10988
FS	T = 0.6025/1.00297	FAST0989
00	220 1#1-NERAY	FAST0990
220 BH	0[1] = 800/11/55Y	FAST0991
230 64		FAST0992
100 04		FAST0993
		FAST0996
240 84	240 LT1,NKRAX	FAST0995
240 60		FASTO996
200 KE	TORN	FASTOROT
EN	B	FASTOODA
SIBFIC A	SKFOR M94/2,XR7	F4670000
CRESULT	RESPONSE FUNCTION AND DETECTOR INPUT FOR FASTER*T.M. TORDAN#VAND	FA310999
su	BROUTINE RESULTILI, L2, NTG, ELF, FGW. TDS . RSP . IDR . IDS . VDI . CBT . VDY	-FAS11000
151	L+MTL,RHD,EAC,L3)	CASILOUI
C D	HKON/LIMITS/NSTORE, NERROR, NSMAX , NAMAX , NEMAY , NEMAY , NETHING	FASILUOZ
1	NEMAX INVMAX INXMAX INXEMAX NEMOD INVEET NUMERA	FAST1003
2	NUNITX-NIMAX -NUMAX -NODER NOOVA - TASE CONTING	FAST1004
3	NNKAX NGHAX NEWAY NUMOD NCHAY HIGHAS NIKANS,	FASTLODS
4	NONAX NGHOD HOWENT NORD HOUNAY HERAX , NIBAX ,	FAST100%~~
5	NYDHAX-NYDHOD-NOCIAL HORSE - HODELO - HODELO - NSDHAX-	FASTLOD7 .
6	NPRINT, NUNTTS, NUMBER VALUE, MODELY, MODELU, MODELY,	FAST1008
C0	KNON HII)	FAST1009
C0	HON/BEGSCA/NSPNAY, INCO	FAST1010
CO.	ANDN/INDEVS/ADDIN/261 TIDU ADDIN/261	FAST1011
nt.		FAST1012
01	$\frac{1}{2} = \frac{1}{2} = \frac{1}$	FASTLOLS
,	HIGT IT FETTING IN IN ISTANIA RSP (L1, L2), IDR(1), IDS(1),	FAST1014
·	ENT (0) (0) (1) (0) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1	FASTIOLS
	HON (ADA(/), BDF(3), IDR(3)	FAST1016
00	HOW TAPEID/RI , H2	FASTIGL7
10	HOR/INPORT/INL, IN2, IN3, IN6, IN5, IN6, IN7, IN8, IN9, IN10, INN(14)	FASTIOLS
100	NGRALLINERAXIGU TO 20	FAST1019
10 10	10 1=1,NEAX	FASTIOZO
20 10		FAST1021
20 100	INZ.GI.DJ CALL READIINEMAX, NTG]	FAST1022
30 201	114 = ELC(1)	FAST1023
00	40 I=1,NE#AX	FASTIOZA
J =	NTG(1)	FAST1026
40 ELF	(J+1) = ELL(1+1)	FASTIOZE
00	50 I=1,NGHAX	EAST1020
50 FG1	([] = ELF(]) - ELF(]+1) +	EAST1027
60 IF(1N3.LE.01G0 TO 120	FAST1028
00	110 N=1, IN3	FAST1029
CAL	L READF(IDH, BDF, ADH)	FA511030
1 =	TDH(1)	FAST1031
00	70 J=1+3	FAS11032

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	•	
70	TOS(J,1) = BDH(J)	FAST1034
	IF(IDH(2).GE.0) GC TO 75	FAST1035
	J = -(DH(2)	FAST1036
	N = HTL[J] + NINAX	FAST1037
	RSP(1,1) = RHO(J) + EAC(1,1)	FAST1038
	[F(H.GT.NIMAX) RSP(1,1) = RSP(1,1) + EAC(1,H)	FAST1039
	DO 11 K=1.NEMAX	FAST1040
	L = NTG(K)	FAST1041
	RSP(L+1,1) = RHO(J)+EAC(K+1,1)	FAST1042
	IF(M,GT,NIMAX) RSP(L+L,I) = RSP(L+1,I) + EAC(K+1,H)	FAST1043
- 11	CONTINUE	FAST1044
	- 1F(LABEL(1+NGMOD/7).GE.D) WRITE(M2,2000)(RSP(J,1),J=1,NGMOD)	FAST1045
2000	FORMAT(1x,11HENERGY DUMP,1P8E12.4)	FAST1046
	GO TO 95	FAST1047
75	CONTINUE	FAST1048
	MAX = MINO(5,NGMOD)	FAST1049
	DO RO J=1, MAX	FAST1050
80	KSP(J,[] = AUN(J+1)	FAST1051
	IFINGMUD.GI.SICALL READE(NGRUD-5,RSP(6,1))	FAST1052
	IF(IDA(2).FG.0)GU (U 100	FAST1053
	00 90 J=LeNGFUD	FAST1054
		FAST1055
100		FASTLUSS
110	PSD/1.11 = ADW/1140CD/1.11	FASILUSI
120	1F(1N4.15.01C0 T0 552	FAST1055
	DO. 130 1=1.3	FAST1057
130	$BDH(I) = D_{-}O$	FAST1060
••••	D0: 150 N=1.1N4	FAST1062
	CALL READS(IDK, ADH)	FAST1063
	T = 10H(1)	FAST1064
	IDR(1) = IDM(2)	FAST1065
	IDS(1) = IDH(3)	FAST1066
	VOL(1) = ADH(1)	FAST1067
	DO 140 J=1,3	FAST1068
	CDT(J,I) = ADH(J+1)	FAST1069
140	XDT(J, E) = ADH(J+4)	FAST1070
150	FST = VECTOR(BDH,COT(1,1),CDT(1,1))	FAST1071
552	NPOMAX = 0	FAST1072
	NVDMAX = 0	FAST1073
	DU 556 1=1, ADRAX	FA5T1074
	18(10x(1).61.0160 10 554	FAST1075
	NPUMAX = NPUMAX + 1	FAST1076
	ULIU DOG	· FAST1077
554	ITTIDSTIJALEAUIRYDRAA = RYURAA + 1	FAST1078
220	NUTRIC - NORAY - NORAY	CAST1000
	TTPOVV - NUCAA - OFVICAA	FA211080

NSDMAX * NVDMOD - NVDMAX	FAST1081
NPOHOD = NPCKAX	FAST1082
	EACTIOR3
	C.C.T. 000
IF(ING.GI.U) CALL READIONSRMAX.H(I)]	FA511084
RETURN	FAST1085
END	FAST1086
	EACTION?
SIBFIC RANDRA H9472+ART	FA311007
CRANDOM+SAMPLING PARAMETER INPUIS FUR PROGRAM FASTER=I.R.JUKDAN+MANL=66	+FA211088
SUBROUTINE RANDOM(RSI.ALP.VMD.GIN.AIN.ALM.ALH.NPC.VEE.L1.L2)	FAST1089
DINENSION NOC 15.11. VEE411.12.111.847(5)	64571090
	EASTIONI
DIMENSION RELETIONED STORATE A INTERACTOR	FA311071
COMMON/TAPEID/M1 ,M2	FAS11092
COMMON/OTHERS/RADIUS+XCT(3)+DELTA +BDC(3)+ATA +AT8 +ATC +	FAST1093
ATO AT BT AS BS MIN INAX -	F45T1094
	EASTIONS
Z RATH TREAK IJDAR TAZERU	FA311075
COMMON/LIMITS/NSTORE,NERROR,NSMAX ,NAMAX ,NRMAX ,NBMAX ,NSMAX,	F#211046
I NEHAX ,NVMAX ,NXMAX ,NXEMAX,NEMOD ,NXSECT,NUNITD,	FAST1097
2 NUNITY, NTRAY, NHEAY, NURDER, NURWA, INELAS, NTRANS,	FASTIOGR
	EASTIONS
3 ARAAA FROMAA FREMAA FREMAA FREMAA FREMAA FREMAA F	FA312037
4 NDMAX +NGRUD +MOPENT +NDMOD +NPDMAX +NPDMOD + NSDMAX +	FAST1100
5 NVDHAX, NVDKOD, NPCINT, HODELP, HODELQ, MODELU, HODELV,	FAST1101
6 NPRINT-NUNITS-NUMBER-XALIDE	FAST1102
COMPONITION TO THE	CACTURE
COMON/10/013/1011102/103/103/103/100/10/100/10/10/100/100/10	PASILIOS
IFTINZ.GT.OJCALL READEIB, RADIUSI	FASIL104
IF(IN3.GT.O)CALL READE(NVMAX,RSI)	FAST1105
LE(NODELP.GT.G)GO TO 30	FAST1106
TE (BY HAY EO 1) CO TO 20	
	C1071107
FSI = 0.0	PASILLUI
DO, LO I×1,NVMAX	FASTILOB
10 FST = FST + RS1(1)	FASTL109
DO 20 INLANAX	E45T1110
20 051(1) + D51(1)/EST	FACTINIS
	5.67.1111
30 [FTIN4.22.0]GU 10 143	PASILITZ
DD,560 I=1,NVMAX	FAST1113.
CALL READE(5,VHD(1,1))	FAST1114
CALL READERS.RATI	FASTINIS
	EACTING
00 40 3-115	CASILLIO
ALP(J, I) = 0.0	FAST1117;.
K = NPC(J.I)	FAST1118
IF(K_FQ_1)60 TO 40	FAST1119-
A1 P(1, 1) = -A1 (G(BAT(1))	FAST1120.
	E4571231
2 / MORALLUDUJII-VEELLJJIIJVEELK +J+1)-VAU(J+1)	FA311121.
40 CUNTINUE	FAS11122
560 CONTINUE	FAST1123
793 IF(INS-GT.O)CALL READE(NEMAX-GIN)	FAST1124
TELING GT OICALL READEINEMAX AIMI	FAST1125
	FACT152/
triture cervico la co	CM3(1120.

(K)
Astronuclear Laboratory

	•	
	CALL READE(NEMAX, ALM)	FAST1127
	DO 50 1=1.NEMAX	FAST1128
50	A(N() = 0.5+AL(G(ALH())	FAST1129
60	LE(INS.LE.0)G0 T0 80	FASTILIO
	CALL READE (NEWAY, ALK)	FASTILI
	DO TO Lal NENAY	FASTILIZ
70	a(y(t) = 0 cash of (a) y(t))	FA311132
		FAST1133
80	1FILM94CE30160 10 40	FA511134
	CALL READELS ATA	FASILISS
	ATA = ALUGIATA?	FASILISE
	A18 # -ALUGIA181/3+141596	FASILLSI
90	RETURN	FAST1138
	END	FAST1139
\$18FT	L EREAD M94/2+XR7	F.1ST1140
CREAD	E *INTEGER INPUT, 2413 FCRMAT	FAST1141
	SUBROUTINE READI(MAX, IDN)	FAST1142
	COMMON/TAPEID/H1 ,M2	FAST1143
	DIMENSION IDM(10000),H(2)	FAST1144
	DO 30 I=1,MAX,24	FAST1145
	NOD = 1 + 23	FAST1146
	TELNOD.GT. NAX1GO TO 10	E45T1147
	READ(N1.1000)(IDN(J).J=I.NOD).H	FAST1148
	60 10 20	FASTINAS
10	SNY # HOD - HAY	EASTILED
		EASTINE
	READ(W) - 10001(10W) [] - bet - 8001. (8 . Set - 1891. 18	FASTLIST
20		FAST1152
20	CONTINUE	FASTILIS
1000	CONVERSION AND AND AND AND AND AND AND AND AND AN	PASILIS
1000	FURNAL (24(3)284)	PASTLISS
2000	FUKMAI [1.K. 2 A9 201 + 2419]	FAS11150
	RETURN	FASTL157
	END	FAST1158
\$1BFT	C EREAD N94/2, XR7	_FAST1159
CREAD	E *FLOATING INPUT, 8E9.0 FORMAT	FAST1160
	SUBROUTINE READELMAX, ADM)	FAST1161
•	CONHON/TAPEID/H1 +H2	FAST1162
	DIMENSION ADM(10000),H(2)	FAST1163
	DO 30 I=1,MAX,8	. FAST1164
	HOD # I + 7	FAST1165
	IF(MOD.GT.MAX)GO TO 10	FAST1166
	READ(H1,1000)(ADH(J),J=1,HOD),H	FAST1167
	GO TO 20	FAST1168
10	JHX = KOD - HAX	FAST1169
	HDD - MAX	FAST1170
	READ(M1.1000)(ADM(J).J=1.MOD).(X.J=1.JMX).H	FAST1171
20	IF(LABEL(1).GE.01WRITE(N2.2000)H.(ADH(1).J=1.NOD)	FAST1172
30	CONTINUE	FASTINT
50		1 83 121 13

1000 FORMAT(8E9.0,244)	FAST1174
2000 FORMAT(1X,244,3H,, 1P8E12.4)	FAST1175
RETURN	FAST1176
END	FAST117T
- STRETC AREAD N94/2.XR7	FAST1178
CREADA ANDIS FRITH INPUT. 1844 FORMAT	FAST1179
	FAST1180
	FAST1181
	FAST1182
	FASTILB3
	FAST1184
ref = 1	FASTLINS
	FASTIIRA
	FAST1187
	EASTIIRE
10 JAX = AUD - RAX	CASTINO
	FA311107
READ(H1, 1000) (AUH(J), J=1, AUD); (X, J=1, JAX); A	FA311190
20 [F(LABEL(1).GE.0) WRITE(A2,2000)H, LADA(31.3*1,A00)	FAST1171
30 CONTINUE	PASILLYZ
1000 FORNAT (2044)	FASTILYS
2000 FORMAT(1X,244,27(1H,),1844)	FAST1194
RETURN	FAST1195
END	FAST1196
\$IBFTC ISREAD M94/2,XR7	FAST1197
SUBROUTINE READIS(HAX, TOH)	FASTL198
DIMENSION [DH(10000], JDM(2, 12]	FAST1199
DO 10 1=1, MAX, 12	FAST1200
MOD = MINO(12, MAX+1-1)	FAST1201
CALL READI(2#NOD-JDK)	FAST1202
BO 10 Ja1+86D	FAST1203
K = 10H(1-1)	FAST1204
10 + 10 + 10 + 10 + 12 + 11	FAST1205
	FAST1206
END	EAST1207
ENU *19575 159540 896/2.997	FAST1208
PURDOUTINE DEADLETHAY, TOH, ADH)	EAST1209
	EAST1210
	EAST1211
	EXETIONS
	EACT1212
	FAST1215
17100.61.MAX/60 10 10	FA311214
KEAU (AL, LOUGICIDACJI + AUA(JI + J= L + RUDI + R	FAST1217
GU 7U 2U	FASILZIO
10 JAX & AUD - PAX	FASILZIT
MOD = MAX	FAST1218
READ(ML, 1000)(IDM(J), ADM(J), J=1, MUD1, (K, X, J=1, JHX), H	FA511219
20 IF (LABEL(1),GE.01WRITE(M2,2000)H, [IDM(J),ADN(J),J=I,MO)) FAST1220
· ·	

30 CONTINUE	FAST1221
	Excelana
1000 FURNAI (6(13+69-0)+244)	PASILZZZ
2000 FORMAT(1X,2A4,3H,6[14,1PE12.4))	FAST1223
RETURN	FAST1224
5400	EACT1726
END	FAS11225
SIBFTC ESREAD M94/2.XR7	FAST1226
SUBROUTINE READES(HAX.ADH)	FAST1227
DINENCION ADDILADOOD TOWICE PORCE	EACT1320
	C.071220
00 10 1=1,KAX+6	PASILZZY
MDD = HINO(6.HAX+1-[]	FAST1230
CALL READIE (800.108.808)	FAST1231
	EACT1212
K = IDK(J)	PAS11233
10 ADM(K) = 80M(J)	FAST1234
DETINON	FAS11235
	FLOTION.
END	FADILEDO
\$18FYC EEREAD M94/2+XR7	FAST1237
CREADEFAILTERNATING FLOATING INPUT, RES.O FORMAT	F45T1239
CHEDDUITING DEADEELHAY, ADM, 6DM3	E4571240
SUCRUCITAE READELTAX, ADDIGONI	FASTLETO
DIMENSION ADA(100007,804(100007,604(2,4)	FA5(1291
K= 0	FAST1242
00 10 T=1-NAX-4	F4511743
	EACT1244
	A311244
CALL READE(2*NUD;CDN)	FAST1245
00 10 J=1.HOD	FAST1246
X = X + 1	FAST1747
LDHIMI - CONVI 41	EACTION
ADALKY - CONCISI	FA511290
LO BDA(K) = CDA(2+J)	FAST1249
RETURN.	FAST1250
ENO	FAST1251
	CASTLE / L
\$10FIG 3KEAU #94/21XR/	FA511252
CREADS * SURFACE FORMAT, 313,789.0	FAST1253
SUBROUTINE READS(IDM.ADM)	FAST1254
CONNON/TAREIO/N1 . H2	FAST1255
DIRENCION CONCAL ADMINI MAN	
DINERSION IDALSI SADAL / JANE 2/	FAS11236
READ(H1,1000)IDN,ADN,H	FAST1257
[F(LABEL(1).GE.G)WR[TE(N2,2000]H.IDN.ADN	' FAST1258
1000 FORMAT(313.769.0.244)	EACT1250
2000 EDBWAT(19 34.30 - 514 109513 4)	FR371237
2000 FORMATTIN, 244738 1314, 17 (212.47)	FASI126U
RETURN	FAST1261
END	FAST1262
STRETC RREAD M94/2. XR7	E4511743
COLOR & MOUNT COURSE FORMER (FO & 1919 FORMER	FA311203
CARAVA - TOCORE SUURCE FURMALL APS-UTERLS FURMAT	PAS(1264
SUBROUTINE READR(IDP,ADP)	FAST1265
COMMON/TAPEID/N1 .K2	FAST1266
DIBENSION ADM(4), IDM(12), 4(2)	FACTIZA T
	FAST1207
KCADINI, LOODI LUN, AUN, H	FAST1268

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1000	EUBH	ATII	213.4	see.	n. 24	41															FAS	11	270
2000	FORM	ATT	x . 2 64	6. 3H		1214	- 1 P	4F 1	2.4	1											FAS	11	271
	PETH	BN		.,						-											FAS	T1.	272
	END																				FAS	TL:	273
* 1957/	606	40	HOA	12.8	87																FAS	11	274
COEADE	* 8	RCDR	NSE	FIINC	TION	Eng	HAT	. 2	13.	144	. 6E	9:0									FAS	11	275
	51100	DUT (ADE	1104	ADM		ú, Ì													FAS	TL:	276
	2004	0017	ADET			. 83	,,00														FAS	ŧi.	277
	OTHE	40.17	. 701		***	121	0.04	141		**											FAS	ŤΪ.	278
	DEAD	1010	1000	112/	100			101		~ '										•	FAS	Ť1	279
	NEAU	1011	(1)		1101	7675		0.0.0		108	40	ы. а	ы								FAS	TI	280
	1 FIL	ADCL		3E • 0		1512	2,22	.000		104		110									FAS	τī	281
1000	COOM	4112	1 3 9 31		C				24			- A									FAS	τī	282
2000	FUKH	ALLL	ו24.	4.50		21.44	2.4	244			061	c • •	·								FAG	τī	283
	REIU	RN																			FAS	πī	284
	END																				FAS	τī	285
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\$1811	, K20	LVE			K/																FA	71	287
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1				NE	HAX		AX.	•NX	AAR	• •		AX +	NEA	ub	• 147	SEL	11	105			EAS		200
	2			NU	NIIX	• • • • •	AX	+NP	FAX		UKU	EK.	NUU	MN		IEL A				••			200
		2		NN	HAX	NGP	AX	*NP	HAX	_* <u>"</u>	VRU		NLA	AX.	+ 11	HAA A	<u>, ''</u>	1.0		, '	EAG		201
	•			ND	XAR	+ NGP	00	• HU	REN	1+0			NPU	CAA.		URU		121					271
	5	•		NV	DHAX	, NVC	HUD	, NP	UIN	1.8	005	ι,	HUD	erc	, m	JUEL		100	er i	· •	E AS		202
	5	•		NP	RINT	, 101	1115	*NU	FUE	R,K	AL I	DE		-							122		273
	CONN	UNVI	NOEX	S/IN	Ϋ́Ρ	+ 1 A Z			SV	· 1	MIL	•	I RH	0	• Đ	(R	•			•	PAS		279
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	?			1 X	TR	.150	IV.	• I A	TN	•1	ATW	•	LES	8	• 1	SSH	•	LDF	N.	•	243		290
	3			IN	TG	+ IEL	.F	* 1 F	GW	• 1	192		110	¥.	113	TUR	•		5	•	TA3		27 (
4		2		1.4	OL	+100)T	10	DT	-1	RŞI		IAL	Ρ	• 11	/HD	,	IGI	P	•	FAS	11	298
	5	a.,		14	EN .	+ I AL	.н	.14	εH	, I	•	,	I NS		• 1	VEE		1 41	n,		FAS		299
	6			15	PW	,156	ΡE	,1A	TD	-1	RSP	•	1 SG	т	•1	I DE	•	110	DE .	•	FAS	11	300
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	3			16	c	+ I NI)	• I U		, 1	٧		1 #		•1:	51	,	151			FAS	11	302
	,			IN	RG	+ ENS	SC .	,15	TP	-1	NRP		I NC	P	• 11	хP		[F)	s		FAS	11	303
1				11	хT	+1F2	KE .	• I F	XA												FAS	τ1	304
	CONN	ON H	(1)																		FA:	iT1	305
	1F(N	POIN	T.GT	.016	0 10	20															FAS	τ1	306
	CALL	'SOB	ER																		FAS	τ1	307
	LENGH	AX-1	+H(1)	WS1.	8118	\$1.1	11 23	101.	н ц	EC)	•Ht	157	1 .H	111	IRG:),н(14	TL I			FAS	11	308
	2 HIL	IDR)	.Ht I	[05]	, HU	VOL	1.HI	IX)T) +	HLI	COT	1,1	(IF	XPI	• H	LIFX	53	, 81	1XP	(P),	FAS	:11	309
	HIIN	SCI,	HUD	ALN)	.H(1	ALH	• H (IRF	(0),	H(1	ELL	1.H	t 15	SHI	ъH)	1 1 S G	11	, NE	400	1)	FAS	TL	310
	60 T	0 10	-						. `												FAS	τ1	311
20	CALL	SOL	VERC	1,NE	NOD ,	NGP	1×+1	кı	(CT)	•н(1CD	τι,	HEI	511	,н	LINR	Gl	,н	INS	sc).	FAS	ai	312
	1	14		HEIN	TL) i	HILF	RHOI		155	H).	HET	SGT) , Ĥ	(16	LL	•н(IN:	51.	#{ }	ES)	FAS	τi	313
	2	•		HLIN	c),,	1111		(11)	(PP)	•HI	IAL	H) .	111	ALF	1) .1	it LF	XP	1.1	11 11	xsi	FAS	τi	314



3H(LSTP),H(INPP),H(INCP),H(IIDR))	FAST1315
10 RETURN	FAST1316
END	FAST1317
\$1BFTC SOBER2 M94/2,XR7	FAST1318
CSOBFR2, SOLUTION OF THE BOLTZMANN EQUATION BY RANDOM SAMPLING	FAST1319
SUBROUTINE SOBER(LI+12+WS,ES+WC+EC +ST+NRG +MTL+TDR+IDS+VOL	FAST1320
1xDT,COT,FXP,FXS,XMP,NSC,ALM,ALF,RHD,ELL,SSH,SGT,L3)	FAST1321
DIMENSION SSHILL, SGT(L3,L2)	FAST1322
COMMON/LIMITS/NSTCRE.NERROR.NSMAX .NAMAX .NRMAX .NBMAX .NSTMAX.	FAST1323
NEMAX ,NVMAX ,NXMAX ,NXEMAX,NEMOD ,NXSECT,NUNITO,	FAST1324
Z NUNITX, NIFAX , NMFAX , NCRDER, NDOWN , INELAS, NTRANS,	FAST1325
3 NNMAX ,NGMAX ,NFRAX ,NVNOD ,NCMAX ,NLMAX ,NTMAX ,	FAST1326
4 NDXAX +NGKOD +NOFENT+NDHOD +NPDHAX+NPDHOD+NSDHAX+	FAST1327
5 NVDHAX - NVDHOD - NPOINT - HODELP - NODELQ - HODELU - HODELY -	FAST1328
6 NPBINT.NUNITS.NUPBER.KALIDE	FAST1329
CONHON/FULIXES/XXX .NTALLY-FREDE .TCTAIN-FOTALE-RHON .SNORM .TO	TEAST1330
	FASTINNI
COMMON/OFFICIAL CONCENTER OFFICIAL ADDRESS AND ATC .	FAST1332
	64671333
1 ALU JAL JOI JAJ 103 JJHLI JJHAK J	FAST1333
E SALA TALA TALA TALAN TALAN	FA311334
DIREASION ELLIS FELLS WELLS FELLS AND IN FELLS AND IN A REAL AND IN A REAL AND A	FAST1333
	FAS(1350
	FAS11337
2 FAPILITE CONTRACT	FAS11338
	FAST1359
SNURA = AMAXIIIUU.U.VECIGRIXCI,BUC,CII	FA511340
	FA511341
IOREGA = I	PAS11342
(FINVDHOD.GI.O) IGREGA = NUMBER + 1	FA511343
CALL GROUP(BDC)	FAS11344
DO 250 NNN=1.NPRINT	FAST1345
DD 240 MAR-1, NUNITS	FAST1346
NTALLY # 1	FAST1347
ERROR = ATD	FAST1348
RUNTOT = 0.0	FAST1349
DO 210 KKK=1,KALICE	FAST1350
IF (KKK.GT.1)GO TO 10	FAST1351
[F[MODELP.GT.0]GO TO 5	FAST1352
PDT = PSTAR(NN,X)	FAST1353
GO TO 40	FAST1354
5 PDT = SPHERE(8DC+STC+C+NST+ST+NRG+NSC)	FAST1355
IF(NST.EQ.0) GO TC 220	FAST1356
NN = NRG(NST) -	FASTL357
DO 6 I=1,3	FAST135B
6 X([] = BDC(]) + C(])+STC	FAST1359
GO TO 40	FAST1360
10 IF(INTALLP+NTALLY)+LE+01G0 TO 220	FAST1361

	LEITOTALN.EC.0.0)60 TO 13	FAST1362
	FRAR # TOTAL F/TOTALN	' FAST1363
	DO 12 INI-NENAX	FAST1364
	1F(FBAR.GE.ELL(1+1))G0-T0 14	FAST1365
12	CONTINUE	FAST1366
13	I = (JHIN + JHAX)/2	FAST1367
14	JBAR = I	FAST1369
	PDT = USTAR(STC, BCC, X, C, NST, ST, NRG)	FAST1370
	IF(NST.EQ.0)GO TO 220	FAST1371
	RUNTOT = RUNTOT + STC	FASIL5/2
	NN = NRG[NST]	FA311373
	PDT = PDT/STC##2	PA511374
	CALL KERNEL(1,NST,ST,NRG)	FA311375
	DG 20 [=1,3	54571377
	x(1) = x(1) + C(1) + S(C)	EAST1378
20	CC(I) = C(I)	EACT1379
	KHIN = JHIN	FASTI 380
	KHAX = JMAX	FASTIBRI
	DD 30 INJFIN+JAAA	FAST1382
	WLII) & PUI+WSII/#EXP(=XPFIL//	FAST1383
30		FAST1384
40		FAST1385
		FAST1386
	TOTALS = 0.0	FAST1387
	TEINEDWAY EC.O. GC TO SO	FAST1368
	NPD = 0	FAST1388
	DD 80 T=1-NDHAX	FAST1389
	16(108(1),GT.0)60 TO 80	FAST1390
	NPD = NPD + 1	FAST1391
	STH = VECTOR(X, XOT(1, 1),C)	FAST1392
	IF (KKK.GT.1)G0 T0 50	FAST1393
	CALL SZERCINN, PCT, X, C)	FAST1394
	GD TO 60	FAST1395
50	CALL SINGLEINN, COSINEIC, CC), 1.0)	FA511396
60	(FIJMIN.GT.JMAX)GC TO 70	FAS11397
	TOT = RUNTOT + STM	FAST1398
	CALL PATHINN, STN, X, C, NST, ST, NRG, NSCI	FAS11399
	CALL KERNEL(1,NST,ST,NRG)	FAST1400
	CALL DETECT(1,-1,1.0/SIM+#2,CUSINEIC,CDITI,TIT,0.0)	FAST1402
70	IFINPD.EQ.NPDMAXIGU TU YU	FAST1402
80	CUNIINUE	FAST1404
40	IF(KKK.L).KALIDE/ 60 10 72	FAST1405
	1F(NYUMUU.EC.07 OL 10 210	FAST1406
95	1 FINAN - 61 - 11 00 10 104	FAST1407
	15 (NODELO CT. 0) CO TO 100	FAST1408
	IT INDECESSION OF TO LOO	



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	NGT - O	FASTIANS
	GD TO 108	EACTIANA
100	FST = VECTORIXCT.3.CC1	EXCTINI
	JEAR - JIERC	EASTIAL?
	GO TO 104	FACTIALL
102	PDX - 1.0	CACT1414
	MGT = 1	EASTIALS
104	FST = RHQ(HN)+SSH(JEAR)	EACTIAIA
	GST = 0.0	EACTIAL?
	M - HTL(NN)	EASTIALS
	(FIN.GT.O) GST = SGT(JBAR.R)	FASTINIO
	ALPHA = 0.0	FAST1420
	HST - FST + GST	FAST1421
	(FINST.GT.O.O) ALPHA . (FST.ALHIJBAR) . GST.ALMIJBARI1/HST	FAST1422
	STA = VECTOR(X.BCC.CP)	FAST1423
	RETA = 0.0 .	FAST1424
	IF(FST.LE.DELTA) GO TO 108	FASTI675
	CALL PATHINN.FST-DELTA.X.CP.NST.ST.NRG.NSCI	FAST1426
	XMPF - 0.0	FAST1427
	DO 106 1=1,NST	FASTL428
	J = NRG(1)	FAST1429
	K - KTLIJI	FAST1430
	SIG = RHD(J)+SSHIJBAR)	FAST1431
	IF(K.GT.O) SIG > SIG + SGT(JBAR.K1	FAST1432
106	XMPT = XMPT + SIG+ST(1)	FAST1433
	[F[XMPT.GT.0.0] BETA = AS*[ALOG[12.0*XMPT]]/4.0	FAST1434
100	IFINUDELV.EC.2) BETA = AS*XMPT/2.0	FAST1435
108	DD 205 LLC+1, TONEGA	FAST1436
		FAST1437
	POR - POR OSTARTHR, X.C.	FASTL438
110		FAST1439
11.7	ISING A TORECAN DEL - DEL CARTANESALPHAT	FAST1440
	TETULE () DECENT PLA PLATEUAT(NUMBER)	FASTL441
		FAST1442
		FAST2443
114	CALL STACLETAN COSTANTS CC. ADDAS	FAST1444
116		FAST1445
	CALL PATHINN, 1. 05430, Y.C. NCT. ST. HPC NECK	FAST1446
	IF(111.FD. TONECA) CO TO 208	FAST1447
	ASTRIA - 1	FAST1448
	STT + 0	FAST1449
	TOT . BUNTOT	FASTLASO
	00 200 Not-NST	FAS11451
	L # NRGINI	PAST 1452
	N . HTL(L)	PAS11953
	IF (NYDNAX. ED. 0100 10 150	PASTINSA
	Contraction of the second seco	TA2-11455

	00 140 1=1,HDMAX	FAST1456
	1F(10R(1).NE.LIGG TE 140	FAST1457
	LEILDS(1).NE-0160 10 140	FAST1458
	ANG . COSINEIC.CETTIL.III	FAST1459
	1FIN.11.016C 10 120	FAST1460
		CASTIANI
		FASTLADI
	KHUN = KHU(L)	PASILADZ
120.53	GO TA 130	PASTING
120	FST . ST(N)/VCL(1)	FAST1464
	101 - TUT + ST(N)/2.0	FAST1465
130	CALL KERNEL (NSTMIN, N-1, ST, NRG) .	FASTL466
	CALL DETECT(1, H, FST, ANG, ST(N))	FAST1467
	IFIN.LT.OI TOT . 101 - STIN1/2.0	FAST1468
	NSTAIN + N + 1	FAST1469
	60 10 150	FAST1470
140	CONTINUE	FAST1471
160		EACTIVAT
130		FASTLATE .
		FAS11473
	K = NSCINJ	FASILATA
	IFIK NSDMAX.LE.0100 TO 200	FAST1475
	MAX- Z - N/NST	FAST1476
	NGT = 0	FAST1477
	00 190 K-1.PAX	FAST1478
	00 160 1=1.60MAX	FAST1479
	1F(10R(1).EQ.1.AND. 105(1).EQ.K160 TO 170	FAST1480
160	CONTINUE	FAST1481
	CO TO 190	FAST1482
170	LELNGT CT. 01C0 TO 180	FASTIART
110		ELETILOS
		FA311464
	CALL HURALINASTINASCICAT	FA311403
	ANG * COSTNELLIGNT	FAST1486
	CALL KERNEL (NSTAIN, N. ST. NRG)	FAST1487
	NSTRIN = N + 1	FAST1488
180	FST = 1.0/(ABS(ANG)=VOL(())	FASTL489
	CALL DETECTII,-1,FST,ARG,0.0)	FAST1490
190	L . MRG(N+1)	FA571491
200	CONTINUE	FAST1492
202	IFILLL .FO. IONEGAL GO TO 220	FAST1493
205	CONTINUE	FASTIANA
210	CONTINUE	EASTIAGE
270	CONTINUE	
660	00 730 1-1-10044	FA311446
	00 230 I-1100AA	PAST1497
	UU 230 JELINGRAX	FASTL498
	FX5(J,1) * FX5(J,1) * FXP(J,1)**2	FAST1499
230	FXP(J,[] = 0.0	FAST1500
235	CONTINUE	FAST1501
240	CONTINUE	FAST1502

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	CALL ANSWER (NNA)	FAST1503
250	CONTINUE	FAST1504
	RETURN	FAST1505
	END	FAST1506
\$18FTC	SOLVE #94/2+XR7	FAST1507
CSOLVE	R*POINT SOLUTION OF THE BOLTZMANN EQUATION*T.M.JORDAN*WANL*1966*	FAST1508
	SUBROUTINE SCLVER(L1.L2.L3,XD1,COT,ST,NRG,NSC,HTL,RHO,SSH,SGT,ELL	FAST1509
L	WS,ES,HC,EC,XMP,ALM,ALH,FXP,FXS,STP,NRP,NCP,IDR)	FAST1510
	DIMENSION XT(3),CT(3),C(3),X(3),CC(3),XC(3),XP(3)	FA5T1511
	DIMENSION XDT(3,1),CDT(3,1),ST(1),NRG(1),MTL(1),RHO(1),SSH(1),	FAST1512
1	<pre>SGT(L2,L1),ELL(1),WS(1),ES(1),WC(1),EC(1),XMP(1),ALM(1)</pre>	FAST1513
^ 2	ALH(11,FXP(L3,L1),FXS(L3,L1),IDR(1)	FAST1514
	COMMON/TAPEID/H1 +M2	FAST1515
	COMMON/LIMITS/NSTORE,NERROR,NSMAX ,NAMAX ,NRMAX ,NBMAX ,NSTMAX,	FAST1516
1	NEMAX ,NVMAX ,NXPAX ,NXEMAX,NEMOD ,NXSECT,NUNITD,	FAST1517
2	NUNITX,NIMAX,NMMAX,NORDER,NDOWN,INELAS,NTRANS,	FAST1518
3	NNMAX ,NGMAX ,NFMAX ,NVMDD ,NCMAX ,NLMAX ,NTMAX ,	FAST1519
4	NDHAX +NGMOD +HOMENT+NDHOD +NPDHAX+NPDHOD+NSCHAX+	FAST1520
5	NVDPAX.NVDMCD.NPCINT.NODELP.MODELQ.MODELU.MODELV.	FAST1521
6	NPRINT, NUNITS, NUPBER, KALIDE	FAST1522
	COMMON/FLUXES/KKK ,NTALLY,ERROR ,TGTALN,TOTALE,RHON ,SNORM , JO	TFAST1523
	COMMON/POINTX/NTGTAL,III +MOP	FAST1524
	COMMON/OTHERS/RADIUS,XCT(3),DELTA ,BCC(3),ATA ,ATB ,ATC ,	FAST1525
1	XAHL, NING, SA, SA, TA, DTA	FAST1526
2	KHIN KHAX JBAR NZERO	FAST1527
	DIMENSION BDCDUN(3)	FAST1528
	COMMON/ENDRUN/NPCRUN	FAST1529
	NPDRUN = Q	FAST1530
	DO 100 I=1.3	FAST1531
100	BDCDUH(I) = BDC(I)	FAST1532
	DO 27 III=1.NCHAX	FAST1533
	NTOTAL = 0	FAST1534
	1F(10B(111),GT,0) 60 TC 27	FAST1535
	NPORUN = NPERUN + 1	FAST1536
	00 1 (=1.3	FAST1537
	XT(1) = X0T(1.111)	FAST1538
1	CT(1) = CBT(1,1[1])	FAST1539
•	CALL GROUP(XT)	FAST1540
	SNORH =ANAX1()00.0.VECTOR(XCT.XT.C1)	FAST1541
	00 30 NNA=1-NPRINT	FAST1542
	DO 29 NHM=1.NUNITS	FAST1543
	IF(MODELP.GT.O) GC TC 53	FAST1544
	NKAIF = 1	FAST1545
•	PDS = PSTARIAN.X1	FAST1546
	[E[NN_ED_0] G0 T0 26	FAST1547
	60 10 94	FAST1548
01	CONTINUE	FAST1549

	PDS = SPHERE(XT,ST0,C,NST,ST,NRG,NSC)
	1F(NST.F0.0) 60 T0 26
	NN = NRG(NSI)
	nn 2 (a).3
	Y(1) = YT(1) + STORC(1)
04	
	NTALLY w 1
	50000 - ATO
	NTALLD - NTALLY
	TOTALE = 0.0
	SID * YELIUKIANALICI
	(1) CYCAO(NH BDS. Y.C)
	GO TO 4
3	TECHNING CO INCALL DATHINN, STO.Y.F.NST. ST.NRG.NSCI
- 4	TELINIA CT INAVIO TO 5
	CALL VEONEL (1. NET. ST. NDC)
	TOT - PUNTOT A STO
	CALL DETECT(1
2	$1 \in \{1, N\}$
	CCT - TOTALE/TOTALN
	TO CET CE CITATILE CO TO R
•	
9	NCT TO
	STT = 0.0
	SIGH = 0.0
	00 J 1+1-NST
	1 = NRGIII
	STG . RHOLITESSHIJBAR)
	STON # STON + STOPST(1)
	K = STI [J]
	TELK CT. OISIG & SIG + SETLIBARAKI

FAST1550 FAST1551 FAST1553 FAST1555 FAST1555 FAST1555 FAST1555 FAST1556 FAST1557 FAST1557 FAST1550 FAST1550 FAST1550 FAST1550 FAST1550 FAST1550 FAST1550 FAST1550 FAST1557 FAST1557 FAST1577 FAS

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	XMPT = XMPT + SIG#ST(1)	FAST1597
	16(NGT.EQ.1160.T0.9	FAS71598
		FAST1599
	16/5 ft . 1 T . 5 TH 10 10 9	FAST1600
	What - what - stcatst - STH1	FAST1601
	$A_{0} = A_{0} = A_{0$	FAST1602
		FAST1603
		FAST1604
	TETALALE CONTRACT AND A TANK A TANK	FAST1605
	TELEVALT CON BETALASAIALOGII2.0*XMPTII/4.0	FAST1606
	TELANDELY CC 2) BETA + ASAYNDT/2.0	FAST1607
		FAST1609
	NNG T NN	FAST1608
		FAST1609
		FAST1610
	IFTXHPR.CI.XAPING TO IT	FAST1611'
10	PDF = 1.0	FAST1612
	NGT = 0	F4ST1613
	G0 10 12	FAS71614
11	[F(XRPH.EQ.O.O)GO TC 14	FAST1615
	PHALF = XHPH/XHPI	FAST1616
	[F(RANNO(NMB).GI.PHALF)GO TO LI	F45T1617
	PDF = 1.07PHALF	EAST1618
	NGT * T	FAST1619
12	NHALF = 1	FAST1620
	00 13 I=1,3	FAST1621
	CD(1) = C(1)	EAST1622
	BDC(1) = XT(1)	FASTI623
13	xc(1) = x(1)	EAST1624
	GO TO 18	64571625
14	PDF = 1.0	EASTIA26
	NGT = 0	EACT1627
	GO TO 16	CACT1678
15	PDF = 1+0/(1+0 -PHALF)	EACT1420
	NGT = 1	EAST1620
16	NHALF = ?	FAST1030 .
	00 17 [=1,3	CAST1637
	xc(1) = x(1)	FAST1032
	CO(1) = -C(1)	FAST1033
	BDC(1) = X(1)	CAST1034
17	X(I) = XT(I)	FAST1033
	NN = NZERO	CASTLOSO
18	ALPHA = 0.0	FAST1037
	IF(XMPT.GT.O.O)ALPHA=(SIGH*ALH(JBAR)+(XMPT-SIGH)*ALH(JBAR))/XMPT	PA311038
	IF([KKK+MODELQ].GT.1] GO TO 300	CA511039
	PDA = QSTAR(NN,X,C)	FA511039
	GO TO 301 .	FASI 1039
300	-PDA = VSTAR(CD,CC,C,BETA,BS*ALPHA)	FA211039
	•	•
	•	

301	CONTINUE	FAST1639
	STM = 1.0E+30	FAST1640
	IFINGT.EQ.01GO TO 19	FAST1641
	PSI = COSINE(C,CD)	FAST1642
	IF(PSI.GT.O.O)STM + STH/PS1	FAST1643
19	CALL PATH(NN,SIM,X,C,NST,ST,NRG,NSC)	FAST1644
	PDT = USTAR(STC,BDC,X,C,NSI,ST,NRG)	FAST1645
	IF(NST.EQ.0)GO TO 26	FAST1646
	NNP = NRG(NST)	FAST1647
	DD 20 1=1+3	FAST164B
	XP(1) = X(1) + STC*C(1)	FAST1649
zö	x(1) = xC(1)	FAST1650
	STM = VECTOR(X,XP,C)	FAST1651
	NN = NNC	FAST1652
	POX = PDF+PCA+PCT/STH++2	FAST1653
	IFIKKK.GT.11GO TO 21	FAST1654
	CALL SZERD(NN+PDS+X+C)	FAST1655
	GO TO 22	FAST1656
21	CALL SINGLE(NN.COSINE(C.CC).1.C)	FAST1657
22	IFIJMIN.GT.JMAXIGO TO 26	FAST1658
	IF(NHALF.EQ.2)60 TO 200	FAST1659
	-CALL KERNEL(1,NST,ST,NRG)	FAST1660
	GO TO 201	FAST1661
200	CALL PATH(NN,STM,X,C,NSTP,STP,ARP,NCP)	FAST1662
	CALL KERNEL(1,NSTP,STP,NRP)	FAST1663
201	CONTINUE	FAST1664
	DO 23 I×JHIN, JHAX	FAST1665
	'EC(1) = ES(1)	FAST1666
23	WC(I) = PUX#WS(I)#EXP(-XMP(I))	FAST1667
	KAIN = JAIN	FAST1668
	KRAX * JHAX	FAST1669
	NN = NNP	FAST1670
	RUNIUS # RUNIUT + SIM	FAST1671
	100 24 1EL.3	FAST1672
	X(1) = XP(1)	FAST1673
		FAST1674
.25	CONTINUE	FAST1675
20		FAST1676
	00 28 FTINDAD	FAST1677
	DU 28 JEINGRAA	FAST1678
	PXS(J,1) = PXS(J,1) + PXP(J,1) + PZ	FAST1679
28	FAF13117 - U.U	FASTI680
411		FAST16B1
29	CALL ANCHEDING	FASTL682
20	CONTINUS	FAST1683
30	CONTINUE	FAST1684
21	-contract	FAST1685

•

	DD 101 1	- 1 - 2									
	00 101										FAST1686
101	BOCILI		04(1)								FAST1687
	RETURN										FAST1688
	ENU										FAST1689
*18FF	C GROUPT	N947	2 + XR 7								FAST1690
	SUBROUT	INE GRI	JUP (X)								FASTIAGE
	COMMON H	1(1)									FASTING
	COMMON/L	IMITS,	NSTOR	,NERROR	RINSHAX	+NAHAX	,NRMAX	+NBHAX	+NSTNA	x.	FASTIANS
	1		NEMAX	*NAMAX	,NXMAX	,NXEHA:	.NEMOD	NXSECT	NUNTT	n.	FASTING
	z		NUNIT	NEMAX	NNFAX	+ NCROEI	R.NDOWN	. INELAS	NTRAN	5.	FASTIAGE
	3		NNMAX	NGMAX	.NFHAX	+ NVKOD	NCMAX	+ NLHAX	.NTHAX		FASTIANA
	4		NDHAX	NGHOD	.HOPENT	, NDMOD	,NPDNA)	. NPDNDI	.NSDMA	y.	FASTIANT
	5		NVOHA	.**************************************	D, NPCINI	,HODEL	,HODELO	. NODELL	J. HODEL	ŵ.	FASTIADE
	6		MPRIN	NUNIT:	S.NUHBER	KALID				•••	FASTIAGO
	COMMON/0	NDEXS	INTP	+ I A Z	• E I SV	, INTL	1 RHO	.IXR	+ TELE		FAST1700
	1		IELW	, I AE	,IBE	+ INSG	.I NPC	. LISN	1.154		EAST1701
	2		IXTR	ISUV	. LATN	LATW	.I ESB	. ISSH	THEN		EAST1701
	3		INTG	, IELF	+ I F GW	ITDS	1 IDV	. IIDR	1105	1	EAST1702
	4		IVOL	, I CDT	. EXCT	IRSI	+I AL P	I VHD	1018	1	EAST170/
	5		TATH	. IALN	. TALH	•1A	.1 NS	IVEE	TVAL		EACT1704
	5		IS₽₩	, ISPE	+IATD	185P	ISGT	.1105	.1101		FAST1705
	7		1565	, NEXT	.IXNP	. I SGR	-1 WS	.165	1100		FAST1108
	9		160	• END	. [U	. TV	.1	. 1 5 1	157	•	FASILIUT
•	3 1		INRG	.INSC	ISTP	+1NRP	INCP	TEVO	1545	•	FASTL/U8
	ŀ		IFXT	, IFXE	. IFXA				441.43	•	FAST1709
	CALL GRO	DUN(X,	L.NEKA	X+H(IST) .HITNR	6).HI TA	501.941	1591			FAST1/10
1	HILINS),H	(IES),	HUIJSN	HILJS	X) .HUIS	PH1.H(1	SP F1.Ht	TYNOL L	*****		FAS11/11
	2H(IGIM),	HITELL	.11					1.0.007.7.90		•	FASIL/12
	RETURN										FAST1713
	END										FAST1/14
\$18FT0	GRODHI	894/2	, XR7								PASILITES
	SUBROUTI	NE GRO	DUN(X,	L1,L2,S	T.NRG.N	sc.rsv		ES. 15N.	ier en		PAST1716
1	SPE, XMP.	AIN.GI	N.ELL)				1421	C213243	32X + 2PI	••	FAST1717
	CONHON/I	NCEXG/	JZERO								FASIL/18
	COMMON/O	THERS/	RADIUS	.XCT (3)	DEL TA	.800133			470		FAST1719
1			ATO	AT	•BT	.45	.85		1410	•	FAST1720
2	1		KHIN	KNAX	JBAR	NZEDT	10 3	JAIN	JUUX	•	FAST1721
	COMMON/L	[HITS/	NSTORE	NERROR	-NSMAX	NAWAY	NDMAY	MOM V			FAS11/22
			NEMAX	NYBAX	NXHAX	NXENAY	NEMOD	NYCCCT	, COLLAR		FAS11723
2			NUNITX	NIMAX	NHWAY	NOPRES	NONUU	INCL AC	+NUNIII	•	FAST1724
3			NAMAX	.NGHAX	NEMAX	NYMOD	NCHAY	MULLAS	+ ALLKAN:		FAST1725
4			NONAX	NGYEE	MONENT	NOMOD	NORMAN	NOCHOD	TRIMAX	.•	FASTE726
5			NVDHAX	NVDHOD	NPOINT	. HODEL P	NODELO	MONTON	IN SOMA		FA511727
6			NPRINT	NUNTTS	NUMBER	- KALIDE		• HUDELU	+ HUDEL I	,	FA571728
	DIMENSIC	N NRG (11.150	(1)	-451	11.6011	1. 10411	1 10441			FAST1729
1	SPW(L2+L	1). SPE	112.11	I-XHPI1	1.47811	1.61811	1.61141	112281			FAST1730
	DI MENSIO	N C131						• •			FAST1731
											FAST1732

NZERD = LCCATE(hGS+X)	FAST1733
STM = VECTOR(X+XCT+C)	FAST1734
CALL PATH(NZERO,STN,X,C,NST,ST,NRG,NSC)	FAST1735
I = NST + 1	FAST1736
DD 1 K=1,NST	FAST1737
I = I - 1	FAST1738
L = NRG(I)	FAST1739
J = [SV{L}	FAST1740
[F(1,GT,0) G0 T0 2	FAST1741
1 CONTINUE	FAST1742
JZERO = NEHOD/?	FAST1743
66 10 100 -	FAST1744
2 NTT = 1	FAST1745
C CALCULATE AVERAGE SOURCE GROUP INDEX	FAST1746
TOTN = 0.0	FAST1747
TOTE = 0.0	FAST1748
MIN = JSN(J)	FAST1749
L X X = X X Y	FAST1750
JHIN = HIN	FAST1751
XAM = XAH	FAST1752
DO 10 I=HIN.MAX	FAST1753
(L1) = SPW(L1)	FAST1754
$LO \in S(I) = SPE(I_{+}J)$	FAST1755
IF(NTT.EQ.1)GO TO 30	FAST1756
CALL KERNEL(1,NTT-L,ST,NRG)	FAST1757
IF(XMP(MIN).EQ.0.0)G0 10 30	FAST1758
DO ZO I=HIN,MAX	FAST1759
20 WS(I) = WS(I)*EXP(-XFP(I))*(1.0 + AIM(()*XHP(I))	FAST1760
30 CALL KERNEL(1.0,ST,NRG)	FAST1761
CALL KERNEL(NTT,NTT,ST,NRG)	FAST1762
DO 40 I=KIN,MAX	FAST1763
FST = GIN(I)+WS(I)	FAST1764
IFIXMP(I).NE.O.O)FST = FST/XMP(I)	FAST1765
TOTN = TOTN + FST	FAST1766
40 TOTE = TOTE + FST+ES(1)	FAST1767
EBAR = TOTE/TOTN	FAST1768
DO 50 I=HIN, MAX	FAST1769
IF(EBAR.GE.ELL((+1))GO 10 60	FAS11770
SO CUNITINE	FA511771
I = (RIN + RAX)/2	FAS11772
	FAST1773
TOO KETOKA '	FAST1774
	PASI 1775
SIDELY STERVE FRIDER CANTINATION FOR ROBERTS STERAT & MORTANAUAL	FA311//0
CISCENU TIATU SUDACE CIPEUNIUN CUR PRUSAM FASIERTIAN, JURUANTMARE	-1700+rA311///
SUBROUTINE SECULIMETER FAAAJULI	FA311//8
CONTRACTOR ANALLICOULD	1 4217114

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									C + C 7 1 790
	COMMON	8(1)							FAST1200
	CORKON/DUM	SZE/MN	*PCS	,X[3]	+C(3)				FASTE/81
	COMMON/LIM	TTS/NSTCR	E, NERROI	NSPAX	.NARAX	•NRMAX	+NBMAX	NSIMAX	. FASIL/82
1		NEMAX	+NVMAX	*NXNAX	,NXEMA)	C,NEMOD	,NXSEC	+NUNITO	, FAST1783
2		NUNITI	X.NIHAX	NNPAX	NORDER	R N DOWN	, INEL AS	+NTRANS	FAST1784
3		NKMAX	+NGPAX	•NFPAX	*NAHOD	*NCHAX	, NL MAX	+NTNAX	FAST1785
4		NDMAX	+NGMOD	+NOPEN1	LONON 4	,NPDMAX	(•NPOHO(,NSDMAX	FAST1786
- 5		NVDMA	K, NVDPC	,NPGINT	F, MODELI	P∎N ODĖL(}, KQDELL	I, HODEL V	 FAST1787
6		NPRIN	T,NUNIT:	5,NUMBER	R,KALIDE	5			FAST1788
	COMMON/INDI	EXS/INTP	, I AZ	+ I 1 SV	, INTL	, 1 RHO	• I XR	,IELL	 FAST1789
1		IELW	, I AE	,188	, INSG	, I NPC	, I J SN	+LJSX	FAST1790
2		IXTR	.ISUV	+IAIN	+ I ATW	,1 ESB	ISSH.	+ I DEN	FAST1791
3		INTG	, IELF	+ IFGW	TIDS	T IDV	+110R	+110S	FAST1792
4		TVOL	11001	. IXCT	IRSI	. I ALP	TVHD	IGIN	FAST1793
		TATM	TALK	ALALH	• I A	.INS	. I VEE	.IVAL	. FAST1794
Ā		T SPH	ISPE	.1410	+ 18 SP	1561	.1105	.1101	. FAST1795
ž		1505	NEXT	TYNP	1568	.1 45	IFS	-190	- FAST1796
		1503	IND	. 10	. 14		151	151	. EAST1707
		INPC	TASC	1510	TNPP	Thre	IFTP	1615	FASTITOR
		LEVI	TEVE	IEVA					EACTITOD
	COMPON (REC)		11.00	111.04					CASTINOO
	1000 - 0	SCATISATA	A. 111.5K						64571801
	INSK 4 U								CAST1801
	an = ana								FAST1002
	PUS = PUP								FAST1003
	00 10 1=143	·							FAST1004
	X = X = X = X = X = X = X = X = X = X =								CASILOUS
10,								1611	FASTIOUS
	CALL SZEUU	SUNAMAX + DI	I.PEFA			K1 +Ht 1/	1367 (11)	3367,	FAST1607
1		HUIJSXI	HIINPUI	HIVE	: 1 - H L I VA	T1 *8(1)	PRI-RU	SPEL	FASTINUS
2	H(185)+H(1	51.H(110)	***						PASILOUY
	RETURN								FASTIBLO
	END								CASILOLL
\$18FTC	SZEDMI P	9472+XR7							FASILBLZ
CSZEDU	H*FIXED SEL	JRCE EVALU	JATION F	UR PROG	RAN FAS	IEK#1.P	- JUKUAN	WANL*I	966#FAS11813
	SUBROUTINE	SZEDUNILI	1+22+234	L4+15V,	XIR*NSC	**1 2M*12	A HUNC +	CE . VAL .	SPN+PAS11814
1	SPE, WS, ES,	DV)							FASILBLS
	DINENSION	DV(1)							PASILBLO
	DIMENSION 4	(3),0(3)	V151.RC	11 (3+3)				÷	FASTIBLI
	DIMENSION	SV(1),XTF	(3,1),	156(1).1	ISNI11,	5X (1) . n	PCIDII	+ 22111+	FASTIBLE
1	,	/EE(L1.L2.	L 31, VAL	111.12	L37, SP5	ICL 4+L 31	, SPE (L4	+L31+WS	(1) FAST1819
	EQUIVALENCE	= {2(1),2)	[]+(2(2)	,22),(2	(3),Z31	.(0(1))	01),(00	21,021,	FAST1820
1	{013},031	. { v { ; } , , v ; }		V2) (V(31,431	{V(4),V	41, (V(S	3, 851	FAST1821
	COMMON/DUKS	SZE/NN	+PES	•X{3}	+C131				FAST1822
	COMMON/POLI	NTX/NTOTAL		HON	•				FAST1823
	COMMON/L1N	TS/NSTCRE	E,NERROF	L,NSMAX	NAMAX	,NRMAX	, NBMAX	,NSTMAX	FAST1824
1		NEHAX	*PAMAX	NXPAX	,NXEMA>	NEMOD	, NX SECT	,NUNITO	FAST1825
2		NUNITO	C.NIMAX	*NHFAX	, NORDER	NDOWN	, INEL AS	,NTRANS	FAST1826

NNMAX NCPAX NEPAX NVROD NCMAX NLMAX NTMAX , 5 NOMAX NCPAD NUBCHT HOMOD NPOMAX NDMGD,MSOMAX, 5 NVPAX,YONGY MPETIT TOUELQ,MOELQ,MOELQ,MOELY, 6 NPEINT,NUNTTS,NUMES,XALIDE COMMON/DTHES/SACIUS.XCTI3),ATA .ATB .ATC , 1 ATD .AT ,BT .AS ,BS ,JMIN .JMAX , 2 NTH .KFAX ,JBAR NZERD COMMON/LSRC/LREG COMMON/SPASH/FORS I COMTINE NON = 0 IF(INVID).EC.NI GG TD 3 OG I 1-1.NVED GO TO 3 2 COMTINE GO TO 1 3 CONTINE H-TRAMSLATE OD 10 1-1-10 Z(L) = URCF **FAST1827** FAST1828 FAST1828 FAST1829 FAST1830 FAST1831 FAST1832 FAST1833 FAST1834 FAST1835 FAST1837 FAST1838 FAST1839 FAST1840 FAST1841 FAST1842 FAST1842 FAST1844 FAST1844 FAST1844 FAST1846 FAST1847 FAST1847 FAST1847 FAST1847 FAST18491 FAST18591 FAST1853 FAST1853 FAST1855 FAST1856 3 CONTINUE C UN-TRANSLATE DO 10 1=1,3 10 Z(1) = X(1) - XTR(1,N) C SOURCE; GEOWEINY CHECK 1 FINGS(M) GT.000 TO 30 C RECTANGULAR D C JARUE S PAU 20 Z HARLES C SPAU 20 Z HARLES C DIRECTION COSINES 20 O(1) = C(1) 1 FININ 105,100,100 C CYLINDRICAL AND SPHERICAL, AZIMUTHAL ANGLE 30 V2 = 0.0 FAST1856 FAST1857 FAST1859 FAST1860 FAST1861 30 V2 = 0.0 IF((ABS(Z1) + ABS(Z2)).GT.0.0) V2 = ATAN2(Z2,Z1) C RADIUS NEXT MAX = NSG(N) + 1 VI = 0.0 DD 40 1=1.HAX 40 VI = VI = 2(1)**2 VI = SQRT(VI) C CVIEIMAX.EQ.316010 50 C CVIEIMAX.EQ.316010 50 C CVIEIMAX.EQ.316010 50 C CVIEIMAX.EQ.316010 50 C ROTATION SETUP. POLAR R = VI FAST1861 FAST1862 FAST1863 FAST1864 FAST1865 FAST1866 FAST1866 FAST1867 FAST1867 FAST1869 FAST1870 FAST1871 R = V1 CPH' = 1.0 FAST1072 FAST1873



	SPH = 0.0	FAST1874
	GO TO 60	FAST1875
С	SPHERICAL, COSINE OF POLAR ANGLE	FAST1876
	50 V3 = Z3/V1	FAST1877
	(F(NN.LE.0) GC 1C 105	
C	RDTATION SETUP, POLAR	FASTIATA
	СРН = ¥3	FASTIR79
	SPH = SQRT(1.0 - CPH**2)	FASTIRAD
	R = VI+SPH	FASTLARI
Ċ	ROTATION SETUP, AZINUTHAL	FAST1882
	60 IF(R.GT.0.0)GO TO 7C	FASTIR83
	CTH = 1.0	FAST1884
	STH = 0.0	FAST1885
	GO TO 80	FAST1886
	70 CTH = 21/R	FAST1887
	STH = Z2/R	FASTIBBB
С	CALCULATE ROTATION MATRIX	FAST1889
	BO CALL ROTATE(CPH,SPH,CTH,STH,ROT)	FAST1890
С	ROTATED DIRECTION COSINES	FAST1891
	00 90 1=1,3	FAST1892
	D(1) = 0.0	FAST1893
	DO 90 J×1+3	FAST1894
	90 $D(1) = D(1) + ROT(1, J) + C(J)$	FAST1895
С	COSINE OF POLAR ANGLE, ANGULAR POF	FAST1896
	100 VS = D3	FAST1897
¢	AZIMUTHAL ARGLE, ANGULAR PEF	FAST1898
	V4 = 0.0,	FAST1899
	(F[[ABS[0]] + ABS[02]].GT.0.0) V4 = ATAN2(02,01)	FAST1900
Ľ,	ALL SUDRCE VARIABLES DEFINED, SET ERROR INDICATOR, TOTAL POF	FAST1901
	JAIN = JANNI .	FAST1902
		FAST1903
		FAST1904
L	CHECK FOR DELTA FUNCTION, ASSOCIUMRED CONRECT	FAST1905
~		FAST1906
c	NOS DELLA FUNCTION, CHECK RANGE	FAST1907
		FAST1908
~	THE PARTY - VECT, 1, ATT (VECK, 1, AT - V(1)) 1.11.0.01GD TO 150	PAST1909 .
c	DO LLO LA V	FAS11910
	DU LLU $J = 2 + \kappa$	FAST1911
	10 CONTINUE	PAS11912
~		FA511913
		FAS11914
	PDSwPDS+(VAL(I,I,N)+(V(I)-VEE(K,I-N))AVAL(K,I-N)+(VEE(I,I,N)-VIT	164671014
	1 = 1/(VEF(A, N) + VEF(K, N))	EAST1017
	LE(NN-GT-Q) CC TO 130	FAST1917
		1 0 0 1 1 7 1 0

FF11LT.33 G0 T0 130 FAST1919 PSGDS = PDS FAST1920 G0 T0 150 FAST1920 L30 CONTINUE FAST1920 L30 CONTINUE FAST1920 D0 THE NUMBER (IN GROUP AND AVERAGE ENERGY FAST1921 D0 140 19 LANIN, JAX FAST1925 D0 1140 19 LANIN, JAX FAST1925 D0 1140 19 LANIN, JAX FAST1927 D0 1140 19 SPE(II.N) FAST1927 L40 EST11 = PDS*PW11.N1 FAST1927 L50 RETURN FAST1927 C REGULAR AND OUTSTOE-RANGE RETURNS FAST1937 C REGULAR FAST1937 COMMON H11 FAST1937 COMMON H11 FAST1937 COMMON/LINITS/NSTORE/NERGO, NEPAX, NAMAX, NENAX, ANBAX, NSTAX, FAST1935 1 NEMAX, NOMOO, NEPAX, NAMAX, NENAX, NEMAX, NEMAX, NETAX, FAST1935 2 NOMAX, NOMOO, NEPAX, NAMAX, NEMAX, NEMAX, NEMAX, NETAX, FAST1935 3 NOMAX, NOMOO, NEPAX, NAMAX, NEMAX, NEMAX, NEMAX, NEMAX, FAST1935 4 NOMAX, NOMOO, NEPAX, NAMAX, NEMAX, NEMAX, NEMAX, NEMAX, NEMAX, FAST1937 5 NOMAX, NOMOO, NEPAX, NEMAX, NEMAX, NEMAX, NEMAX, NEMAX, FAST1935 4 <												
PSORS = PDS FAST1920 0 00 1050 FAST1920 130 CONTINUE FAST1921 130 CONTINUE FAST1921 130 CONTINUE FAST1921 131 CONTINUE FAST1921 131 CONTINUE FAST1922 131 CONTINUE FAST1923 131 CONTINUE FAST1923 131 CONTINUE FAST1923 131 PDSSSPUTIAN FAST1923 140 EST11 = SPELTNI FAST1923 150 RETURN FAST1933 150 RETURN FAST1933 150 RETURN FAST1933 150 RETURN FAST1933 150 RETURN		1F(].L	T.3) GO	TO 130)							FAST1919
00 T0 150 FAST1921 130 CONTINUE FAST1922 0 DEFINE NUMBER IN GROUP AND AVERAGE ENERGY FAST1923 0 DA 10 I-JURIJAZA FAST1921 JMAX + JSX(N) FAST1923 0 140 I-JURIJAZA FAST1923 100 140 I-JURIJAZA FAST1925 100 140 I-JURIJAZA FAST1925 100 140 I-JURIJAZA FAST1926 100 140 I-JURIJAZA FAST1927 100 150 RETURA FAST1927 100 150 RETURA FAST1927 100 150 RETURA FAST1927 100 RETURA FAST1927 100 RETURA FAST1937 COMMON H11 FAST1937 100 RETURA ERERGE NUMAI - NERADA NESMAX , NAMAX - NORMAX , NORMAX , NSTMAX, FAST1937 100 RETURA ERERGE NUMAI - NERADA , NERAAN , N		PSORS	* PDS									FAST1920
130 CONTINUE FAST1922 JMAX * JSX(N) FAST1922 D DI 40 (1-JMIN, JAX) FAST1922 D DI 40 (1-JMIN, JAX) FAST1922 LOBFINE, NUMBER IN, GRUUP AND AVERAGE ENERGY FAST1922 LOB 501 (-JMIN, JAX) FAST1923 LOB 501 (-JMIN, JAX) FAST1923 LOB 501 (-JMIN, JAX) FAST1923 LOB 601 (-JMIN, JAX) FAST1923 LOB 601 (-JMIN, JAX) FAST1931 C REGULAR MD DUTSIDE-RANGE RETURNS FAST1932 SUBFICI KERNLE M94/2, XR7 FAST1931 C REQULAR NEREE PATH CALCULATION FOR PROGRAM FASTER*T.N.JORDAN*MALF667AST1933 FAST1933 C DOHMON/LINITX, NINAX, NNKAX, NNEMAX, NEMAX, NEMAX, NSTMAX, FAST1935 FAST1935 C ONMON/LINITX, NINAX, NNKAX, NNEMAX, NNEMAX, NSTMAX, FAST1935 FAST1935 C ONMON/LINITX, NINAX, NNKAX, NNEMAX, NNHAA, NSTMAX, FAST1935 FAST1932 C ONMON/LINITX, NINAX, NNKAX, NNEMAX, NNHAA, NSTMAX, FAST1935 FAST1932 C ONMON/LINITX, NINAX, NNKAX, NNHAA, NNKAA, NKAX, NTKAX, FAST1935 FAST1935 C ONMON/LINITX, NINAX, NNHAA, NNKAR, NONDO, NDONAX, NUNTOL, FAST1945 FAST1935 C ONMON/LINITX, NINAX, NNHAA, NKAXA, NNHAD, NNKAX, NKAX, FAST1935 FAST1935 </td <td></td> <td>GO TO</td> <td>150</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>FAST1921</td>		GO TO	150									FAST1921
C DEFINE NUMBER IN GROUP AND AVERAGE ENERGY FAST1923 JAAX > JSXINI FAST1923 DD 140 I=JHIN,JMAX FAST1925 NST1925 JANK > JSXINI FAST1925 DD 140 I=JHIN,JMAX FAST1925 LAGGULAR AND DUTSIDE-RANGE RETURNS FAST1927 LSGULAR AND DUTSIDE-RANGE RETURNS FAST1937 CCHEMEL #MEAN FREE PATH CALCULATION FOR PROGRAM FASTER*T.N.JORDAN*WANL+66FAST1932 COMMON H11 NEXTANAX ANAXAX ANAKAX ANAKAX ANAKAX ANAKAX ANSTAX, FAST1935 L ONHOW LINITS KENRER (NSPAX ANAKAX ANAKAX ANAKAX ANSTAX, FAST1935 COMMON H11 NEXAX NYNAX ANAKAX ANAKAX ANAKAX ANAKAX ANSTAX, FAST1935 L ONHOW LNITS KENRER ANAKAX ANAKAX ANAKAX ANAKAX ANSTAX, FAST1935 L ONHOW LNITS KENRER ANAKAX ANAKAX ANAKAX ANAKAX ANAKAX ANSTAX, FAST1935 L NUMAX NYNDMO, NOPENT NUMEDE-MODELO, MODELV, MODELV, FAST1940 COMMON/INDEXS/INTP 1A2 (159 LIKTL RH0 (1XR)ITAX FAST1951 L LELW 1AE A BE INSG INPC (125N + 115X FAST1957 L ONHOM/INDEXS/INTP 1A2 (159 LIKTL RH0 (1XR)ITAX FAST1957 L ONHOM/INDEXS/INTP 1A2 (159 LIKTL)INTE (150 LIKT) FAST1945 L LELW (1AE (150 LIKT) (151 LIKT) (151 LIKT) FAST1945 L LELW (1AE (150 LIKT) (151 LIKT) (151 LIKT) FAST1945 L LELW (1AE (150 LIKT) (151 LIKT) (151 LIKT) FAST1945 L LELW (1AE (150 LIKT) (157 LIKT) (151 LIKT) (151 LIKT) FAST1945 L LELW (1AE (150 LIKT) (157 LIKT) (151 LIKT) (151 LIKT) FAST1945 L LELW (1AE (150 LIKT) (157 LIKT) (151 LIKT) (157 LIKT	1	30 CONTIN	UE									FAST1922
JAAZ = JSKIN DAAZ = JSKIN SIGE COMPANY SIGE COMPANY SI	сò	EFINE NUN	BER IN C	80UP	AND AVER	AGE ENE	RGY					FAST1923
D0 140 I-JMIN, JMAX NST1 PDS*SPVII.N1 140 EST1 = DSS*SPVII.N1 FAST1927 140 EST1 = SPE(I,N) CREGULAR MD OUTSIDE-RANGE RETURNS ISD RETURN SIPTCEMENL M96/22,N87 CREMULE VM6/22,N87 CREMEL VM6/22,N87		JNAX =	JSX(N)									FAST1924
witil = PDS*Spuil.wi PAST1926 140 EST11 = SPEIL.Wi FAST1927 150 RETURN FAST1927 STIPTC EVENUE MAD DUTSTDE-RANGE RETURNS FAST1927 STIPTC EVENUE MAD DUTSTDE-RANGE RETURNS FAST1927 STIPTC EVENUE MAD DUTSTDE-RANGE RETURNS FAST1927 STIPTC EVENUE MAD AP2, NAT FAST1931 COMMON HIL FAST1931 COMMON HIL FAST1931 COMMON HIL NAXAX, NAMAX, NAMAX, NBMAX, NSTAX, NSTAX, FAST1935 1 NEMAX, NYMAX, MXAX, NAMAX, NBMAX, NBMAX, NSTAX, FAST1935 2 NNMAX, NOMOD, NEPAX, NAMAX, NBMAX, NBMAX, NTAX, FAST1935 3 NNMAX, NOMOD, NPOIAN, NAMAX, NEMOD, NCMAX, NTAX, FAST1935 4 NOMAX, NOMOD, NPOIAN, NUMAX, NEMOL, NEMOL, NDOELU, MODELU, FAST1940 5 NUMAX, NOMOD, NPOIAN, NIESS ISS 6 NOMAX, NCMOD, NDOELD, MODELD, MODELD, MODELU, FAST1940 6 NOMAX, NCMOD, NDOELT, NDMOD, NDOAX, NCMOD, NDOAX, NCMOD, NDOELD, MODELU, FAST1940 6 NUMAX, NCMOD, NDOELD, MODELD, MODELU, MODELU, FAST1940 6 NUMAX, NCMOD, NDOELD, MODELD, MODELD, MODELU, FAST1945 1 ITT, NUMITS, NITT, ITT, ITT, ITT, ITT, ITT, ITT, IT		00 140	I=JHIN.	XAML								FAST1925
140 ESTIJ = SPE(I,N) CREGULAR MD OUTSIDE-RANGE RETURNS 150 RETURN END 150 FTC KERNEL M0422 X07 CONTON H (ALL ATLON FOR PROGRAM FASTER*T.H.JORDAN*WANL&GAST1931 CONTON H (I) CONTON H (I) CONTO		85(1)	= PDS+SP	WILL N								FAST1926
C REGULÁR AND DUTSIDE-RANGE RETURNS FASTI920 LSO RETURN FASTI920 END FASTI920 END FASTI920 SUBCUTINE KENNLE M94/2, XR7 CKENEL M94/2, XR7 CKENEL M94/2, XR7 COMMON/LINITS/KSTORE, NERNOR, NSPAX, NAMAX, NCHAA, NSPAX, NSTMAX, FASTI935 COMMON/LINITS/KSTORE, NERNOR, NSPAX, NAMAX, NCHAA, NSKAX, NSTMAX, FASTI935 COMMON/LINITS/KSTORE, NERNOR, NSPAX, NAMAX, NCHAA, NSKAX, NSTMAX, FASTI935 COMMON/LINITS/KSTORE, NERNOR, NSPAX, NAMAX, NCHAA, NSTMAX, FASTI935 COMMON/LINITS/KSTORE, NERNOR, NSPAX, NAMAX, NCHAA, NSCT, NUNTO, FAST1936 1 NUMAX, NCKRO, NKRAX, NYKAX, NSCKS, NCHAA, NSTMAX, FAST1935 3 NUMAX, NCKRO, NCHAX, NURDER, NORMO, NCHAA, HILAX, NTKAX, FAST1935 4 NUMAX, NCKRO, NOPENT, NOMED, NCHAA, HILAX, NTKAX, FAST1937 5 NUMAX, NCKRO, NOPENT, NOMED, NCHAA, HILAX, NTKAX, FAST1937 5 NUMAX, NCKRO, NOPENT, NOMED, NCHO, KILAK, NTKAX, FAST1937 5 NUMAX, NCKRO, NOPENT, NOMED, NCHAA, HILAX, NTKAX, FAST1936 6 NPPINT, NUNTS, NUPEGR, NGLU, MODELU,	1	40 ES(1)	= SPE(I.	N)								FA5T1927
150 RETURN FAST1920 END FAST1920 STOPTC KERNLE M94/2, XRT FAST1930 SCREMEL*MEAR FREE PATH CALCULATION FOR PROGRAM FASTER*T.M.JORDAN*MAIL F647511932 FAST1930 SUBROUTINE KENNEL (HIN, MAX, ST.NAG) FAST1930 CORMON/LIMITS/STORE, PERCORA, NSFAX, NAMAX, NRMAX, NBMAX, NSTAX, TAST1935 FAST1930 CORMON/LIMITS/STORE, NERCORA, NSFAX, NAMAX, NRMAX, NBMAX, NSTAX, FAST1935 FAST1930 CORMON/LIMITS/STORE, NERCORA, NNEMAX, NNEMAX, NSTAX, FAST1935 FAST1937 NNMAX, NCHAX, MFAX, NNEMAX, NNEMAX, NTMAX, FAST1938 FAST1937 NNMAX, NCHAX, MFAX, NNEMAX, NNEMOD, NNDAX, NLTAX, FAST1938 FAST1930 SNMMAX, NCHAX, NCHAX, NNEMAX, NNEMOD, NNDAX, NLTAX, FAST1939 FAST1940 SNMMAX, NCHAX, NCHAX, NNEMAX, NNEMOD, NNDAX, NLTAX, FAST1939 FAST1940 SNMMAX, NCHAX, NCHAX, NNEMAX, NNEMOD, NNDAX, NLTAX, FAST1930 FAST1945 SNMMAX, NCHAX, NCHAX, NNEMAX, NNEMOD, NNDAX, NLTAX, FAST1930 FAST1945 SNMMAX, NCHAX, NCHAX, NNEMAX, NNEMAX, NLTAX, FAST1930 FAST1945 SNMMAX, NCHAX, NCHAX, NNEMAX, NNEMAX, NCHAX, NLTAX, FAST1945 FAST1945 SNMMAX, NCHAX, NCHAX, NNEMAX, NCHAX, NLTAX, FAST1945 FAST1945 SNMMAX, NCHAX,	ĊŔ	EGULAR AN	D OUTSIC	E-RANG	SE RETUR	INS						FAST1928
END FAST1930 END FAST1931 CKERNLE M94/2,XR7 FAST1931 CKERNLE MEAN FREE PATH CALCUATION FOR PROGRAM FASTERT.N. JORDAN-WANL-60FAST1932 FAST1933 COMMON H11 S NUMAX, NCMOR, MORENT, NDEDD, NCMAX, HURAN, NTANA, FAST1930 S NUMAX, NCMOR, MORIT, NDEDD, MORDEL, MODELU, MODELU, MODELU, FAST1940 COMMON/INDEXS/INTP, 142, H154, H174, H181, H14, H14, H14, H14, H14, H14, H14, H1	1	50 RETURN										FAST1929
SIGHTC KEENLE M94/2, XR7 FAST1931 CCRNEL *M64/2, XR7 FAST1931 FAST1931 CORMON FREE PATH CALCULATION FOR PROGRAM FASTER*T.N.JORDAN*MALLOFOFAST1932 FAST1935 CORMON H11 FAST1931 FAST1931 CORMON H11 FAST1935 FAST1935 CORMON H11 FAST1935 FAST1935 CORMON H11 FAST1935 FAST1935 CORMON/LINITA, HITAX, MARX, NERAX, NERAX, NERAM, HUNDO, KASECI, NUNITO, FAST1936 FAST1935 A NUMAX, NCROX, MFRAX, NUMEX, NUMIDO, NCBAX, HULAS, NTRANK, FAST1939 FAST1931 A NUMAX, NCROX, MFRAX, NUMOO, NCBAX, HULAS, NTRANK, FAST1939 FAST1941 COMMON/INCEXS/FINIT, MONTS, NUMEGA, KALLOE HUO 'LISM 'LISK, FAST1937 FAST1943 COMMON/INCEXS/FINIT, MONTS, NUMEGA, KALLOE HUO 'LISM 'LISK, FAST1945 FAST1945 COMMON/INCEXS/FINIT, MONTS, NUMEGA, KALLOE HUO 'LISM 'LISK, FAST1945 FAST1945 COMMON/INCEXS/FINIT, MONTS, TAT, MARS, 'NERGA, SISS 'LIDE 'LIDI 'FAST1946 FAST1945 COMMON/INCEXS/FINIT, MONTS, TAUMOGA, FAST1945 FAST1945 COMMON/INCEXS/FINIT, MONTS, TAUMOGA, MOSA, HUNDEL, 'FAST1945 FAST1945 COMMON/INCEXS/FINIT, MONTS, TAUMOGA, MOSA, NUMEGA, 'LISM 'LISK, 'FAST1945 <	_	END										FAS/1930
CKEENELE MERAN FREE PATH CALCULATION FOR PROGRAM FASTER*T.H.JORDAN*WANL=066FAST1932 SUBBOUTINE KERNEL (MIN, MAX, ST. NAG) FAST1933 COMMON H(1) COMMON/LINITS/NSTORE/NERADA, NSPAX, NAMAX, NRMAX, NBMAX, NSTNAK, COMMON/LINITS/NSTORE/NERADA, NSPAX, NAMAX, NRMAX, NBMAX, NSTNAK, ST1934 COMMON/LINITS/NSTORE/NERADA, NSPAX, NAMAX, NRMAX, NBMAX, NSTNAK, ST1934 SUBMON/LINITS/NSTORE/NERADA, NSPAX, NAMAX, NRMAX, NBMAX, NSTNAK, NEMAX, NSTORE/NEMAX, NSPAX, NAMAX, NRMAX, NBMAX, NSTNAK, NEMAX, NSTORE/NEMAX, NSPAX, NJEMAX, NSPAX, NSTNAK, NDMAX, NCMOD, NSPAX, NJEMAX, NSPAX, NAMAX, NKAKA, NTKAK, TTKAK, NDMAX, NCMOD, NOPENT, NDMOD, NCMAX, NLMAX, NTKAK, FAST1935 SUBMAX, NCMOD, NOPENT, NDMOD, NCMAX, NLMAX, NTKAK, FAST1935 SUBMAX, NCMOD, NOPENT, NDMOD, NCMAX, NLMAX, NTKAK, FAST1935 Z LINIT, SUU, SIGN, NJEMAX, NUFSOR, SISS, LIDEN, FAST1945 Z LINIT, SUU, SIGN, NJEMA, NIESS, SISS, LIDEN, FAST1945 Z LINIT, SUU, SIGN, SISS, SISS, SISS, LIDEN, FAST1945 Z LINIT, SUU, SISS, SISS, SISS, SISS, SISS, SISS, FAST, SISS, SISS	\$18	FTC KERNL	E 894/2	2 . XR 7					•			FAST1931
SUBROUTINE KERNEL (MIK, MAX, ST.NAG) FAST1933 COMMON H(1) COMMON/LIMITS/NSTORE, MERNOR, NSPAX, NAMAX, NRMAX, NSTAX, FAST1935 1 NEWS/LIMITS/NSTORE, MERNOR, NSPAX, NATEAX, NEMAX, NSTAX, FAST1935 2 NNMAX, NORMO, MERNOR, NSPAX, NATEAX, NEMAX, NSTAX, FAST1935 3 NNMAX, NCMAX, MFAX, MYNDO, NCMAX, HLMAX, NTMAX, FAST1935 5 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1935 5 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1935 6 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1935 5 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1935 6 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1935 5 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1935 6 NNDMAX, NCMON, MOPENT, NDMON, NEDMAX, HPDODO, NSDAX, FAST1945 6 NIT, NUNITS, NUMEER, KALLOE ND, ISK, ISLX, FAST1945 7 NITG, IELF, IFGW, INTL, IRN, IESS, ISS, IDEN, FAST1945 7 NITG, IELF, IFGW, ITSY, INTL, IRNG, ISS, ISS, IDEN, FAST1945 7 NITG, IELF, IFGW, ITSY, INTL, ISS, ISS, IDEN, FAST1945 7 NIEGS, MEN, ISPE, IAID, ISKS, ISS, IDE, IDI, FAST1945 7 NIEGS, MEN, ISPE, IAID, ISSP, ISGT, IDE, IDI, FAST1945 7 NIEGS, MEN, ISPE, ISTY, INTL, ISS, ISST, FAST1957 8 NAMA, NCMO, NIESE, ISSF, INAP, IKCP, IFFS, FAST1957 8 LIFT, IFXE, IFXA, INAP, IKCP, IFFS, FAST1957 1 LIFT, IFXE, IFXA, INAP, IKCP, IFXS, FAST1957 1 LIFT, IFXE, IFXA, ISTY, INA, INA, AX, ST, NAGI 7 AST1955 1 LIFT, RERDINH (LALL, MIAEL, HIELL, HIELL), HIELEN, HIELS, FAST1957 1 SUBROUTINE KERDUNH (LALL, MIAEL, HIELL, HIELL), HIELEN, HIELS, FAST1957 1 NAK, ST, MAEL 10 NTC KERONMI, MIAL, XAH, A& BELL, ELL, ELK, ES, SH, ST, ST, NAGI 7 AST1957 1 NAK, ST, MAEL 10 NTC KERONMI, MILL, AND, A& BELL, ELL, ELK, ES, SH, ST, ST, ST, ST, ST, ST, ST, ST, ST, ST	CKE	RNEL*HEAN	FREE PA	ATH CAL	CULATIO	IN FOR F	ROGRAM	FASTER	T.N.JO	RDAN+WAI	NL+66	FAST1932
COMMON H11) FAST1934 COMMON H11) FAST1934 COMMON/LIMITS/NDEANEROR,NSPAX,NAMAX,NRMAX,NBMAX,NSTAK,FAST1935 NEMAX,NVMAX,WXAX,NLEKAX,NEMAX,NBMAX,NSTAK,FAST1935 NUMAX,NCMAC,NMAX,HZKAX,NEMAX,NGMAX,NSTAK,FAST1930 NUMAX,NCMAC,NCMAX,HORAN,NDC,HOLAN,HORAN,HORAN,FAST1930 NUMAX,NCMAC,NCMAX,HORAN,NCMAX,HORAN,HORAN,FAST1930 NUMAX,NCMAC,NCMAX,HISVALL,HAUL,HOLAN,HORAN,HORAN,FAST1930 NUMAX,NCMAC,NCMAX,HISVALL,HAUL,HAUL,HAUL,HAUL,FAST1940 NERTIT,NUHSK,NLEY,HORAN,HORAN,HORAN,HORAN,HORAN,HAUL,FAST1940 NERTIT,NUHSK,NLEY,HAUL,HAUL,HAUL,HAUL,HAUL,FAST1940 NERTIT,HAUL,HAUL,HAUL,HAUL,HAUL,HAUL,HAUL,HAUL		SUBROU	ITENE KER	RNEL (M	IN,MAX,S	T, NAG 1						FAST1933
COMMON/LIMITS/NSTORE.NERROD.NSFAX ,NAMAX ,NEMAX ,NEMAX ,NSTMAX, FASTI935 1 NNAX, NYAAX ,NXAX, NYABAX,NEMDO,NXSCT.NUNITO, FASTI936 2 NUNITX,NIHAX,NAMAX,NGROEA,NOON, INELAS,NITAANS, FASTI937 3 NNAX, NCARAY, HFAX,NYADO,NCHAX,NEMDO,NXSCT.NUNITO, 4 NUMAX,NCARO, MCHAT,NAMO,NCHAX,NEMDO,NSONAX, FASTI939 5 NUMAX,NCARO,NOPOIT,NOHOL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGOEL,NGEL,NCA,NCHAX,NTAX,NITS, FASTI937 2 NINAX,NCARO,NCHAG,NITS,NITS, NITL 6 NUMAX,NCARO,NCHA,NCHAN,NITS, NITL 6 NUMAX,NCHAM,NITS,NITS,NITL, IENG, INPC, LISH, IJSX, FAST1937 2 NINA,NCHAM,NITS,NITS,NITL, IENG, INPC, LISH, IJSX, FAST1943 3 NINA,NCHAM,NITS,NITS,NITL, IENG, INPC, LISH, IJSX, FAST1943 4 NUMAX,NCHAM,NITS,NITS,NITL, NITL, IENG, INPC, LISH, IJSX, FAST1945 4 NUMA, NITS,NITS,NITL, NITL, IENG, INPC, LISH, IJSX, FAST1945 5 NINH, IALH, IALH, IA, NI S, ISSN, IDDN, FAST1946 5 NINH, IALH, IALH, IA, NI S, ISS, ISSN, FAST1946 6 NISPE, IAID, IRSP, ISGT, IDDE, INDE, FAST1946 7 NISGS,NEXT, VIATAP, ISGN, INS, ISS, ISSN, FAST1945 1 NITL, IENG, ISSN, NITL, FAST1947 6 NIEC, INF, INT, INP, ISSN, ISSN, FILSS, FAST1945 1 NIEL, INF, INTL, INTL, INTL, INTL, INS, INSS, FAST1945 1 NIEL, INTL, INTL, INTL, INTL, INTL, NIELS, FAST1945 1 NIEL, ISSN, AND, NIELLI, ISSN, MILLS, NIELS, FAST1945 1 NIEL, NIELL, ISSN, MILL, ISSN, MILLS, FAST1945 1 NIEL, NIELL, ISSN, MILL, ISSN, MILLS, FAST1945 1 NIENS, NAST1955 1 NIEL, NIELLI, FAX, NIN, INTL, INTL, NIELS, FAST1955 1 NIENS, NIELLI, FAX, NIN, NIELLI, FAX, NIN, MAX, ST, NAG 1 NIENS, NI, MILL, NIELLI, HILL, NIELLI, MILL, NIELS, FAST1955 1 NIENS, NI, MILLS, NIELLI, FAX, NIN, MAX, ST, NAG, NIE, FAST1955 1 NIENS, NIN, MILL, NIELLI, NIELLI, SHI, NIELLI, MILLI, FAST1955 1 NIENS, NIN, MILL, NIELLI, SHI, NIELLI, FAX, NIN, FAST1955 1 NIENS, NIN, MILL, NIELLI, SHI, NIELLI, MILL, FAX, ST, NAG 1 NIENS, NIN, MILL, NIELLI, SHI, NIELLI, MILL, FAST1955 1 NIENS, NIN, MILL, NIELLI, SHI, NIELLI, MIELLI, MILLI, FAST1955 1 NIENS, NIN, MILL, NIELLI, SHI, NIELLI, SHI, NIELLI, FAST1955 1 NIENS, NIN,		COMMON		H(1)								FAST1934
1 ΝΕΜΑΧ ,ΝΥΜΑΧ ,ΜΧΕΜΑΧ ,ΝΕΚΒΑΛ ,ΝΕΚΒΟ ,ΝΧSECT,ΝUΝΙΤΟ, FAST1936 2 ΝΝΙΤΧ,ΝΙΝΑΧ ,ΝΑΚΑΧ ,ΝΕΚΒΑΛ,ΝΟΟΝ, ΝΙΚΑΣ,ΝΙΤΑΛΣ, FAST1937 3 ΝΝΝΑΧ ,ΝΟΚΑΣ ,ΜΕΛΑΧ ,ΝΗΝΟ ,ΝΟΚΑΧ ,ΝΕΚΑΣ,ΝΙΤΑΝΤΑΧ , FAST1938 4 ΝΟΜΑΧ ,ΝΟΚΑΣ ,ΜΕΛΑΧ ,ΝΥΝΟ ,ΝΕΛΑΧ ,ΝΕΚΑΣ,ΝΙΤΑΝΤΑΥ , FAST1936 5 ΝΝΝΑΧ ,ΝΟΚΑΣ ,ΜΕΛΑΧ ,ΝΗΝΟ ,ΝΟΚΑΧ ,ΝΕΚΑΣ,ΝΙΤΑΝΤΑΥ , FAST1939 6 ΝΟΜΑΧ ,ΝΟΚΑΣ ,ΜΕΛΑΧ ,ΝΗΝΟ ,ΝΕΛΑΧ ,ΝΕΚΑΣ ,ΝΙΤΑΧ , FAST1939 6 ΝΟΜΑΧ ,ΝΟΚΑΣ ,ΜΕΛΑΧ ,ΝΗΝΟ ,ΝΕΛΑΧ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΑΤΑΣ , FAST1930 7 ΝΟΚΑΣ ,ΝΟΚΑΣ ,ΜΕΛΑΣ ,ΝΑΙΟΕ 1 ΙΚΑΣ ,ΝΟΚΑΣ ,ΜΕΛΑΣ ,ΝΑΙΟΕ 1 ΝΕΛΑΣ ,ΝΟΚΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΕΛΑΣ ,ΝΑΣΤ398 4 ΝΟΕΙ ,ΝΙΧ ,ΝΙΚΑΣ ,ΝΕΛΑΣ ,ΝΕ		COMMON	/LINITS/	NSTOR	E+NERROF	.NSFAX	, NAMAX	,NRHAX	+NBRAX	.NSTRA	x,	FAST1935
2 NUNITX, NIHAX, NHAAX, NGROER, NODNN , INELAS, NITAANS, FAST1937 3 NINAX, NGROZ, NFAX, NYGO, NCHAX, HIAX, NITAAN, FAST1937 4 NUHAX, NGROZ, NFAX, NYGO, NCHAX, HIAX, NITAAN, FAST1939 5 NUDHAX, NGROZ, NGPENT, NDHOD, NCHAX, HIAX, NITAAN, FAST1939 5 NUDHAX, NGROZ, NGPENT, NDHOD, NCHAX, HIAX, NITAAN, FAST1939 6 NPPINT, NUHITS, NUPEGA, KALIDE 1 COMMON/INGEXS/IPP / 14 + 16 + 11 L + 10 + 12 + 12 + 12 + 12 + 12 + 12 + 12		1		NEMAX	.NVHAX	,NXHAX	.N XEMA	K,NEMOD	NX SEC	T-NUNIT	ο,	FAST1936
3 NNMAX, NCRAX, MFFAX, NVMOD, NCMAX, HLMAX, NTMAX, FAST1938 4 NDMAX, NCRAX, MCFAX, NOVENT, NDMOD, NFDAX, HDMODN, NSMAX, FAST1939 5 NVDMAX, NCRAX, MCPEIT, NDGEL, HODEL, MODEL, MDDELV, FAST1940 6 OFFINIT, NDMITS, NUMEGR, ALLOE HUO, IXR, IELE COMMON/INCEXSJPI, INT, NDHAT, NUMEGR, ALLOE HUO, IXR, IELE 1 IELW, IAC, IBE, INSG, INPC, ILSN, IJSX, FAST1943 2 IELW, IAC, IBE, INSG, INPC, ILSN, IJSX, FAST1943 3 INTG, IELF, IFGW, ITOS, IIDV, IIDR, IIDS, FAST1945 4 IVQL, ICOT, IXCT, IRSI, IALP, IYWO, IGIH, FAST1945 5 IAIM, IALM, IAL, IA, IAS, IVEE, IVAL, FAST1945 5 IAIM, IALM, IAL, IA, IAS, IVEE, IVAL, FAST1945 6 ISPW, ISEE, IDD, ISGS, ISS, IIDE, IDI, FAST1945 8 IEC, IND, IVU, IV, IW, ISI, ISI, FAST1957 1 IFXI, IFXE, IFXA, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, IVU, IV, IW, ISI, ISI, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, ISIF, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFXE, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFX, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFX, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFX, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFX, INFP, INCP, IFXF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFX, INFP, INCP, IFXF, INFF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, IFX, INFF, INCP, IFXF, INFF, FAST1957 1 IFXI, IFXE, IFXA 8 IEC, IND, INIC, INIC, INIC, INIC, INIC, INIC, INF, FAST1957 1 IFXI, INF, FAST1957 1 IFXI, INFF, FAST1957 1 IFX		2		NUNITE	C.HIHAX	.NHHAX	NORDE	R, NOOWN	+ INEL AS	S.NTRAN	5.	FAST1937
4 NUMAX ,NCHOD ,NDEHT,NDMDD ,NPDMAX, HPDHDD ,NSDMAX, FAST1939 5 NUDMAX ,NCHOD ,NPDIAT, NDDELP MOBEL, MDEUL, MDEUL, MDEUL, 6 NPFINT,NUHTS, NUPBER, KALIDE 1 COMMON/INDEXS/INTP 1A2 , 115V , IATL , IRHO , IXR , IELL FAST1942 1 ELK , 1AU , 1BE , INTS , IATL , IRHO , IXR , IELL FAST1943 2 INTG , IELF , 1FG , INTS , INT , IRHO , IXR , IELL FAST1943 3 INT , IELL FAST1942 4 INTO , IELF , IFG , INTS , ILD , ICD , IDS , ISS , IJSX , FAST1945 4 INTO , IELF , IRS , INTS , ILD , ICD , IDS , ISS , IJSX , FAST1945 5 INTM , IALH , IAL , IA , INS , IVE , INTO , IGIN , FAST1945 6 ISFW , ISFP , IATO , IRS , INT , INTO , IGIN , FAST1945 7 ISGS , HEXT , IXAF , ISGS , INT , ISI , IST , FAST1945 8 IEC , IND , IU , IV , IW , ISI , IST , FAST1945 1 INT, INSC , ISFP , INT , INSC , INS , IES , INC , FAST1945 8 IEC , IND , IU , IV , IW , ISI , IST , FAST1945 1 INT, INSC , ISFP , INT , INSC , INS , IES , INSC , FAST1945 1 INT, INSC , ISFP , INT , INSC , INS , IES , INSC , FAST1945 1 INT, INSC , ISFP , INT , INSC , INS , IST , FAST1955 1 INT , INSC , ISFP , INT , INSC , INST , IST , FAST1955 1 INT , INSC , ISFP , INT , INSC , INST , ISS , INST , FAST1955 1 INT , INSC , ISFP , INT , INSC , INST , ISS , INST , FAST1955 1 INT , INSC , ISFP , INT , INSC , INST , ISS , INST , FAST1955 1 INT , INSC , ISFP , INT , INSC , INST , ISS , INST , FAST1955 1 INT , CALL KERDUM , INSC , INST , ISS , INT , INST , INST , FAST1955 1 INT , CALL XERDUM , INST ,		з.		NNMAX	NGMAX	₽NF#AX	, NVHOD	*NCHAX	+ NE MAX	+NTHAX		FAST1938
5 ΝΥΟΜΑΧ,ΝΌΜΟΟ,ΝΡΟΙΝΤ,ΝΟΕΕL,ΜΟΣΕLO,MODELU,MODELU, FASTI940 6 ΝΥΡΗΤ,ΝΝΗΤΧ,ΝΥΠΕΛΕ,ΝΑΙΟΙΕΡ,ΜΟΣΕLO,MODELU,MODELU, FASTI940 COMMON/INDESS/INTP /122 ,ITSV INTL , IRTL , IRTL , IRTL , ISLL , FASTI942 1 ITT , ISLN , INTL , IRTL , IRTL , IRTL , IRTL , IRTL , ISLL , FASTI942 3 INTG , IELF , IFGW , ITOS , ITOY , IIOR , ITOS , FASTI945 4 IVUL , ICOT , IXGT , IRTL , IALP , IVW , IGIN , FASTI945 5 IATM , IALH , IAL , IAS , IVEE , IVAL , FASTI945 6 ISPW , ISPE , IATD , IRSP , ISGT , IDE , ITOI , FAST1945 7 ISGS , MEAT , IRVP , ISGR , INGE , INGE , INGE , INGE , FAST1945 7 ISGS , MEAT , IRVP , ISGR , INGE , INGE , INGE , INGE , FAST1945 8 ISGS , MEAT , IRVP , ISGR , INGE , INGE , INGE , FAST1945 9 INGE , INSC , IFSF , INP , IFKP , IFKS , FAST1951 1 IFXT , IFXE , IFXA CALL KEROUMURADI, INT (INFLIGE), MILBEI, MITELI), MILEN, MILSE , IST1957 RETURN MAX,ST,NGI) 8109TC KEROMI M4/2, XAT CALL KEROUMURILILZ, XMP,AE,BELL, ELL, ELX, ES, RAD,SSH, MTL, SCT, NIN, FAST1955 SUBROUTINE KEROUMULILZ, XMP,AE,BELL, ELL, ELX, ES, RAD,SSH, MTL, SCT, NIN, FAST1955 10 MAX, ST, NGCI), FELL, ALWES, RAD,SSH, MTL, SCT, NIN, FAST1955		4		NDMAX	, NG KOD	* KOKENT	, NDHOD	,NPOHA)	(, NPDHO	D, NSONA.	x,	FAST1939
6 ΝΡΕΙΝΤ,ΝΟΗΝΤ, ΝΟΡΘΕΑ,ΚΑLΙΟΕ FAST1941 COMMON/INDEXS/INTP, IA2, 1154, IATU, IATU, IATU, IATU, IATU, IATU, FAST1942 1 ELW 1AE / IBE / INTG / IAT, IATU, IESD 1558, IJDEN / FAST1943 2 INTR ISUU / IATU, IATU, IESD 1558, IJDEN / FAST1943 3 INTU / IATU, IATU, IESD 1558, IJDEN / FAST1943 3 INTU / IATU, IATU, IATU, IESD 1558, IJDEN / FAST1943 5 INTU / IATU, IATU, IATU, IESD 1558, IJDEN / FAST1946 5 INTU / IATU, IATU, IATU, IATU, IESD 1558, IJDEN / FAST1945 6 ISPW 159E / IATU, IATU, IATU, IATU, ISS 1, ISST / FAST1945 7 ISSS NEXT / IATU, IATU, IATU, ISS 1, ISST / FAST1950 9 INRC 1ND / IUT, IV / IW / ISI / IST / FAST1950 1 CALL KEROUK(MENZI , IFZA , IFFAA / INTEE), INTEL, INTEL, FAST1957 1 CALL KEROUK(MENZI , IFZA , IFFAA / INTEE), INTEL, INTEL, INTEE, FAST1950 1 INTER, IATU, IATU, IATU, ISST , FAST1957 1 INTER, IATU,		5		NVDMA:	K+NVDHOD	0+NPOEN1	,HODEL	P.H GDEL	A HODEL	U, MODEL	٧.	FAST1940
COMMON/INDEXS/INTP ,12 ,115 ,115 ,117 ,1840 ,1XR ,1ELL , FAST1942 L COMMON/INDEXS/INTP ,12 ,115 ,117 ,147 ,185 ,119 ,110 ,110 ,110 ,110 ,110 ,110 ,110		6		NPRIN	F, NUNETS	S.NUFBER	.KALID	6				FAST1941
L LELW , LAE , LBE , LNSG , LNPC , LJSN , LJSX , FAST1943 2 LXTR , LSUW , LATN , LATN , LATN , LESB , LSSN , LDEN , FAST1944 3 LATT , LSUW , LTGT , LLST , LSSN , LLST , LLST , LLST , FAST1945 4 LATT , LLST , FAST1945 5 LST , LLST , FAST1945 6 LST , LLST , FAST1945 7 LSG , LLST , LLST , LLST , LLST , LLST , LLST , FAST1945 8 LEC , LLST , LLST , LLST , LLST , LLST , LLST , FAST1950 9 LNGG , LNST , LLST , LLST , LLST , LLST , FAST1950 1 LFT , LFZ , LFZA CALL KERDUHK LENDI, HL LST , LLST , LLST , FAST1950 1 LFT , LLST , LLST , LLST , LLST , LLST , FAST1950 1 LFT , LLST , LLST , LLST , LLST , LLST , FAST1952 CALL KERDUHK LST , LLST , LLST , LLST , FAST1952 1 LTT , LLST , LLST , LLST , LLST , LLST , LLST , FAST1953 1 LST , LLST , LLST , LLST , LLST , LLST , FAST1952 1 LNT , LLST , LLST , LLST , LLST , LLST , LLST , FAST1952 1 LNT , LLST , LLST , LLST , LLST , LLST , LLST , FAST1955 1 LNT , LLST , FAST1955 1 LNT , LLST , FAST1957 1 LNT , LLST , FAST1957 1 LNT , LLST ,		CONNON	I/ ENDE XS/	/INTP	, I A Z	,11SV	. INTL	, 1 RHO	, I XR	,1ELL		FAST1942
2 IXTR .ISUV .IATN .IATN .IESB .ISSH .IDEN . FAST1944 3 INTG IELE .FIGW .ITOS .IEUN .ILON .IIDS .FAST1945 4 IVOL .ICOT .XCT .IRSI .IALP .IVMO .ICIN .FAST1946 5 IATN .IALM .IAL .IAL .IAL .IAL .IAS .IVEC .IVAD .ICIN .FAST1946 6 ISPN .ISPE .IATD .IRSP .ISGT .IDE .ITDI .FAST1946 7 ISEC .INO .IMPR .IVM .ISS .IST .FAST1946 9 ING .INSC .ISTP .INPP .INCP .IFXP .IFXS .FAST1950 9 ING .INSC .ISTP .INPP .INCP .IFXP .IFXS .FAST1951 1 INTE .IFXA .INTL.IFXE .INTL.INTL.INTL.INTL.INTL.INTL.INTL.INTL		1		LELW	.IAE	•IBE	, INSG	+INPC	+ I J SN	,1J5X		FAST1943
3. INTG , IELF , IFGW , IIOS , IIDV , IIOR , IIDS , FAST1945 4. IVUL , ICOT , IXET , IRSI , IALP , IYUN , IGIM , FAST1945 5. IALM , IALH , IAL , IA , IAS , IYEE , IVAL , FAST1947 6. ISSN , INEXE , ISSN		2		IXTR	.ISUV	, IATN	. I ATH	•1 ESB	# I S SH	, IDEN		FAST1944
4 IVOL ,ICOT ,IXCT ,IRST ,IALP ,IVMO ,IGIM , FAST1946 5 IAIM ,IALM ,IAL ,IA ,IN , INS ,IVEE ,IVAL , FAST1947 6 ISPW ,ISPE ,IATO ,IRSP ,ISGT ,IIDE ,IIDI , FAST1948 7 ISGS ,NEXT ,IXT ,IRSP ,ISGS ,INS ,IES ,INC , FAST1949 8 IEC ,IND ,IU ,IV ,IW ,ISI ,IST , FAST1950 9 IEC ,IND ,IU ,IV ,IW ,ISI ,IST , FAST1950 1 IFIN ,IEXE ,IFX ,INN ,INC ,IFAP, IFRS , FAST1950 1 IFIN ,IEXE ,IFX ,INN ,INC ,IFAP, IFRS ,FAST1957 1 A IFIN ,IEXE ,IFX ,INN ,INC ,IFAP, IFRS ,FAST1957 1 A IFIN ,IEXE ,IFX ,INN ,INC ,IFAP, IFRS ,FAST1957 1 A IFIN ,IEXE ,IFX ,INN ,INC ,IFAP, IFRS ,FAST1957 1 A IFIN ,IFXE ,IFX ,INN ,INC ,IFAP, IFRS ,FAST1957 1 A IFIN ,IFXE ,IFX ,INN ,INC ,IFAP, IFRS ,FAST1957 1 BIFTC KERDUH ,H4/2, XAT ,FAST1957 1 BIFTC KERDUH ,H4/2, XAT ,AE BE ,ELL,IELN ES, FAB, SSN, WTL, SGT, HIN , FAST1957 1 DIFENSION XH011, JACE ,JAPA ,AE BE ,ELL,IELN ES, FAB, SSN, WILSGT, JNN , FAST1957 1 DIFENSION XH011, JACE ,JAPA ,AE BE ,ELL, ELLN ES, FAB, SSN, WILSGT, JNN , FAST1957 1 DIFENSION XH011, JACE ,JAPA ,AE BE ,ELL, ELLN ES, FAB, SSN, WILSGT, JNN , FAST1957 1 DIFENSION XH011, JACE ,JAPA ,AE BE ,ELL, ELLN ES, FAB, SSN, WILSGT, JNN , FAST1957 1 DIFENSION XH011, JACE ,JAPA ,AE BE ,ELL, ELLN ES, FAB, SSN, WILSGT, JNN , FAST1957 1 DIFENSION XH011, JACE ,JAPA ,JACE ,JAC		3,		INTG	, IELF	.IFGW	, ITDS	•1 IDV	IIOR	,1105		FA\$T1945
5 IAIM ,IALM ,IALM ,IA ,IAS ,IVEE ,IVAL , FAST1947 6 ISSM ,ISSP ,IATD ,IRSP ,ISGT ,IIOE ,IIOI , FAST1947 7 ISGS ,MEXT ,IXMP ,ISGR ,INS ,IES ,INC , FAST1950 9 INGG ,IASC ,ISTP ,INMP ,INCT ,IFXP ,IFXP ,IFXS , FAST1950 1 IAISG ,IASC ,ISTP ,INMP ,INCP ,IFXP ,IFXP ,IFXS , FAST1951 1 IFXG ,IASC ,ISTP ,INHP ,INCP ,IFXP ,IFXP ,IFXS , FAST1952 CALL KERDUHARENDO ,I.HI (IXMP),MI (IAE),HI IBE(),HI IBE(),HI IBE(),HI IBE(),HI IBE(), HI IBE(),HI IBE(), HI IBE(), FAST1952 CALL KERDUHARENDO ,I.HI (IXMP),MI (IAE), HI IBE(),HI IBE(), HI IBE()		4		1 VOL	+ICDT	, IXCT	• 18 S I	+TALP	. LAND	,IG1M		FAST1946
6 15PW ,15PE ,1ATD ,1RSP ,1SGT ,1IDE ,1IDI , FAST1948 7 ISGS ,HEXT ,1XPP ,1SGT ,IW ,1ES ,IMC ,FAST1949 8 IEC ,1ND ,IU ,IV ,IW ,ISI ,1ST ,FAST1950 9 INR, INSC ,1SF ,INP, INCP ,1FXP ,IFXS ,FAST1950 1 INR, INSC ,1SF ,INP, INCP ,1FXP ,IFXS ,FAST1951 1 KIRNO ,HIIXMP),HIIAEI,HIIBEI,HIIBEI,HIIBEI,HIIBEI,HIIES), FAST1955 RETURN FURN ,HIRNO ,HIIXMP, HIIAEI,HIIBEI,HIIBEI,HIIBEI,HIIBEI, FAST1955 810FTC KERDMI M94/2,XR7 CARDUH-M5AN FREE,PAH , CALCULATION FOR PROGRAM FASTR=7.H, JORDAN-9MAH, 466FAST1595 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES,HAD,SSH,WTL,SGT,HIN, FAST1955 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES,HAD,SSH,WTL,SGT,HIN, FAST1955 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES,HAD,SSH,WTL,SGT,HIN, FAST1959 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES,HAD,SSH,WTL,SGT,HIN, FAST1955 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES,HAD,SSH,WTL,SGT,HIN, FAST1955 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES,HAD,SSH,WTL,SGT,HIN, FAST1955 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES, HID, SGT, JAK, A, ST1955 1 IMENSION XH011, JAZ, XMP,AE,BE,ELL,ELW,ES, HID, SGT, JAK, FAST1955 1 IMENSION XH011, JAZ, XMP, AE,BE, ELL, ELS, HID, FAST1955 1 IMENSION XH011, JAZ, XMP, AE,BE, ELL, ELS, SH, JAK, JAS, JAZ, JAZ, JAZ, JAZ, JAZ, JAZ, JAZ, JAZ		5		IAIM	,IALH	,IALH	, I A	, INS	+ I VEE	• [VAL		FAST1947
7 ISGS NEXT 1XMP 1SGR 1MS FES IMC FAST1999 9 INRG INAC ISIG NEXT FAST1990 9 INRG INAC ISIG NEXT FAST1991 1 INRG INAC ISIG FAST1992 1 INRG INAC ISIG FAST1992 1 INRG INAC ISIG FAST1992 1 HIRMUNEMOD, I.HIIXMPJ, MIIALHIBEL, HIBEL, HILELJ, HILELJ, HILELJ, HILELJ, HILELJ, FAST1993 FAST1935 1 HIRMUJ, HIXSHJ, MIIALINTU, HINTU, HIISGI J, MIN, MAX, ST.NRGI FAST1935 1 TENDM MAY, ST.NRGI FAST1935 1 MAX, ST.NRGI FAST1945 FAST1945 1 MAX, ST.NRGI FAST1945 FAST194		6		I SPW	,ISPE	+ TAYD	, IRSP	•1 SGT	+11DE	+1101		FAST1948
8 IEC (ID (IV (IV (IX FAST1950 9 INGC IST (IST) (IST) (IST) FAST1952 1 IFXI IFXE (IST) (IST) (IST) FAST1952 1 IFXI IFXE (IST) (IST) (IST) FAST1952 1 IFXI (IST) (IST) (IST) (IST) FAST1952 1 ITATO (IST) (IST) (IST) (IST) FAST1955 1 RETURN FAST1957 FAST1957 FAST1957 FAST1957 1 BIBFTC KERDUH H04/2, XAT FAST1957 FAST1957 CORDUPTINE KERDUH(ILL2, XMP, AE, BE-LL-ELW, ES, FHD, SM, HTL, SGT, HTN, FAST1959 FAST1950 FAST1950 1 MAS, ST, ANGL (ILL1), FELLH, H011, SCT11, H11, SCT1, H11, FAST1950 FAST1950 1 MAST, ST, MOL SCT11, H21, SCT14, H11, SCT11, H11, SCT1, H11, FAST1951 FAST1950 1 MAST, ST, MOL SCT11, H011, SCT14, H11, SCT1, H11, SCT11, H11, FAST1961		7		ISGS	, NEXT	*IXHD	, I SGR	• I WS	+1ES	.INC		FAST1949
9 ING , IASC , ISIP , INGP , IACP , IFXP , IFXS , FAST1951 1 L IFXS , IFXA , IFXA , IFXA , IFXA , FAST1952 CALL KERDUH,NEMOD,I,HIIXMPJ,HIIAE,HHIBEI,HIIELJ,HIIELJ,HIIES), FAST1953 1 HIIKMD,HIISSHJ,HIIATLJ,HIISGIJ,MIN,MAX,ST,NRG] FAST1954 RETURN FREMAN FREE,PAIH CALCULATION FOR PROGRAM FASTR9T, MJORDANWAN, 466FAST1957 SUGROWI NM04/2,XR7 CKERDUM+MEAN FREE,PAIH CALCULATION FOR PROGRAM FASTR9T, MJORDANWAN, 466FAST1957 SUGROWI INE KERDUH (LL1,Z,XMP,AE,BE,ELL,ELW,ES,RHD,SSH,MIL,SGT,HIN, FAST1995 DIMENSION XMPII,JAEIJ,BELLI,ELLY,ELW(1),ESSIJ,NRGIJ,MIL(1), FAST1996 DIMENSION XMPII,JAEIJ,BELLI,ELLY,ELW(1),ESSIJ,NRGIJ,MIL(1), FAST1996 1 MAX,SINRG1 2 KHIN , KANAX , MJORLAT , BOCISJATA , ATB , ATC , FAST1996 1 ATD , AT , BT , AS , BS , JMIN , JMAX , FAST1966 2 KHIN , KANAX , MJAR, MJERO		8		IEC	+ IND	,10	,1V	+EW	• ISI	,151		FAST1950
L IFXI .IFXE .IFXA CALL KERDUHNEKGO, I.HI(IXP), HI (AE), HI (BE), HI (BEL), HI (ELW), HI (BE), FAST1932 L RETURN RETURN RETURN BIDÖTC KERDUH MEKGO, I.HI (IXP), HI (AE), HI (BC), MIN, MAX, ST, NRG) SIDÖTC KERDUH SIDÖTC KERDUH MAYAZ, KAT CARDUHNEKARN FAGEL JALL (ALCULATION FOR PROGRAM FASTEROT, H.JORDANONAN, HAGFAST1935 SUBROUTINE KERDUH(L), LZ, XMP, AE, BE ELL, ELW, ES, ARD, SSH, MTL, SGT, MIN, FAST1955 J IDTKS ION XMM(L), AELI, AELI, AELI, ELL, ELW, ES, ARD, SSH, MTL, SGT, MIN, FAST1955 J IDTKS ION XMM(L), AELI, AELI, AELI, AELI, AELI, SSH(L), SS(L), NRG(L), HIL(I), FAST1960 DIMENSION XMM(L), AELI, AELI, AELI, AELI, I.SSH(L), SSH(L), NRG(L), HIL(I), FAST1961 COMMON/OTHERS/KAADULSX, XTJ, ADELA, JACOSIJA, TA, ATB, AATC, FAST1964 L ATD .AT, ABL, ABAR, NZERD		9		INRG	,INSC	.ISTP	+ INRP	, I NCP	IFXP	,IFXS		FAST1951
CALL KEROUM(NEMDD,1,H(IXMP),H(IAE),H(IBE),H(IBE),H(IBE),FAST1953 L H(IRMD),H(ISSH),H(IAE),H(ISGT),MIN,MAX,ST,NRG] FAST1955 RETURN FAST1955 SIBTIC KEROWN H04/2,XRT CKEROUMREAN FREE_SATH CALCULATION FOR PROGRAM FASTERT,M.JORDANWARL FAST1957 SUBROUTINE KEROWN (LIL2,XMP)AE,BE,ELL,ELK,ES,RRD,SH,MTL,SGT,HTW,FAST1957 SUBROUTINE KEROWN (LIL2,XMP)AE,BE,ELL,ELK,ES,RRD,SH,MTL,SGT,HTW,FAST1957 SUBROUTINE KEROWN (LIL2,XMP)AE,BE,ELL,ELK,ES,RRD,SH,MTL,SGT,HTW,FAST1950 DIMENSION XMP(I),AE(I)ABE(I)FEL(I),ELK(I),ES(I),NRG(I),TTL(I), FAST1962 L STIJ,RAG(I)SGT(LIL2,SSH(I) COMON/OTHERS/RAGIUS,XCT(I)SOCIA),SSH(I),ATA ,ATB ,ATC , FAST1963 L ATD ,AT ,BT ,AS ,BS ,JMIN ,JMAX , FAST1964 2 KHTW, KMAX ,MAR, MZERD		1		1 F X 1	•1FXE	, LF XA						FAST1952
L H(IRHO),H(ISSH),H(INTL),H(ISGT),MIN,MAX,ST,NRG) FAST1956 RETURN FAST1956 END FAST1956 SUBTC KERDMI M94/2,XR7 CKERDUM+MEAN FREE,PATH CALCULATION FOR PROGRAM FASTRET,H,JORDANWARL#OFFAST1958 SUBROUTINE KERDWILL,L2,XMP,AE,BE,ELL,ELW,E5,XR9,SSH,MTL,SGT,MIN, FAST1950 L MAX,ST,NRG) DIMENSION XMP(I),AE(I),BELL(I),ELW(I),ES(I),MRG(I),HTL(I) FAST1960 DIMENSION XMP(I),SGT(L1,L2),SSH(I),ES(I),MRG(I),HTL(I) COMMON/OTHERS/RADUS,XGT(A),DELTA,BDC(3),ATA ,ATB ,ATC ,FAST1963 L ATO ,AT ,BL AS, BS ,JMIN ,JMAX , FAST1964 2 KMIN ,KMAX ,MAR, MZERO		CALL K	ERDUMIN	ENOD,1	HIEXMP	HELAE	.HI IBE	1.HILL	L),H(EE	LW)+H(I	ES),	FAST1953
RETURN FAST1955 RETURN FAST1955 \$10FIC.KEDNH M94/2,XRT CKEDNH M94/2,XRT CKEDNH M94/2,XRT CKEDNH M54/2,XRT SUBROUTINE KERDUN LLU2,XMP,AE,BE,ELL,ELW,ES,RHO,SSM,MTL,SGO,MIN, PGST1950 SUBROUTINE KERDUN LLU2,XMP,AE,BE,ELL,ELW,ES,RHO,SSM,MTL,SGO,MIN, PGST1950 IDIRESION XMOILJ,AE(1),BEILJ,IJ,ELL(1),ELW(1),ES(1),MTG(1),MTL(1), FAST1960 IL ST(1),RHO(1),SGT(1),ELL(1),ELW(1),ES(1),MTG(1),MTL(1), FAST1962 COMMON/OTHERS/KADIUS,XCT(3),DELTA, BOC(3),ATA , ATB , ATC , FAST1963 I ATD ,AT ,BT ,AS ,BS ,JMIN ,JMAX , FAST1964 2 KMIN ,KMAX ,MAR ,MZERD		1	н	(IRHO)	,H(ISSH	0.HU INTO	L),H(15	GT),MIN	,MAX,ST	+NRG)		FAST1954
END FAST1956 SIBTIC KERDMI M94/2,XR7 CKERDUM+MEAN FREE PATH CALCULATION FOR PROGRAM FASTRET, H,JORDANWARL#OFFAST1958 SUBROUTINE KERDWILLL2,XMP,AE:BE.ELLELW.ES;ARD,SSH,MTL,SGT.HIN,FAST1990 1 MAX,ST.NRG DIMENSION XMP(1),AE(1),BELL(1),ELW(1),ES(1),MTC(1),MTC(1) 4 ST(1),RAC(1),BELL(1),ELW(1),ES(1),MTG(1),MTL(1) 5 ST(1),RAC(1),SGT(1),L2),SSH(1) COMMON/OTHERS/RAGUUS,XCT(3),DELTA 1BOC(3),ATA ,ATB ,ATC COMMON/OTHERS/RAGUUS,XCT(3),MAT ,AS ,BS ,JMIN ,JMAX , FAST1960 2 KMIN ,KMAX ,MAR ,MZERO		RETURN	4									FAST1955
<pre>SIGPTC KEROMI M9/2,x87 FAST1957 FAST1957 SUGROUTINE KEROUNILI,2,XMP,AC,BE,ELL,ELW,ES,AND,SSN,WTL,SGT,MIN, FAST1959 SUGROUTINE KEROUNILI,2,XMP,AC,BE,ELL,ELW,ES,AND,SSN,WTL,SGT,MIN, FAST1959 INFENSION XHOIL,ACI,ACI, ELLI, KES, ELLI, FAST1952 COMMON/OTHERS/AGUIUS,XCT313,DOELTA, BOCIS1,ATA, ATB, ATC, FAST1962 COMMON/OTHERS/AGUIUS,XCT313,DOELTA, BOCIS1,ATA, ATB, ATC, FAST1963 L ATD, AT, ABL, ASS, 4,85, JMIN, JMAX, FAST1964 2 KNIN, KMAX, VABA, HAZERD</pre>		END										FAST1956
CKERDUM+MEAN FREE PATH CALCULAITON FOR PROGRAM FASTERTI, JORDAN HANL+66FAST1958 SUBGROUTINE KERDUMLIL,2,XMP,AE,BBE-LEL,ELW,ES,XHD,SSH,MTL,SGT,NTN, FAST1990 I MAX,ST.NRG) DIMENSION XMP(I),AE(I),BEL(I),ELM(I),ES(I),MRG(I),MTL(I) FAST1901 I ST(I),RHO(I),SGT(LI,L2),SSH(I) COMMON/OTHERS/RADUS,XGT(3),OE(IA 1BOC(3),ATA ,ATB ,ATC ,FAST1903 I ATO ,AT ,BT ,AS ,BS ,JMIN ,JMAX , FAST1964 2 KHIN ,KMAX ,MAR ,MZERO	\$18	FTC KERD	(1 N94/	2,XR7								FAST1957
SUBROUTINE KEROUMILILZ,XMP,AE,BE_ELLELW,ES,MHD,SSH,MTL,SGT,MIN, FAST1990 1 MAR,ST,MRG DIMENSION XMP(I),AE(I),BEC(I),EL(I),EM(I),BEC(I),MTL(I), FAST1900 201MENSION XMP(I),AE(I),BEC(I),SSH(I),SSH(I),MTG(I),MTL(I), FAST1900 COMMON/OTHERS/KAADUSX,XETAJ)DELTA,BOCTSIJAITA,ATB ATC COMMON/OTHERS/KAADUSX,XETAJ)DELTA,BOCTSIJAITA,ATB ATC ATO AAT ,BE AAS ,BS ,JMIN ,JMAX , FAST1906 2 KMIN ,KMAX ,MBAR ,MZERO	CKE	RDUH+HEAN	I FREE_P.	AJ HTA	LCULATI	DN FCR I	PROGRAM	FASTER	*T.H.JO	RDAN#WA	NL #6	6FAST1958
L FASTI96 DIMENSION XMP(1), AG(1), BEL(1), EL(1), EL(1), ES(1), MT(1), MT(1), FASTI96 L ST(1), RHO(1), SGT(1), L2), SSH(1) COMMON/OTHERS/RAGUUS, XGT(3), DECTA, BOC(3), ATA , ATB , ATC , FASTI963 L ATO , AT , BL , AS , BS , JMIN , JMAX , FASTI964 2 KHIN , KMAX , MAR , MZERO .		SUBROL	ITINE KE	RDUMEL	1,12,XM	P.AE.BE	ELLIEL	W.ES.RH	D,SSH,M	TL.SGT.	MIN.	FAST1959
DIMENSION XMP(1),AE(1),BE(1)=ELL(1),ELM(1),ES(1),MRG(1),XTL(1), FAST1961 l :ST(1),RAG(1),SGT(1:L2],SH(1) COMMON/OTHERS/RADIUS,XCT(3),DELTA ,BDC(3),ATA ,ATB ,ATC , FAST1963 l ATO ,AT ,01 ,AS ,05 ,JMIN ,JMAX , FAST1965 2 KMIN ,KMAX ,JAGA ,MZERO .FAST1965		1		M	AX, ST.N	RGI					•	FAST1960
L		DIMENS	ION XMP	(1).AE	(1),8EL	I) .ELL(1),ELW(1), ES(1),NRG(1),#TL(1	۱.	FAST1961
COMMON/OTHERS/RADIUS,XCT43,JOELTA ,BOC(3),ATA ,ATB ,ATC , FAST1963 l Ato ,AT ,Bt ,AS ,BS ,JMIN ,JMAX , FAST1964 2 KMIN ,KKAX ,J&R ,MZERO . FAST1965		1	-571	11.RHO	(1),SGT	LLI LZI	SSH(1)					FAST1962
L ATO +AT +BT +AS +BS +JMIN +JMAX + FAST1964 2 KMIN +KMAX +JBAR +NZERO . FAST1965		CONHON	I/OTHERS.	/RADIU	S.XCT13	I,DELTA	,BOC(3	J,ATA	ATB	+ATC		FAST1963
2 KMIN KMAX JBAR NZERO . FAST1965		ι.		ATO	, AT	181	, AS	*8 5	+ JHIN	XAML+		FAST1964
		2		KMIN	,KHAX	,JBAR	NZERO					FAST1965

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CONHON/LENT	TS/NSTORE .NE	RROR-NSMAX	NAMAX	-NRHAX	.NBMAX	.NSTHAX.	FAST1966
1	NEMAX .NV	MAX .NXHAD	-NXENA	K-NEKOO	-NXSECT	.NUNITD.	FAST1967
2	NUNITY .NI	HAY _NHHAD	NORDE	R-NOOWN	, INFL AS	NTRANS.	FAST1968
1	NNMAX .NG	HAX NEMA	-AVHOD	-NCHAX	NI NAX	NTHAX .	FAST1969
	NONAY NG	HOD HORES	T .NOHOD	NPOHA	NPDHOD	NSDHAK.	F45T1970
2	NUCKAY NY	DHOD, NROIL	T. MODEL	0. NODEL	NODELU	I. NODEL V.	EAST1971
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	0						FAST1976
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CORMON	H(1)						FASTINGA
COMMON/DUMS	TH/NN .PS	PDA					FASTING
COMMON/LINE	TS/NSTORE NE	REOR-NSMAX	AMANAX	-NSMAX	-NBNAX	-NSTRAX-	FAST2000
· 1	NEMAX .NV	HAX .NXHAX	NXEMA	.NENOD	•NXSECT	NUNITO.	FAST2001
2	NUNITX-NI	HAX .NHHAX	NORDE	R.NDDWN	.INELAS	.NTRANS.	FAST2002
3	NHMAX .NG	HAX .NEMAX	NVHOD	.NCRAX	NLHAX	NTRAX .	FAST2003
4	NDBAX -NG	NOD .NOMEN	T NDMOD	-NPDMAX		-NSDRAX.	FAST2004
5	NVDMAX - NV	DHOD.NPOIN	T. MODEL	P.NODELO	. MODELU	NODEL V.	FAST2005
6	NPRINT-NU	NITS.NUMBE	R.KALTO	e .			FAST2006
CONHON/INDE	XS/INTP .IA	7 .115V	. INTS	•18H0	. 7 X R	atell a	FAST2007
1	IELN .IA	E IBE	INSG	.I NPC	.IJSN	.IJSX .	FAST2008
ż	IXTR .15	UV FLATN	TATH	•1 ESB	I S SH	IDEN	FAST2009
3.	INTG .IE	LF IFGW	. ITDS	1107	LIDR	TIDS	FAST2010
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5	IATH . LA	LH TALH	.IA	INS	. IVEE	.IVAL .	FAST2012
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e	INRG	INSC	ISTP	INRP	INCP	FXP	,IFXS		FAST2016
í í	IFXT	IFXE	.IFXA	• - ·	-				FAST2017
сонномия	GSCAZNSRNA	X-INSR							FAST2018
DIMENSION	N(1)								FAST2019
FOUTVALE	CE (N(1) H	(1))							FAST2020
NN × NNN									FAST2021
PSI = AAA	1								FAS12022
PDA = 888	3								FAST2023
INSR = 0									FAS12024
EF (NSRMA)	(.LE.0) GO	TO 10							FAST2023
DO 5 [×1;	NSRFAX								EAST2027
IF(NN.EQ.	N(I)) INSR	= 1							EAST2028
5 CONTINUE									FAST2029
10 CONTINUE			******				1.81110	E).	FAST2030
CALL SING	JUNI NDUWN N	DKDEK 1	I RELAS	* 1CHAA)	CD1 . M11	14.142	(DEN).		FAST2031
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KETORN									FAST2034
	N04/2. XR7								FAST2035
CS INDUNESTINGE	SCATTER ING	CALCUL	ATION F	OR PROG	RAN FAS	TER+T.M	.JORDAN	•WAN	LFAST2036
SUBROUTL	SINDUNIL	1.12.13	+14+L5+	MTL . RHC	, IDE, ID	1,5	GS,ESB,	SSH.	FAST2037
1 '*	0	EN.WS.E	S, WC, EC	,ELL)					FAST2038
DINENSIO	N MTL(1),RH	0(1),10	EIL1+L2	,L31,IC	1114,13),SGS[1	,1),E	5811	IFAS12039
1.	,SSH(1),DE	N(1).WS	(1),656	1) MC(1	1,60(1)	.ELL(1)	*KWX(I)		FAST2040
COMMON/D	JMS EN/NN	.PSI	*60¥						FAS12041
CONHON/O	THERS/RADIU	IS, XCT (3);DELTA	,BOC(3	ATA, G	,ATB	ALL	•	FAST2042
. 1)	ATD	- , AT	.87	+AS	+B S	, JAIN	+ JHAX	•	FAS12043
2	KNIN	,KMAX	JBAR	+NZERC		UDMAN	NCTH	w.	FAST2044
CONHON/L	INITS/NSTOR	E, NERRO	R.NSPAX	.NAMA		* NORAA	T.NIINTI	n.	FAST2046
1	NERAZ	NVNAX	INCOMA A	+ 4000		- INEL	S.NTRAS	is.	FAST2047
2	NUNT	APRIL MAA	ALC PAR		NCHAY	- NE NAY	NTHAN		FAST2048
3	KONA	NCHOR A	- HOWER	TANDHOI	NODHA	X.NPDHC	D NSDM	x.	FAST2049
2	NUCHA		D.NPOIL	T. MODEL	P-HODEL	D. HODEL	U. NODEL	.v.	FAST2050
2.4	10071	T.NUNTT	S-NIINRS	R . X AL 1	F				FAST2051
бет ж О.	0		3 11101-01		-				FAST2052
N = NT()	NN1								FAST2053
INTN a N	FRAX + 1								FAST2054
JHAX = 0									FAST2055
00 10 1-	1.NEMAX								FAST2056
WS(1) *	0.0								FAST2057
10 ES(1) =	0.0								+AST2058
IFIN.LT.	O) GO TO 92	20							FA512059



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	IF(NXSECT.NE.1)GO TO 220	FAST2060
100	PSIN = PDA	FAST2061
	1F(M.EQ.0)GC TO 175	FAST2062
	PLN2 = 0.0	FAST2063
	PLM1 = 1.0	FAST2064
	DO 139 L=1,NORDER	FA512065
	DO 120 K=1,NDOWN	FAST2066
	[F(IDE(K,L,N).LE.0)GO TO 130	FAST2067
	JMIN = KMIN	FAST2068
	N = IDE(K,L,M)	FAST2069
	KMOD = HINO(KMAX,NEMAX + 1 - K)	FAST2070
	IF(KNIN.GT.KNOD)GO TO 130	FAST2071
	1 = KMIN + K - 2	FAST2072
	80 110 J=KMEN,KM00	FAST2073
	E = E + 1	FAST2074
110	IWS(1) = WS(1) + WC(J)+SGS(J,N)+PSIN	FAST2075
	JHAX = HAXO(JHAX,[]	FAST2076
120	CONTINUE	FAST2077
130	PLHZ=[PS[*PLH1*FLOAT[2*L-1]-PLH2*FLOAT[L-1]]/FLOAT[L]	FA512078
	PLHZ = PLH1	FAST2079
	PLH1 = PLHZ	FA5T2080
	PSIN = PDA*PLHZ	FAST2081
139	CONTINUE	FAST2082
	KNOD = MINO(KMAX, INELAS)	FAST2083
	[F(KMOD.LT.KMIN] GO TO 160	FAST2084
	80 150 J=KHIN,KNOC	FAST2085
•	K = ID((J,H)	FA5T2086
	IF(K.EQ.0) GO TO 160	FAST2087
	N = K/1000	FAST2088
	MAX = HINO(NEMOD-J,K-1000*N)	FAST2089
	1 = 3 - 1	FAST2090
	DO 140 K=1, PAX	FAST2091
	1 = 1 + 1	FAST2092
140	WS(I) = WS(I) + WC(J) + SGS(K,N) + DA	FAST2093
	JHAX = HAXO([,JHAX)	FAST2094
150	CONTINUE	FAST2095
160	DD 170 I=JMIN, JMAX	FAST2096
170	(E2[1] = E28(1)+W2(1)	FAST2097
	FSI = DER(A)	FAST2098
10	FSt = 9.0*PST*PUA*(FST + RHO(NN))	FAST2099
	1F(FS).LE.0.0160 10 900	FAST2100
	KAT * PS1**2	FAST2101
	AIN = KAIN	FASTZLOZ
	DU ZUU JERMINARAX	FASTZLO3
	C = KAIVELLJJ	FAST2104
	UU IOU ITAIN,NEMAX	FAST2105
	171E-0E-ELL1(+1))60 TO 190	FAST2106

180 CONTINUE	FAST2107
GO TO 210	FAST2108
190 MIN = I	FAST2109
JHIN = MING(JHIN,I)	FAST2110
* WSC = FST#SSH(J)*WC(J)	FAST2111
WS(I) = WS(I) + WSC	FAST2112
200 ES(I) = ES(I) + WSC#E	FAST2113
(XANL, NIN) OXAN = XANL, NIN) OXAN = XANL	FAST2114
GO TO 900	FAST2115
COMPTON SCATTERING	FAST2116
220 MIN = KAIN	FAST2117
PSIN = 1.0 - PSI	FAST2118
PSIS = P51**2 - 1.0	FAST2119
GST = RH0(NX)+0.49875	FAST2120
IF(H.GT.O)GST = GST + DEN(M)	FAST2121
GST = PDA+GST	FAST2122
DD 250 J=KHIN,KHAX -	FAST2123
RAT = 0.511/(0.511 + PSIN+EC(J))	FAST2124
E = RAT+EC(J)	FAST2125
DD 230 I=NIN.NENAX	FAST2126
IF(E.GE.ELL(1+1))GD TO 240	FAST2127
230 CONTINUE	FAST2128
GO 10 260	FAST2129
240 MIN = I	FAST2130
II, NIMLIONIM = NIMLIONIN, II	FAST2131
FST = %C(J)+GST+RAT++2+(RAT + 1.0/RAT + PSIS)	FAST2132
WS(1) = WS(1) + FST	FAST2133
ES(I) = ES(I) + #ST#E	FAST2134
250 CONTINUE	FAST2135
260 JMAX = MIN	FAST2136
900 IF(JMIN.GT.JMAX)GC TO 920	FAST2137
DO 910 I=JHIN, JHAX	FAST2138
IF(WS(I), NE+0+0) = S(I) = S(I)/WS(I)	FAST2139
910 CONTINUE	FAST2140
920 RETURN	FAST2141
END	FAST2142
SIBFTC TRACE M94/2, XR7	FAST2143
CTRACER*PARTIAL PATH LENGTHS FOR PROGRAM FASTER*T.H.JORDAN*WANL*1966*	FAST2144
SUBROUTINE PATH (NNN,SSS,XXX,CCC,MMN,ST,NRG,NSC)	FAST2145
COMPON HELS	FAST2146
COMMON/DUMTRA/NN +STH +NST +X(9) +C(9) +CX(9)	FAST2147
COMMON/LIMITS/NSTORE,NERROR,NSMAX ,NAMAX ,NRMAX ,NBMAX ,NSTMAX,	FAST2148
1 NEHAX ,NVHAX ,NXHAX ,NXHAX,NEHOD ,NXSECT,NUNITD,	FAST2149
2 NUNITX, NIMAX , NEWAX , NCRDER, NDOWN , INELAS, NTRANS,	FAST2150
3 NNMAX , NAMAN, DOHVA, JAFAN, JAMAN, JAMANN, JAMANN, JAMAN, JAMAN, JAMAN, JAMAN, JAMAN, JAMAN, J	FAST2151
4 NDHAX ,NGHCD ,MOHENT, NONDD ,NPDHAX, NPCHOD, NSDNAX,	FAST2152
5 NVDMAX,NVDMQD,NPGINT,MCDFLP,MODELQ,MODELU,MODELV,	FAST2153

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6	NPRIN	T.NUNTT	S-NUKRE	R.KALLO	IF			FAST2154
CONNON/INDEXS	TNTP	.147	.1150	. THTI		• I XR	• I F1 I	. FAST2155
1	TOTAL	TAF	186	THSG	TNPC	. LJSN	.1.15x	FAST2156
2	IXTR	. L SUV	LATN	LATH	TESB	- ISSH	1DEN	FAST2157
	INTG	TELE	.IFGN	TIDS	-1 (DV	I IDR	.TIDS	FAST2158
1	TVDI	TCOT	TXDT	1851	TALP	TVAD	.IGIN	F45T2159
	TATM	TALM	TALH	. 14	TNS	IVEE	IVAL	EAST2160
6	I SPU	ISPE	. LATD	TRSP	J SGT	1105		- FAST2161
ž	1565	NEXT	. IXMP	- I SGR	1 115	IES	.INC	FAST2162
. A	TEC	IND	TU	.19		151	.151	FAST2163
G	INRG	INSC	ISTP	THRP	INCP	TEXP	.IFXS	FAST2164
í	IFXT	TEXE	TEXA					FAST2165
DIRENSION XXX	11.00	c/11						FAST2166
NN > NNN		,						F4572167
STH CCC								FAST2168
00 10 1-1.3								FAST2169
								EAST2170
								EAST2171
				MI 147 1		artset.		54573177
	THAN 311	TW1	511A1FJ	CT 1 . CT .	NOC .NCC	1 10.377		EAST2173
	10790			5179517	1100 1130	,		EAST2174
957000								FA312114
REFORM								FA312173
ATTETC TOACHT HOLAS	~~~							FA312110
\$10FIL IKAUML M9472								- CACTOLTO
CIRADUR-PARITAL PATE	I LENG	105 208	PROGRA			ST CT	ANL - 1960	- FASIZIIA
DIMENSION MID	13 42		***********	**************************************		NOC / 1 1	NCC / 11	CAST2119
DIMENSION NIPI	11144		1.0237.78	5462463		MAGILI	********	FAST2180
			ALT 1 1 3 C	2,17	c			FAST2101
CONHON () INT TO	NN	1216	1021	**(3)	+C 1 41	+62191		FAS12162
CURRON/LINIIS/	NUTURI	NUMAN	K, NSPAK	+ RARAA	THERE A	TURAL	INTER	FASI2103
1	ACRAA	, NYRAA	INADRA .	, AAEAA	ALGENUU	. AASEL		FAST2104
2	NUNLEY	NCHINAK	ALCHINA .	NUROD	Renouse	+ INCLA	STRIKANS	CAS12107
2	HONAX	HONDO	JOFFAA	*******	THURAN	+ GLAAA	, HICOMAN	, FASIZIOD
2	NURAA	+16400	* HUREN		-RPORA	APURU:	U, NSUMAA	A312187
2	INVOIRA !!	. RYUNU	Ushruin	I MODEL	P HODEL	11 HOULE	OPHONEL A	A312180
	APRIA	I FUDALE.	2 * UONOE	K, KALIO	•			FA312107
00 110 1 1.5								FA312190
								LW2151A1
AL173) * AL17								CARTAINA
ALIT6) # XLLJ#	*2							FAST2192
CIT. 31 - 3 040	*2 X(J)							FAST2192 FAST2193
C(1+3) = 2.04C	*2 X(J) (I)*X	11)						FAST2192 FAST2193 FAST2194
C(I+3) = 2.04C C(I+6) = C(I)+	*2 X(J) (I)*X(X(J)	(I) • C(J)+:	x(1)					FAST2192 FAST2193 FAST2194 FAST2195
C([+3] = 2.0*C C([+6] = C([]* CX[]*3] = C([]*	*2 X(J) ([]*X(X(J) **2	(1) • C(J)+:	x(I)					FAST2192 FAST2193 FAST2194 FAST2195 FAST2195 FAST2196
C(1+3) = 2.0*C $C(1+6) = C(1)*$ $C(1+6) = C(1)*$ $110 CX(1+6) = C(1)$	*2 (J) (I)*X (X(J) *02 *C(J)	(I) • C(J)*:	x(1)					FAST2192 FAST2193 FAST2194 FAST2194 FAST2195 FAST2196 FAST2197
C([+3] = 2.0*C C([+6] = C([]* CX([+6] = C([]* 110 CX([+6] = C([] D0 120 I=1+NSP	*2 (J) (I)*X (J) (I)*X (J) *02 *02 *C[J] *AX	(I) • C(J)*:	x(1)					FAST2192 FAST2193 FAST2194 FAST2195 FAST2196 FAST2196 FAST2197 FAST2198
C([+3] = 2,0*C C([+6] = C([] CX[]+6] = C([] CX[]+6] = C([] 110 CX[]+6] = C([] DO 120 [=1,*NS* 120 ND[[] = 0	*2 (J) (I)*X (J) *02 *C(J) AX	[]) 	x(I)					FAST2192 FAST2193 FAST2194 FAST2195 FAST2195 FAST2196 FAST2196 FAST2198 FAST2198 FAST2199

	3 NNMAX INGMAX INFMAX INVADD INCHAX INLMAX INTMAX I	PAST
	A NDMAX ,NGROD ,MOMENT,NDROD ,NPDMAX,NPOHOD,NSOMAX,	FAST
1	5 NVDHAX, NVDHOD, NPDINT, HODELP, HODELQ, HODELU, HODELV,	FAST
	6 NPRINT, NUNITS, NUMBER, KALIDE	FAST
	DO 110 I=1.3	FAST
	J = I + I - 30(1/3)	FAST
	X(I+3) = X(I)++2	FAST
	(1+6) = (1)x+(1)	FAST
	C(1+3) = 2.0*C(1)*X(1)	FAST:
	C(1+6) = C(1)*x(1) + C(1)*x(1)	FAST
	CX(1+3) = C(1)++2	FAST
110	CX(1+6) = C(1)+C(J)	FAST
	DG 120 I=1,NSMAX	FAST
120	ND(I) = 0	FAST
	II = NN	FAST

-	
' STT = 0.0	FAST220L
, DO 410 N=1,NSTMAX	FAST2202
00 400 H=1,3	FAST2203
GO YO(130,140,160),M	FAST2204
130 IHIN = []	F45T2205
0 = 10	FAST2206
SP * 1.0E+38	FAST2207
GO TO 150	FAST2208
140 IF(NXT.EQ.0)60 10 460	FAST2209
IMIN = NXT	FAST2210
150 THAX = IMIN	FA5T2211
GD TO 170	FAST2212
160 IMIN = 1	FAST2213
IMAX = NRMAX	FAST2214
170 DO 390 (=IMIN. (MAX	FAST2215
(F(H.LE.2)GQ TO 190	EAST2216
IF((NXT - []*(IP - I).EQ.0)60 10 390	FAST2217
DO 180 Jal-NBMAX	EAST2219
IF(NS(J,1),E9,0)60 10 390	FAST2210
IF(LABSINSP - NS(1,1)/10001,F0,1000100 TD 190	EAST2220
180 CONTINUE	EAST2221
60 10 390	ELETOTO
190 D0 340 J=1.NBMAX	EACT2122
IF(NS(1,1),F0,0)(0 to 250	54672223
KK * NS(1,1)/1000000	FAS12224
K = 55(1,11/1000 - 1000 KK)	FAST2223
IE(IM.GT.1).AND. (X.EC.1).100 TO 340	EAST2220
	FA312227
LE(ND(K)-GT-D)GD TD 210	EAST2220
ND(K) × 1	64512227
USK1 = A7(K)	F4312230
V(k) = 0.0	EAST22221
H(K) = 0.0	E1572232
HAX = NTP(K).	FAS12233
00 200 L+1.HAY	FA312234
HIKI = HIKI + XII I+AEI	EAST2223
V(K) - V(K) + C(L)AA(L,V)	54572223
IF(I_GT_3)W(K) = V(K) = (V(I) = A(I), V)	FR312231
200 CONTINUE	FAST2239
210 IF(N,1F-1)GD 10 220	FAS12240
IFIELDATIKE BUILT & STRAUTEL & STRAUTELLA DIO DIO DO	FR312241
220 [F(N)(K)] = 21 230 290 360	FAS12242
230 NO(k) = 2	FA312243
[F[W X]] 250.240.240	FA312244
260 1E(V/K).E0.0.01C0 TO 310	PAS12245
	FA312246
1E(S1(1,K),(T,0,0)CO, TO 310	FAS12247
	PAST2248

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:

SI(2.K) = S[(1.K]	FAS12249
GO TO 290	FAST2250
250 1 # 2	FAST2251
60 TO 270	FAST2252
260 1 3 1	FAST2253
270 E x -0.5+V(K)/W(K)	FAST2254
E a U(K)/W(K)	FAST2255
$H = F \pm 2 = F$	FAST2256
1F(F,(F,0,0)60 T0 280	FAST2257
IF(F.LE.0.0)60 TO 310	FAST2258
1F(H.1.E.0.0)60 TO 310	FAST2259
280 H = SORT(H)	FAST2260
ST(1-K1 = F - H	FAST2261
$1 \times 1 + 1 - 2*(L/2)$	FAST2262
SILL-K) * E + H	FAST2263
290 L = 1	FAST2264
$IF(KK,GT,0)L \approx 2$	FAST2265
SB = SI(L-K) - STT	FAST2266
1F(SB) 300,320,330	FAST2267
300 L = L + 1 - 2*(L/2)	FAST2268
[F(S](L,K).GT.STTIGO TO 340	FAST2269
310 ND(K) # 3	FAST2270
GO TO 340	FAST2271
320 [F(FLOAT(KK)*(V(K) + 2.0*STT*W(K)).LT.0.0160 TO 340	FAST2272
330 IF(SB.GE.SP)GO TO 340	FASY2273
SP = SB	FAST2274
jj = j	FAST2275
LL = X	FAST2276
340 CONTINUE	FAST2277
350 IF(M.LE.1160 TO 360	FAST2278
11 = 1	FAST2279
NS(JJ, IP) = 1000+NSP + 1	FAST2280
GO TO 410	FAST2281
360 [F[JJ.EQ.0]60 TO 415	FAST2282
370 NRG(N) = I	FAST2283
IFISTN.GT.(STT. + SPI)GO TO 380	FAST2284
NSC(N) = 0	FAST2285
STINJ = STH - STT	FAST2286
GO TO 420	FA512287
380 NSC(N) = LL	FAST2236
ST(N) = SP	FAST2288
STT = STT + SP	FAS12289
[F(NTP(LL).LE.3)ND(LL) = 3	FAST2290
NSP = NS(JJ,11/1000	FAST2291
NXT = NS(JJ;1) - 1000=NSP	FAST2292
NXXX = 0	FAST2293
[F[NXT_LE_NRMAX] GO TO 385	FAS12294

	1F(NXXX.GT.10) GO TO 420	AST2296
	NXT = 0	FAST2297
385	IP = 1	FAST2298
390	CONTINUE	FAST2299
400	CONTINUE	FAST2300
	NS(JJ.IP) = 1000+NSP + MIN0(999-NRMAX+NXXX+1)	FAST2301
	60 10 420	FAST2302
410	CONTINUE	FAST2303
	N = NSTHAX + 1	FAST2304
415	N = N - 1	FAST2305
420	NST # N	FAST2306
430	PETTIRN .	FAST2307
450	END	FAST2308
* 1851		FAST2300
CNUCH	A BEINGERGE - NORMAL CALCULATION FOR PROGRAM FASTERET.H. IORDANBUAN BAS	FAST2310
CHOM:	CURRENTIAL NORMAL CHANNESS, YYY, CCC. OOD1	CACT2311
		CACTORIZ
	CONDUCT BALL A CONDUCTOR DECODER DECAMAN STATE AND AND A DECAMAN A CONDUCTOR DECAMAN AND A DECAMAN A	CACT2312
	COMMONYLINI STATUCTION CONTRACT TARGER TARGER TROPA TROPA TASTARAT	EACT3314
	L REMAX JAVAAN JAVAAN JAVENKAJACHUU JAVASCIJAUNIIUJ : BIINTTY JIVAY JAVAAN JAVENKAJACHUU JAVASCIJAUNIIUJ :	EACT221E
	C BUILLA ALLA A MARKA ANDERA DURA ALLE ANALASA	CACT2314
	2 INTERA JAURAA INFPAA INTOU JAURAA INTAAA INTAAA INTAAA I	FAS12310
		PAS12317
	S NYDRAX, RYDRCD, RPOINT, ADDELY, ADDELU, ADDELU, ADDELU, ADDELV,	FA512318
	o NPKINI, NUNIIS, NUNDER, KALIDE	FA512314
	CUMMUN/INDEXS/INTP , IAZ , IISV , IAIL , IKHU , IXR , IEEL ,	FAS12320
	L LELN TIAE TIBE TING TIMPC TIJSN TIJSX T	PAS12321
	Z IXTR ISUV IATN IATW IESE ISSH IDEN	FAS12322
	3 INTG , IELF , IFGW , ITDS , ILDV , ILDR , ILDS ,	FAST2323
	A IVOL , ICOT , IXCT , IRSI , IALP , IVHD , IGIR ,	FAST2324
	5 IAIR , IALH , IALH , IA , INS , IVEE , IVAL ,	FAST2325
	6 ISPN ,ISPE ,IATO ,IRSP ,ISGT ,IIDE ,IIDI ,	FAST2326
	7 ISGS ,NEXT ,IXMP ,ISGR ,IWS ,IES ,INC ,	FAST2327
	a IEC IND IU IV IN ISI ISI	FAST2328
	9 INRG +INSC +ISTP +INRP ,INCP ,IFXP ,IFXS +	FAST2329
	1 IFXT IFXE IFXA	FAST2330
	CALL NORDUM(NAMAX,I,H(INTP),H(IA),NNN,SSS,XXX,CCC,DDD)	FAST2331
	RETURN	FAST2332
	END	FAST2333
\$18FT	C NORDH1 #94/2+XR7	FAST2334
CNORD	UM+SURFACE NORMAL CALCULATION FOR PROGRAM FASTER*T.M.JORDAN+WANL*66	FAST2335
	SUBROUTINE NORDUN(L1,L2,NTP,A,KNN,STT,XP,CP,C)	FAST2336
	DIMENSION NTP(1), A(L1,L2), XP(3), CP(3), X(3), C(3)	FAST2337
	00 10 I=1,3	FAST2338
10	X(1) = XP(1) + STT+CP(1)	FAST2339
	I = NNN	FAST2340
	FST = 0.0	FAST2341

NXXX * NXT - NRMAX

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FAST2295

$c_{1} = 0$
TETT+63-15 HAVIC()) = 213346(2+6.5)
IF((J+6) = IE - MAX(C(J)) = C(J) + X(K) + A(J+6 - 1)
[5((J+3).LE.RAX)C(J) * C(J) + 2.0*x(J)*A(J+3.1)
$[f(J_{+}LE_{+}MAX)C(J_{+}) = C(J_{+}) + A(J_{+})]$
20 FST = FST + C(J)**2
IF(FST+NE+L-0)FST = SORT(FST)
DO 30 J=1,3
30 CIJH = CIJYEST
RETURN
END
\$IBETC ROTAT H94/2+XR7
CROTATE+ROTATION MATRIX
 SUBROUTINE ROTATE(CPF,SPH,CTH,STH,ROT)
DIMENSION RGT(3,3)
10 R01(1,1) = CTH+CPH
ROT(2,1) = -STH
RUT(3,L) = CTH+SPH
ROT(1,2) = STH+CPH
ROT(2,2) = CTH
ROT(3,2) = STH#SPH
ROT(1,3) = -SPH
RU1(2,3) = 0.0
KUII3,3) = LPH
FORTAL GROUT HTTP://ANI
SPH = SORTIAMAXIIO.0.1.0 - (PH++21)
IFISPH-GT-9-01G0 T0 10
CTH = 1.0
STH = 0.0
GU TO 20
10 CTH = C(L)/SPH
STH = (12)/SPH

ROT(2,1) = -STH
ROT(3,1) = CTH+SPH
ROT(1,2) = STH#CPH
ROT(2,2) = CTH
ROT(3,2) = STH#SPH
ROT(1,3) = -SPH
ROT(2,3) = 0.0
R01(3,3) = CPH
RETURN
END
\$IBFTC CROT M94/2,XR7
CROTATC*ROTATION MATRIX GIVEN DIRECTION
SUBROUTINE ROTATC(C,ROT)
DIMENSION C(3)
CPH = C(3)
SPH = SQRTIAMAXIIO.0.1.0 ~ CPH**2
IF(SPH.GT.0.0)G0 TO 10
CTH = 1.0
STH = 0.0
GU TO 20
10 CTH = C(L)/SPH
STH = C121/SPH
20 CALL ROTATE(CPH,SPH,CTH,STH,ROT)
0 E 71104

20 CALL RETURN END ' \$18FTC DOT -M94/2,X87

CCOS INE#001	еворист									EAST2389
FUNCI	TION COST	NE 1 Y . Y	•							EAST2300
DINE	STON XIN	1. 7(3)								CAST2301
A # 0										EACT7307
00 10	1=1-3									FAST2393
10 A = 4	+ X111+	Y(1)								FAST2394
COSIN	E = A									FAST2395
RETUR	N									FAST2396
END										FAST2397
SIBFTC TALL	YS 1947	2, XR 7								FAST2398
CDETECT*FLU	IX CALCUL	ATIONS	FOR PRO	GRAM F	ASTERPT.	H. JORDA	N+BANL+	1966		FAST2399
SUBRO	UTINE DE	TECTLE	11, JJJ,	AA, 888	(222					FAST2400
CONNO	IN	H(1)								FAST2401
COMMO	N/DUNDET	/1	• K	FST.	. ANG	•5 TV				FAST2402
CONNO	N/LIMITS.	/HSTOR	E,HERROF	t,NSHAX	, NAMAX	*NRMAX	, NBHAX	.NSTNA	۲,	FAST2403
1		NEMAX	, NVHAX	*NXHAX	*NXEMAX	NEMOD	+NXSECT	+NUNITS		FAST2404
2		NUNIT	X,NIHAX	,NMPAX	, NORD EP	L*NOOWN	.INELAS	, NTRANS	5.	FAST2405
3		NNMAX	, NGMAX	,NFMAX	,NYMOD	INCHAX	•NLMAX	,NTMAX		FAST2406
4		NOMAX	+NGMOD	*NONEN1	•NDKOD	+NPDHAX	(+NPDNOC	,NSDMA:	κ.	FAST2407
5		NVDHA	X.NVDHOL	,NPOINT	,MODELP	M ODEL	, RODELU	+ NODEL 1		FASTZ408
6		NPRIN	T.HUNITS	NURBER	,KALIDE					FAST2409
CONNO	N/ INUEXS	/INIP	+ IAZ	+1154	, INIL	.IKHU	LXR	11STL	•	FAS12410
1		IELW	.IAE	+18E	INSG	,I NPC	, CJSN	,IJSX	•	FAST2411
5		THE	.1507	, LAIN	, LAIN	+1458	+155H	+ LUEN		PAS(2412
,	÷.	1100	11207	, 1. 68		11104	+ I COR	,1105	•	PASI2413
2		TATM		7 44 1	I IRSI	+1 ALP	1465	1014	•	FA312919
2		TCOM	TSOF	TATO	1000	*1 NS	ITRE	TIDI	•	FAS12415
,		1505	NEYT	TYNO	terp	1 301	TEC	-196	•	CACT2417
Ŕ		TEC	180	.10	. 19		.151	.151		FAST241A
9		INRG	INSC	ISTP	INRP	INCP	TEXP	TEXS	2	FAST2419
i		IFXT	IFXE	TEXA					•	FAST2620
1 = 1	11			••••						FAST2421
Ĥ × Ĵ										FAST2422
FST =	AAA									FAST2423
ANG =	888								i i	FAST2424
5TV =	CCC								1	FAST2425
1P =	NEXT								i	FAST2426
tr =	[P+MAXO()	VLMAX.	23						i	FAST2427
CALL	DETOUNIL	RGMAX	NEROD, N	OMENT . H	([WS]+H	(LES),H	il INTG),	H(lFXT)		FAST2428
1H(1FX	P1.H(IFXE	E) .H(16	FXA),HU	RH0),H(IAE .HU	IBE1.H	ISSH) .H	LISGTI,		FAST2429
2H (I X M	P},H(1G1)	43+HCI	P}.H(IT)	HEIAIN	111					FAST2430
RETUR	N _						-			FAST2431
END										FAST2432
SIBEIC TALL	T A94/2	C+ XR7								FAST2433
CUELECT#FLU	X TALLYS	FUR PF	UGRAN F	ASTER						FAST2434
SOBRU	DIANE DEI	UDHCLI		LABRE	5+NIG+F	XT #FXP#	FXE#FXA	#RHO#AE	, 5E,	FAST2435

FAST2342 FAST2344 FAST2345 FAST2345 FAST2345 FAST2347 FAS

FAST2380 FAST2381 FAST2382 FAST2383 FAST2384 FAST2385 FAST2386 FAST2386 FAST2387 FAST2388

FAST2388

LSSH,SGT,XMP,GIM,P,T,AIM)		FAST2436
DIHENSION WS(1), ES(1), NTG(1), FXT(L2,L1), FXP(L2,L1), FXE(L2,	11),	FAS12437
IFXA(L4,L2,L1),RHO(1),AE(1),8E(1),SSH(1),SGT(L3,L1),XMP(1),	GIM(1)+	FAST2438
2P(1),T(1),AIH(1)		FAST2439
COMMON/DUMDET/I ,M ,FST ,ANG ,STV		FAST2440
CONMON/OTHERS/RADIUS,XCT(3),DELTA ,80C(3),ATA ,ATB ,AT	с,	FAST2441
1 ATO AT BT AS BS JHIN J	AX +	FAS12442
Z KHIN , KNAX , JBAR , NZERU		PASI2443
COMMON/FLUXES/KKK ,NTALLY,ERRUR ,IUTALN,IUTALE,RHUN ,SP		1FA512444
CUMMUN/LIMITS/NSTUKE;NEKKUK;NSPAX ;NAMAA ;NKMAA ;NDMAA ;N	NITO.	EAST2444
I NERAX FRYNAX FRANKA FRAERAAFREROUD FRASCUIPR	DANC.	EACT2447
	NAY .	FAST2448
S NORAX HORAX HITPAK HITPAK HOROD NORMAX NORMAN HI	DNAY.	EAST2449
E NUCKAY NUCKOD NOCINT, NODEL D. NODEL D. NODEL II. NO	INFLY.	FAST2450
AND ANT NINETYC NINEED, FR IDS		EAST2451
		FAST2452
		FAST2453
		FAST2454
ARGULAR RUDENIS		F4512455
(FULHAX.LE.0)00 10 20		FAST2456
P(1) = ARO P(2) = 1 Spectrum C=0 S		FAST2457
TELNIMAY 16,2100 TO 20		FAST2458
00 10 1#3-NI NAX		FAST2459
10 P(1) = (F) DAT(2+L-1)+ANG+P(L-1) - FLOAT(L-1)+P(L-2))/FLOA	((L)	FA5T2460
20 IFINTHAX.1E.0160 TO 30		FAST2461
1FIN.GF.01G0 TO 30		FAST2462
T(1) = TOT/SNORN		FAST2463
(F(NTHAX.EQ.1)G0 TO 30		FAST2464
DO 25 L=2.NTNAX		FAST2465
25 T(L) = T(1) + T(L-1)		FAST2466
30 DO 80 K=JHIN, JHAX		FAST2467
IF(WS(K).EQ.0.0 1GD TO 80		FAST2468
GST = FST+WS(K)+EXP(-XMP(K))		FAST2469
IF(H.LT.OIGC TO 40		FAST2470
SEG = RHON +{AE(K}*SSH{K} + BE{K}*SSH{K+1}}		FAST2471
IF(M.GT.0)SIG = SIG + {AE(K)*SGT(K,M) + BE(K)*SGT(K+1,M)}		FAST2472
ATN = EXP(-SIG+STV)	-	FAST2473
AST = [1.0 - ATN]/SIG .		FAST2474
GST = GST+AST		FAST2475
XMP(K) =·XKF(K) + SIG*STV		FAST2476
40 [F[GST.EQ.0.0]GO TO 80		FAST2477
J = NTG[K]		FAST2478
FXT(J,1) = FXT(J,1) + GST		FA512479
FXP(J,I) = FXP(J,I) + GST		PAS12480
FXE(J,1) = FXE(J,1) + GSTPES(K)		FA512481
HST = GST#XNP[K]#GIM[K]#AIN[K]		FA512482

HST = ABS(HST)	FAST24	83
IF(ABS(GST).GT.(ERROR#FXP(J.[])) NTALLY =	NTALLY + 1 FAST24	84
TOTALN = TOTALN + HST	FAST24	85
TOTALE' TOTALE + HSTPES(K)	FAST24	686
FXA[1,J,1] = FXA[1,J,1] + GST	FAST24	87
KK = NOM + 1	FAST24	88
[F(KK.GT.1) FXA(KK.J.1) = FXA(KK.J.1) + GS	T FAST24	89
LI = NUNDO + 3	FAST2A	ion
	FAST24	101
TELINSP.CT.OL EVALUES 1.13 + EVALUES	CCT FAST24	6.02
11 = 11 + NSRIAY	FAST24	6.
	EAST24	64
10/000 (5 NCMAY) 574/00. 1.1) - 574/00. 1.1)	+ CST 545724	05
	EAST24	
15/10 MAY 15 0100 TO 40	FA3124 547724	190
	FAST21	
UU SU L-IINLAAA	FA3124	100
$\mathbf{A}\mathbf{A} = \mathbf{A}\mathbf{A} + \mathbf{I}$	FASIZ	199
$50 FXA(KK_1J_1) + FXA(KK_1J_1) + GS(+P(L))$	FASIZ	
60 IFINIMAX.LE.UJGU JU 80	PA3123	201
1F(M.L1.0166 10 68	FASIZ	502
ASI = SIG - SIVEAIN/11.0 - AINI	PASIZ	503
(() = ((U) + AS1)/SNUKK	PAS123	
IFINIMAK.ED.IIGO TO 68	FASIZ	202
DU 63 L=2,NIMAX	FASIZ	200
63 ILL) # ILLI#SIL~L]	FASIZ	507
68 CONTINUE	FASIZ	508
DU 70 LºL,NIMAX	FASIZ	20.4
	FASIZ	210
70 FXALKK, J, LI = FXALKK, J, LJ + GSI=1(L)	PASIZ	211
BO CONTINUE	FASIZ	212
RETURN	PASIZ	213
END	PASIZ	214
\$18FTC ANSWRE N94/2, XR7	FASTZ	>15
CANSWER*FLUX PRINTOUT FCR PROGRAM FASTER	FASIZ	>16
SUBROUTINE ANSWER (NNN)	FASIZ	217
COMMON H(1)	FAST25	518
COMMON/LIMITS/NSTORE,NERROR,NSMAX ,NAMAX ,	NRMAX ,NEMAX ,NSIMAX, FASIZ	>19
1 NEMAX ,NYMAX ,NXMAX ,NXEMAX,	NEROD INXSECTINUNITU, FAST2	>20
2 NUNITX,NIMAX ,NUMAX ,NGRDER,	NDOWN , INELAS, NIRANS, FAST2	521
3 NNMAX NGMAX NFMAX NVHOU	NUMAX INLAAX INIAAX I FASI2	>22
4 NOMAX , NGAUD , MUMENI, NDHOD ,	NPURAX, NPUMUU, NSURAX, FASI2	>23
5 NVUMAX, NVDMOD, NPCINT, RODELP,	HUDELQ, HUDELQ, HUDELV, PAST25	24
6 NPRINT, NUNITS, NUMBER, KALIDE	FAST2	225
COMMON/INDEXS/INTP . IAZ . IISV . IMIL .	INHU INK ILELL FASTE	>26
I IELN , IAE , IBE , INSG ,	INPL HIJSN HIJSK + PASIZ	227
Z IXIR JISUV JIATN JIATW J	1258 #155H #10EN # FAST2	248
3 INTG , IELF , IFGW , ITOS ,	LIDV .ILUK .LIDS . FAST2	>29

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4	1 VOL	,1CDT	, I X D T	, 1851	+I ALP	*IAWD	,IGIM	, FAST2530
5 ,	IAIN	+IALM	+ I ALH	• I A	•1 NS	IVEE	,IVAL	FAST2531
6	ISPW	, ISPE	, LATD	, IRSP	+I SGT	. I TOE	,1101	FAST2532
7	1 SG S	.HEXT	,IXMP	• 1 SGR	• E ¥S	•1ES	+ INC .	FAST2533
6	160	IND	.10	¥14	.EW	151	, IST	FAST2534
9	INRG	. INSC	.ISTP	. INRP	. I NCP	. IFXP	IFXS	FAST2535
1	IFXI	. IFXE	IFXA	-		• • • •		FAST2536
100 = NEXT								FAST2537
ILE = NEXT	+ MOMENT							FAST2538
CALL ANSOUN	(NGHAX.)	AGENC.	ROHENT.	HETODY.	HEETOVE	. HI TI ET	HITEXT	EAST2539
1	HLIFXED	HI IFXS	.HITEX	AL.HETP	LET .HIT	FGW1.HI	INS) HET	ES1. FAST2540
2811963-8116	C).H(110	S1.HI IR	SPI-NNN	HITNS	NR HAXI			FAST2561
RETURN								EACT7547
END				•				EACTOCAS
STRETC ANSONI MO	6/2.887							EACT2644
CANSDUNEFINAL PROF	FSSING			E FASTE	R FLUXE			FAS12547
SUBPOLITINE	NCOUNT	1.12.13	.1 4. 100	109.11	S. SYT. S	YE EYC	GV8 . E. E . I	CU EACT2644
IAF-BE-ERB-FI	T.TES.P	CD-NWN.	NS.151			AC 11 A 31		EACT2647
CONBON NOVE	11							EACT2640
CONNON /REGS	TA/NSPMA	Y. THCD						CACT2640
	WIAL.ID	0/11.10	V/13.TI	612.11.	TYDEI2.	E1 01177	e1 .	EAST2560
1 51	1111.12		1.171.5	~~~	31 6044			CAS12330
2 51	¥/11.60	1111 TO	C/2 31	A3111+L		L//AC11	100113.14	FA312371
5	C/11.EV		1 21	0031074				CI PASI2552
	/1 THT 1 1	11011	1.1.1.1.2.1		** * *****			PA512353
	1.17861	/ / / #/ 4	1 NMKOD	+ LIN2II	11 0011			PA312004
in the second	(001/3)	00173	fout (4)	1110011	17,0011			FAS12333
2	1007137	001314	1001141					FAS12000
0.11 TYDE (4)	, 50 400				CC 4 410			FAS12337
144 564 44714		0466444	KC 7411	0204144	30 41 11	1100,940	AUDIAUI	AR, FAS12330
	5/85100			NAMA Y	NOMAY	HOMAY	NCTHAT	FAS12009
	NEWAY	NUNAY	NYMAY	NACHA	V.NEMOD	NYCECT		FAST2500
;	NUNIT	V NTWAY	NUMBER	NOROE	P NOOVN	TWELT	TRUNITO	CAS12701
1	NNHAY	NCHAY	NEWAX	- NYHOD	NCHAY	NI NAY	NTHAT	CAST2562
Ĩ.	NONAY	NCHOD	NONEN	T NOROD	NODA	NODNO	NCONSY	CACTORAL
5	NUDHA	NUDHO	D. NORTH	T. NODEL	P.HODEL	NOOFLI	L MODEL V	EAST204
<i>i</i> .	NODIN	LUNTT	C. NUMBE			athores	incore is	FAST2503
CONNON/PRIENT	VINTOTA		- 201	- FRALID	~			ELET2647
CONNON/TAPE	0/81	. 112	1104					EACT2560
COMMONICASET	DINACE	NOACE	LINES	1 106 7				FAST2500
CONTONICASE	N/NPDPIN			TC THE A				54572570
DIMENSION LA	NSI AL.W		NS/1 5-1	21				EAST2671
DATA STUTC. DA	CC/4H 11	E 4404	TIL PIC	11111				EAST2572
IEINWN GO II	81014	- 0		n • • 30	.,			FA314714
1. (444.20.1)		- •						FAS12273
	,							FR312579
TIEL IN AND								PASI20/5
1001111 = 1	113							FA3125/6

	TLE(2.1) = PASS	FAST2577
	LIH2 = LIH1 + NVHOD	FAST2578
	ITH3 = IIN2 + NSRNAY	FAST2579
	LIM6 = LIN3 + NCMAX	FAST2580
	LTHS = 13NA + NEMAX	EAST2581
	NHND = 11H5 + NTHAX	FAST2582
	00.60.1=1-5	EAST2583
	15((1)((1)-5C-15)((1+1)) (0 TO 6C	FAST2584
		FAST2585
	HAX = STHIJATJ	FAST2586
	16(1 - 2) 5 - 15 - 20	FAST2587
5		FAST2588
-		FAST2589
10		EAST2590
10		FAST2591
16		FAST2592
.,		EAST2503
		5AST2594
10		EACTIEDE
10		FAST2504
20		EAST2597
20		EACTOOD
70	DO JO JERINAA	FAST2576
30		FAST2379
40	DO SU JERINARA	FA312000
		FAS12001
50	[LE[K,J] =]TPE[K,I]	FAS12002
50		FAST2603
70		FAST2004
	IF (HUDELP LEG. OF NIDIAL * NPP	FA312005
	$x_N = FLUAr(RIGIAL)$	FA312006
	XII = XN/FLOAT(NUTAL - AUTAL)	FAS12007
	AIDIAL # NIUTAL	FA312008
	AS = AN + Z	FA512009
	U0 240 1*1, NUROD	FA312010
		CASTZOLL
		FAST2012
	IF (LABEL(4).GE.UI WRITE(R2,200C) (DOT,APP	FAS12013 .
2000	PORMAI(IX.32(INT), IMPLOXES FUR DELEDUR, 14, 6M AFTER, 16, 6M PACKET	5FA512019
	1,32(1H+1/14x,22HCALCULATED AVERAGE, 3124H NUMBER FLUX CREAGE FI	CASTZOLS
	20237152,214PRECISION ENERGY-MEV,2112H THIS GROUPS,2112H DERIVA	CAST2016
	SIVED CURULATIVED	PA31201 /
	LINES - LINES - L	FA512018
		PA312019
		FA312020
	DO 110 J=1,NGMAX	FA512621
	DU 80 K=L+6	FA512622
80	GUT(K) = 0.0	PA\$12623

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	DUT3 = FXT(J+1)/Xh	FAST2624
	1F(0013.E0.0.0)60 TO 100	FAST2625
	OUTA * EXELA 11/XN	F45T2626
	QUI2 * QUI4/QUI3	FAST2627
	D0 90 Ka5-6	FAS12628
	$\Pi H T (K) = G H T (K-2) / FG W (3)$	FAST2629
90	OUT(K+2) = OUT(K+2) + OUT(K-2)	FAST2630
	FST = (FxS(1,1) - xN*(0)T3**2)/xS	FAST2631
	IE(EST,GT,O,O)OUT) = SOBT(EST)/OUT3	FAST2632
100	IF(1 ABEL 11).GE.0)WRITE(M2.20101J.001	FAST2633
2010	FORMAT (1X.5HGROUP.14.3H1PE11.4.7E12.4)	FAST2634
	AE(J) = (DUT2 - ELF(J+1))/FGW(J)	FAST2635
	BE(J) = (ELF(J) - OUT2)/FGW(J)	FAST2636
	FLX(J) = CUT3	FAST2637
110	ERR(J) = GUT1	FAST2638
	IF(NFNAX.EQ.0160 TO 170	FAST2639
	DO 160 J=1-NEMAX-8	FAST2640
	MAX = NINO(J+7.NFNAX)	FAST2641
	MOD = MAX - J + 1	FAST2642
	IF(LABEL(3).GE.0)WRITE(N2.2020)[0UT.NPF.((TDS(L.K).L=L.3).K=J.N	AX1FAST2643
2020	FORMAT(1X,24(1H*), 34HNUMBER FLUX RESPONSES FOR DETECTOR,14.6H A	FTEFAST2644
	IR+16+8H PACKETS+25(1H+)/12X+24A4)	FAST2645
	LINES = LINES - 1	FAST2646
	DG 120 K=1.HOD	FAST2647
	$aus(k) \neq 0.0$	FAST2648
	EMN(K) = 0.0	FA512649
120	EHX(K) = 0.0	FAST2650
	DD 140 K=1,NGMAX	FAST2651
	L = 0 '	FAST2652
	130 H=J,HAX	FAST2653
	1 = 1 + 1 -	FAST2654
	$FST = FL_X(K) + (AE(K) + RSP(K, M) + BE(K) + RSP(K+1, M))$	FAST2655
	OUT(L) * FST	FAST2656
	OUS(L) = GUS(L) + FST	 FAST2657
	FST = FST+ERR(K)	FAST2658
	EMN(L) = EMN(L) + F5T++2	FAST2659
130	EHX(L) = EHX(L) + FST	FAST2660
	IF(LABEL(1).GE.O)NRITE(M2,2010)K,(DUT(L),L=1,KOD)	FAST2661
140	CONTINUE	FAST2662
	IF (LABEL(L), GE.O)WRITE(M2, 203C)(OUS(L), L=1, NOD)	FAST2663
2030	PORMAT (1X,6HTUTALS,6[1K.), [PE11.4,7612.4]	FAST2664
	DU [50 L*1+MUU	PA512665
	OUT(L) = 0.0	FAST2666
	FSI = UUSILI	FA512667
	OUS(L) # 0.0	PAST2668
	IF1F51.80.0.0160 10 150	PAST2669
	ODI(L) = SORI(ERN(L))/FS)	, PAS12670

	OUS(L) = EMX(L)/FST	FAST2671
150	CONTINUE	FAST2672
	1F (1AB EL (1), GE.0)WRITE(M2+2035)(OUT(L)+L=1+NOD)	FAST2673
2035	FORMAT (11, 12HMIN FRROR 10F11-4.7E12.4)	FAST2674
2033	LE (1 AB E) (1) - GE - 0) WRITE (M2 - 2040) (0US(L) - L=1- MOD)	FAST2675
2040	EUDNAT (11-12HNAX FRADR 1PE11.4.7E12.4)	FAST2676
140		FAST2677
170		FAST2678
1.10		FAST2679
		FAST2680
		F4512681
	TE (1 A B ((3) CE 0) WP (TE (H2, 2050) JOHY .NPE. (/ T E (K - 1) .K + 1 - 2) . [DE(1) .	1 FAST2682
		FAST2683
2050	1-370447 CONMATIN 2611041.2200000000 SIJIX NOMENTS FOR DETECTOR.14.64 AFTER	-FAST2684
2050	TURNALIAISSING ISSING STATUS AND	CAST7695
	I DEC A TINCCA I	FAST2686
		EACT 2687
	DU 190 K=1, KGMAX	EACT2400
		FAST2000
	DU 180 ALJ.RAX	FAS12009
		FAST2090
190		FAS12071
		FAS12092
	[F(LASEL117.5E.U)#RTIE(A2;2010)R;(OUTC);L=1:A0D7	FAST2073
140		EACT240E
		CICT2604
		FAST2070
	Du 200 L+1, Aub	FAS12071
200	001(1) = 0.0	FA512098
	00 210 C*1, NGRAX	FAS12099
	H = 0	FAS12100
	DO 210 N=J, MAX	PAS12/01
	H = H + 1	FAST2702
210	OUTINI = OUTINI + FXAIN,L,II+(AE(L)+RSPIL,RI+BE(L)+RSPIL+L,RII/A	1 PASI2703
	TF(J.EQ.1) OUT1 = XTT+OUT1	FASI2/04
	IF(LABEL(1).GE.D)WRITE(M2,2060)(1051C,K).L=1,3),400(112).L=1,R00)	FAS12705
2060	-FORMAT(1X,3A4,1PE11.4,7E12.4)	FAS12700
220	CONTINUE	FAST2707
230	CONTINUE	FAS12708
Z40	CONTINUE	FASIZIUS
	00 250 I=L,RDM0D	FAST2710
	DD 250 J=1+NGHAX	PASIZILL
250) FXA(1, J, () = 0.0	FA512712
	IF (NNN.LI.NPRINI)GU TU YUU	FASIZILS
	LF(NPOINT.EQ.0) GO TO 300	FAST2714
	IFINPORUNALTANPOMAXI GU TU 870	FAST2715
300) IF(LABEL(I)_GE.O) WRITE(M2.3000)	FAST2716
3000	FORMAT(1X,22(1H+),63HBOUNDARY SEARCH PARAMETERS, (SURFACE,NOST P	RUFAST2717

LBABLE NEXT REG	(ON),22(1H+))		FASTZ718
DO 340 [=1, NRM	AX		FAS12719
MAX 3 HINDINAH	AA+C AY-1+7)		FAST2721
K = 0			FAST2722
DD 310 L=J.MAX			FAST2723
H = NS(L, I)	10 330		FAS12725
X = X + 1	10 320		FAST2726
N = H/1000			FAST2727
MPNR(K) = H -	1000*N		FAST2728
N = N/1000	- 11+18 - 100		FAS12729
320 JE(K.EQ.DIGR T	- 11+IN - 100 1 340	10+11	FA5T2731
IFILABEL(1).GE	.01 WRITE(M2,3	301C)1, {RIGHT, [ANS(L], MPNR(L], L=1, K}	FAST2732
3010 FORMAT(LX,6HRE	\$10N.15.8(A3	, 14, 1H, , 13, 1H)))	FAST2733
330 CONTINUE			FA512734
BTO CONTINUE			FAST2736
DO 890 I=1,NDM	00		FAST2737
DO 890 J=1,NGM	AX'		FAST2738
FXT(J, I) = 0.0			FAS12739
$F_{x}(J, I) = 0.0$	•		FAST2741
IF (NOMENT.EC.O	1GG TO 890		FAST2742
DO 880 K=1.MOH	ENT		FAST2743
880 FXA(K, J, I) = 0	•0		FAST2744
900 RETURN			FAST2746
END			FAS12747
\$18FTC PSTARX #94/2	, XR7		FAST2748
CPSTAR *RANOUM SELEC	TION OF SOURCE	E VECTOR FOR PROGRAM FASTER*T.M.JORDAN	IPFAST2749
FUNCTION PSTAK	1		FAS12750
COMMON	4(1)		FA5T2752
COMMON/DUMPST/	NN POT .	x(3)	FAST2753
COMMON/LINITS/	STORE NERROR.	NSPAX ,NAHAX ,NRHAX ,NBHAX ,NSTHAX,	FAST2754
1 2	NERAX INVRAX I	NAMAX INGROFS NORWALLASS ACTINUNITO	FAS12755
3	NAMAX .NGMAX .	NFMAX ,NVMOD .NCMAX .NLMAX .NTMAX .	FAST2757
4	NOMAX .NGROD .	HOMENT, NOKOD ,NPDMAX, NPDHOD, NSDMAX,	FAST2758
5	AVONAX, NVDKOD,	NPOINT, NODELP, MODELQ, NODELU, MODELV,	FAST2759
6	PRINT, NUNITS,	NUPBER, KALIDE	FAST2760
LOARDAY LADEXSY		IBE INSG INPC IJSN IJSK	FAST2762
z	XTR , ISUV ,	TATH , TATH , TESB , ISSH , IDEN ,	FAST2763
3	INTG .IELF ,	IFGW ,ITDS ,ILDV ,IIDR ,ILDS ,	FAST2764
4 5 6 7 8 9 1 CALL PSTDUM(NX 1 NNN = NN HI NNN = NN HI 1 NNN = NN	IVOL .1CDT . (AIM .1ALM . (SPW .1SPE . (SGS .NEXT . (SGS .NEXT . (NG .1NSC . (FXT .1FXE . (NSG).H(IXTR))	IXOT ,IRSI ,IALP ,IVND ,ICIM , IALH ,IA ,INS ,IVEE ,IVAL , IATO ,IRSP ,ISGT ,IICE ,IICI , IXAP ,ISGR ,INS ,IES ,INC , U ,IV ,IN ,ISI ,IST , ISTP ,INRP ,INCP ,IFAP ,IFAS , IFAA),HIINPCI,HIVEEJ,HIIVNO),HIIALPJ,	FAST2765 FAST2767 FAST2768 FAST2768 FAST2768 FAST2770 FAST2771 FAST2773 FAST2773 FAST2773 FAST2775 FAST2776
5 5 7 8 9 1 Call PSTDUM(NX 1 0 NNN = NN H1 0 (=1,3 10 XXX(1) = X(1) PSTAR = PDT	EVOL +1CDT + (AIA +1ALM + SpW +159E + (SGS +NEXT + EC +1ND + (NRG +1NSC + (NRG +1NSC + (AX,5)1+((IRSI (NSG)+((IXTR))	IXOT , IRSI , IALP , IVND , IGIN , IALH , IA , INS , IVVE , IVAL , IATO , IRSP , ISGT , IIOE , IIOI , IMP , ISGR , IMS , IES , IMC , IU , IV , IM , ISI , IST , ISTP , INRP , IXCP , IFXS , IFXA J, HITMPCI, HITVEEJ, HITVHOJ, HITALPJ,	FAST2765 FAST2767 FAST2767 FAST2767 FAST2769 FAST2770 FAST2772 FAST2772 FAST2774 FAST2774 FAST2774 FAST2776 FAST2776
4 5 6 7 8 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 1 1 2 3 1 1 3 1 3	IVOL +1CDT + (AIM +1ALM + SOS +1SPE + SOS - NEXT + INRG + NO + (NRG + NO + (FXT + 1FXE + 1)))))))))))))))))))))))))))))))))))	IXDT .IRSI .JALP .IVND .ICIN . IALH .IA .INS .IVEE .IVAL . IAT .IST .IST .IVEE .IVAL . INT .IST .IST .IST .IST .IST . IST .IST .INST .IST .IST . IFXA	FAST2765 FAST2767 FAST2767 FAST2768 FAST2770 FAST2770 FAST2772 FAST2772 FAST2773 FAST2774 FAST2774 FAST2777 FAST2777
4 5 6 7 8 9 1 Call PSTDUM(NX 1 10 NNN = NN 00 10 (+1,3 10 XXX(1) = X(1) PSTAR = POT RETURN EEDD	IVOL +1CDT + IAIN +IALN + ISOS +ISPE + ISOS +NEXT + ISOS +NEXT + ISOS +NEXT + INOS + ISOS + I	IXOT ,IRSI ,IALP ,IVND ,IGIM , IALH ,IA ,INS ,IVEE ,IVAL , IATO ,IRSP ,ISGT ,IIOE ,IIOI , IXP ,ISGR ,IMS ,IES ,IUC , IU ,IV ,IM ,ISI ,IST , ISTP ,INR ,INCP ,IRFP ,IFRS , IFRA ,INPCI,HIIVEE),HIIVNOJ,HIIALP},	FAST2765 FAST2767 FAST2767 FAST2769 FAST27769 FAST2771 FAST2771 FAST2773 FAST2773 FAST2775 FAST2775 FAST2776 FAST2776 FAST27780
4 5 6 7 7 8 9 1 CALL PSTDUM(NX) 1 NN = NN 00 10 [+1,3 10 XXX[1] = X[1] PSTAR = POT REDRA SIBFTC PSTONL M94/2 CPSTONL4 M94/2	1001 .1007 . AIN .154 . SGS	IXOT ,IRSI ,IALP ,IVND ,IGIN , IAH ,IAS ,INS ,IVEE ,IVAL , IAP ,ISG ,ISS ,ITOE ,IIOI , IAP ,ISG ,ISS ,ISS ,IKC , IU ,IV ,IM ,ISI ,IST , ISTP ,INSP ,INCP ,IFXP ,IFXS , IFXA , HINPCI,HIVEE,HIVND),HIIALP), VECTOR FOR PROGRAM FASTER*T.M.JORDAM	FAST2765 FAST2766 FAST2766 FAST2769 FAST2769 FAST27769 FAST27769 FAST27773 FAST2773 FAST2773 FAST2775 FAST2775 FAST2775 FAST2776 FAST27779 FAST27779 FAST27779 FAST27779
4 5 6 7 8 9 1 1 call PSTDUM(NX 9 10 call PSTDUM(NX 9 10 (Ft,3 10 XXX(1) = X(1) PSTAR = PDT RETURN SIBFTC SISTONI M94/2 CPSTOUMFARNOUM SELEC SUBROUTINE PST	IVOL .1CDT . IAIN .1ALM T. ISCS .NEXT . ISCS .NEXT . ISCS .NEXT . ING .NSC . ISC	IXOT , IRSI , IALP , IVHD , IGIM , IALH , IA , INS , IVEE , IVAL , IATO , IRSP , ISGT , IIOE , IIOI , IXP , ISGR , IMS , IES , IAC , IU , IV , IM , ISI , IST , IST , INR , INCP , IFAP , IFAS , IFAA , INRC , YEE, YHO, ALP, NSG, XTH) SI, IMPC, YEE, YHO, ALP, NSG, XTH)	FAST2765 FAST2767 FAST2767 FAST2769 FAST2776 FAST2776 FAST2771 FAST2771 FAST2773 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2777 FAST2777 FAST2777 FAST2777 FAST2777
4 5 6 7 7 8 9 1 CALL PSTDUM(NX) 9 1 CALL PSTDUM(NX) 0 10 14 1 2 2 2 2 2 2 2 2 2 2 2 2 2	IVOL , ICOT ISPN , ISPE ISPN , ISPE ISOS , ISPE	IXOT , IRSI , IALP , IVWD , IGIM , IALH , IA , INS , IVWE , IVAL , IATD , ISSG , ISS , IKC , IU , IV , IM , ISS , IKC , IU , IV , IM , ISI , ISS , ISTP , INAP , INCP , IFXP , IFXS , IFXA , I , HIINPCI, HIVEE), HIIVHOJ, HIIALPJ, SI, MPC, VEE, VHD, ALP, NSG, XTAJ	FAST2765 FAST2766 FAST2768 FAST2768 FAST2770 FAST2770 FAST2771 FAST2772 FAST2774 FAST2774 FAST2776 FAST2776 FAST2776 FAST2776 FAST27780 FAST27782 FAST2780 FAST2782 FAST2782
4 5 6 7 8 9 1 1 Call PSTDUM(MX) 1 Call PSTDUM(MX) 1 M 1 MNN = NN 0 Io I=1,3 10 XXX(I) = X(I) PSTAR - POT REDOW SIGNOR SUBSTOR SUBSTOR SUBSTOR SUBSTOR SUBSTOR SUBSTOR SUBSTOR SUBSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SUBSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN OTHERSTOR SIGN SIGN SIGN SIGN SIGN SIGN SIGN SIGN	100L +1CDT + (AIR +1ALA + 15PK +1SPE - 15CS +1KET + 15CS +1KE 14KC + 1KE 14KC + 1KE 14KC + 1 14KC	IXOT , IRSI , IALP , IVND , IGIN , IALH , IA , INS , IVEE , IVAL , IATO , IRSP , ISGT , IIOE , IIOI , IATP , ISGR , IMS , IES , IAC , IU , IV , IM , ISI , IST , IFRA , INP , IACP , IFRA , IFRA , INP , IACP , IFRA , ISI, INPC, , HI VEE), H(IVND), H(IALP), SI, NPC, VEE, VND, ALP, NSG, XTR) X130 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X131 X1	FAST2765 FAST2766 FAST2768 FAST2768 FAST2770 FAST2770 FAST2772 FAST2772 FAST2774 FAST2774 FAST2774 FAST2774 FAST2774 FAST2774 FAST2774 FAST2776 FAST2776 FAST27763 FAST27763 FAST27763
4 5 6 7 8 9 1 CALL PSTDUM(NX 1 NN = NN 10 0 X 11 = 1,3 0 X 11 = 1,3 10 5 X 10 F	tyol. +COT isin +LLM ispu +ISPE iscs +NEXT	IXOT , IRSI , IALP , IVWD , IGIM , IALH , IA , INS , IVVE , IVAL , IATO , IRSP , ISGT , ITOE , IIVAL , IXPP , ISGR , IMS , IES , INC , IU , IV , IM , ISI , IST , ISTP , INRP , INCP , IFAP , IFAS , IFAA IST , INR , INCP , IFAP , IFAS , ISTA , INR , INCP , IST , IST , IST , INR , INR , INRAA , ISTAAX	FAST2765 FAST2766 FAST2767 FAST2769 FAST2770 FAST2771 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAS
4 5 6 7 8 9 1 1 CALL PSTDUM(MX 1 1 MIN = NN 0 L0 1=1,3 10 XXX(1) = X(1) PSTAR = POT EMD 10 1=1,3 10 XXX(1) = X(1) PSTAR = POT SUBROWTNE EMD SUBFC PSTONI M94/2 COMMON/CUMPST/ DIMENSTON TRUE COMMON/CLINITS/ L	IVOL .TCDT . IAIR .IALM . ISPN .ISPE . ISCS .HEXT . IEC .HNO . INGC .INSC . IAC .INSC . IAC	IXOT , IRSI , IALP , IVND , IGIN , IALH , IA , INS , IVEE , IVAL , IATO , IRSP , ISG , IIOE , IIOI , IATP , ISG , IMS , ISS , IAC , IU , IV , IM , ISI , IST , IST , INP , INP, IFAP , ITRS , IST , INP , INP, IFAP , ITRS , IST , INP, INP, IST , IST , IST , INP, IST , IST , IST , INP, IST , IST , IST , INP, IST , IST , IST , IST , INP, IST , IST , IST , IST , INP, IST , IST , IST , IST , IST , INP, IST ,	FAST2765 FAST2766 FAST2767 FAST2769 FAST2769 FAST2770 FAST2771 FAST2771 FAST2773 FAST2775 FAST2775 FAST2775 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776
4 5 6 7 8 9 1 CALL PSTDUM(NX 1 NNN = NN H1 NNN = NN H1 NNN = NN H1 PSTAR = PDT RETURN END SUBROUTINE PST CONTAUDA SELE CONTAUDAL SELE 1 1 1 2 	tvol. .tcot. tain .tsp. tsp. .tsp. tscs. .tsp. tscs. <td>IXOT .TRSI .IALP .IVHD .IGIM . IALH .IA .INS .IVEE .IVHL . IATD .IRSP .ISGT .IIOE .IIOI . IAMP .ISGR .IMS .IES .INC . IU .IV .IM .ISI .ISI .IST . ISIP .INRP .INCP .IFAP .IFXS . I.H INPC.L.H(IVEE).H(IVHD).H(IALP). .XI</td> <td>FAST2765 FAST2765 FAST2765 FAST2765 FAST2765 FAST2765 FAST2770 FAST2770 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST27776 FAST27776 FAST2777777777777777777777777777777777777</td>	IXOT .TRSI .IALP .IVHD .IGIM . IALH .IA .INS .IVEE .IVHL . IATD .IRSP .ISGT .IIOE .IIOI . IAMP .ISGR .IMS .IES .INC . IU .IV .IM .ISI .ISI .IST . ISIP .INRP .INCP .IFAP .IFXS . I.H INPC.L.H(IVEE).H(IVHD).H(IALP). .XI	FAST2765 FAST2765 FAST2765 FAST2765 FAST2765 FAST2765 FAST2770 FAST2770 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST2776 FAST27776 FAST27776 FAST2777777777777777777777777777777777777
4 5 6 7 8 9 1 CALL PSTDUM(MX) 1 NNN = NN 0 10 1*t,3 10 XXX(1) = X(1) PTTAFA POT EMD 10 XXX(1) = X(1) PTTAFA POT EMD 10 XXX(1) = X(1) PTTAFA POT EMD 10 XXX(1) = X(1) PTTAFA POT SUBFC PSTDN1 M94/2 COMBON/DUMPST/ 0 14 COMBON/LIMITS/ 1 2 - 3 - 3 - - - - - - - - - - - - -	IVOL TCDT IAIA IAIA ISPN ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC ISC	IXOT , IRSI , IALP , IVND , IGIN , IALH , IA , INS , IVEE , IVAL , IATO , IRSP , ISGT , IIOE , IIOI , IATO , IRSP , ISGT , IIOE , IIOI , IU , IV , IN , ISI , IST , ISI , INP , ISR , IFF , IFFS , ISI , INP , INP , IFF , IFFS , ISI, HINPCI, HIVEE, H(IVHO), H(IALP), VEEVOR FOR PROGRAM FASTER*T.M.JORDAM SI, MPC, VEE, VMO, ALP, NSG, XTR) X130 KINC, VEE, VMO, ALP, NSG, XTR) X131 KINC, NSMAX , NAMAX , NEMAA , NSMAX, NTAKA , NEMAX, NEMAA , NSMAX, NAMAA , NCHACE, NCOUN , INELAS, NTRAKS, NAMAA , NCHACE, NEMAA , NEMAA , NSMAX, NAMAA , NCHACE, NEMAA , NEMAA , NSMAX, NCHACHACHAC, NEMAA , NEMAA , NSMAX, NCHACHACHACHACHACHACHACHACHACHACHACHACHAC	FAST2765 FAST2766 FAST2766 FAST2768 FAST2769 FAST2770 FAST2770 FAST2770 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2775 FAST2776 FAST2776 FAST2780 FAST2786 FAST2786 FAST2786 FAST2786 FAST2786 FAST2786
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Astronuclear Laboratory

	IPINSGINI - II	60+80								FA312012
60	00 70 (=1.3									FAST2813
70	X(I) = VB(I)									FAST2814
	GO TO 110									FAST2815
60	X131 = VB(31)									FAST2816
	R = VB(1)									FAST2817
	GD TO 100									FAST2818
90	8 = VB(1)+SQR1	11.0 -	- VE(3)	*21						FAST2819
	X(3) = VB(1)+V	1118								FAST2820
100	¥(1) = R#COS()	8(2))								FAST2821
100	Y121 - 04CTN()	81211								FAST2822
	LEANDCAL NO. CT	1100			INSCINE.					F4512823
	11 110 1-1 2									EAST2024
110	00 120 141+5	11074	N.1							FAST2825
120										5 ACT 2024
	NN = LOCATEINE									FAS12020
	RETURN									FA512021
	END									FA512828
\$10FT	C SPHEER N94/2	, XR 7								FAS12829
C SPHE	RE#INITIAL SOUP	ICE VE	CTOR FRE	OM SPHEF	RE FOR #	PROGRAM	FASTER	•T.#.JOS	RDAN	*FA512830
	FUNCTION SPHER	EIYYY	,	Z,HMH,51	r.NRG.NS	50)				FAST2831
	DIMENSION YYY	11,22	2(1)							FAST2832
	COMMON	8(1)								FAS12833
	CONBON/DURSPH	INST	.PDT	•STC	•X(3)	•C (3)				FAST2834
	COMMON/LENTS	NSTCR	F.NERRO	-NSMAX	NAHAX	-NRHAX	- NBHAX	+NSTHA:	x.	FAST2835
	1	NENAX	. NVHAX	NXMAX	NXEMA	.NEMOD	NXSEC	T-NUNIT	n.	FAST2836
	2	NUNTT	Y.NIHAY	NHHAT	NIGOL	R.NORWN	. INFLA	S.NTRAN	ς.	FAST2837
	1	NNNAY	NCHAY	NEWAY	NUMOR	NCHAY	NIMAY	NTRAY		EAST2839
	,	NDHAY	PC BOO	HONEN	NCHOO	HODHA	LOONO	DINSONA		EACT2830
	-	NURAA	FREADE	HUPER	+ HEHOU	APDR4	HORE	U HOOT	<u>.</u>	FAST2037
	2	NYUMA	X+NVUNU	D, NPCIN	A HODEL	, TUDEL	** HUUEL	OFHODEC.	۰.	PAS12040
	6	NPRIN	1,40411	SINUFAC	CARACIO	c				CAS12041
	CUMMUN7 INDEXS.	INTP	. LAL	,115V	, INIL	*I KHU	+128	HELL	•	PAS12842
	1	IELW	+ LAE	,18E	, [NSG	, INPC	, I JSN	+LJSX		FA512843
	2	IXTR	, t SUV	+IATN	, FATW	, I ESB	, ISSH	. IDEN	,	FAS12844
	3	INTG	, I EL F	, IFGW	+11DS	•1 IOV	+110R	*11DS		FAST2845
	4	1 VOL	,1001	+ I XCT	, IRSI	+1 ALP	, [VHD	, IG [M		FAST2846
	5	IAIM	,[ALM	,IALH	, I A	, INS	,IVEE	+1 VAL	,	FAST2847
	6	1 S P ¥	+1SPE	+ IATD	, IRSP	+1 SGT	,110E	+IID1		FAST2848
	7	I SG S	,NEXT	+1 X MP	+1 \$GR	+1₩S	, IE S	+I¥C		FAST2849
	8	LEC	, IND	+ IU	, I V	114	,151	,IST	÷.	FAST2850
	9	INRG	. INSC	•15TP	TINRP	.INCP	. LEXP	+ IFXS		FAST2851
	i	IFXI	. IFXE	. IF XA						FAST2852
	00 10 1=1/3									FAST2853
10	x(1) = YYY(1)									FA512854
10	CALL SOUDOWIN	GN00 - 1		1.01150	V1.6(10	HD1 . H/ I	ссы).н <i>і</i>	THTLN		EA1.12856
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	MMM = NS1									FA312857
	AAA × STC									PAS+2858

00 20	[=1,3 -								FAST2859
20 22211	<pre>> * C(1)</pre>								FAST2860
SPHER	E = PDI								FAST2861
RETUR	N								FAS12862
END	-								FAST2863
REACTC SOUN	41 NO4/2.197								FAST2864
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LNSCI									FA312001
DIMEN	210M 12A(1)*20	VII), NKG	111,511	1113010	CI +C 21 +	2281111	mil(1)+		FA512868
1	XP(1), TRA	(11,188()	11,840(1)					FAS12869
DINEN	510N RCT(3,3),	C(3)							FAS12870
CONNO	4/DUKSPH/NST	*PCT	•STT	•X[3}	+C (3)				FAS12871
CONKO	V/LINITS/NSTOR	E,NERROR,	NSFAX	, NAMA X	NRMAX	, NO MAX	ANTEN,		FAST2872
1	NENAX	+NVHAX	NXMAX	+NXEMAX	,NEMOD	+NX SECT	NUNITO	۱,	FAST2873
2	NUNIT	X.NIMAX .	NHHAX	,NCRDER	+ N COWN	+ INEL AS	,NTRANS		FAST2874
3	NNMAX	NGHAX	NFMAX	NYHOD	NCHAX	NLHAX	NTHAX		FAST2875
4	NOMAX	+NGMOD	HOPENT	NDHOD	-NPOHAX	• NPD800	-NSDKAX		FAST2876
5	NVOBA	X-NVDMCD.	NPCINT	- HGDE LP	.NCDELC	+ NODELU	+ NODEL V		FAST2877
6	NPRIN	I.NUNITS	NUPRER	KALLDE		,			FAST2878
ักการการ	N/POINTY /NTOTA	1.111	NON						FAST2879
CONHO	N/Thosys/17680		,,						FAST2880
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· · · · · · · · · · · · · · · · · · ·	KMEN	, KRAA	JBAK	INZERU					FA512083
DIMEN	SIUN XS(3)								FA512884
CONNO	A/SPASHL/PSORS								FAST2885
DATA	21/3.141593/								FAST2886
COMMO	N/LL SREG/LLREG								FAST2887
DIMEN	SION NSC(1)								FAST2888
C NEW METHO	D. SETUP SPHER	ICAL VOL	UNE						FAST2889
130 STM =	VECTOR(X,XCT,	C)							FAST2890
CALL	ROTATC(C+ROT)								FAST2891
NN =	LOCATEINGS	3							FAST2892
PHIM	N = -1.0								FAST2893
EST =	STN##2 - RADI	US**2							FAST2894
15(65	T.GE. 0. A10HINT	N = 500T.	16531/5	TH					EAST2895
STH a	STN & PAOTIIS								FAST2896
ATY -	-ATA/11.0 - P								FAST2897
00.14	5 NTAY-1.100								EAST2000
NTOTA	- ATOTAL - 1								EAST2070
901 -	CAUDIC/DUININ	.1.0.1.0		2118548	0 61-01				EAST2000
PUT =	SAMPLELPHININ	31003100	******	\$11+3M	incat-ri	,,,,,,,,,,,	1-10111	167	FAS12900
2016 =	SQR11120 - DI	514-23							FA512901
0(1)	* SNP*COSITHE								FA212902
D(2)	= SNP#SIN(THE)								FA512903
00 15	0 1*1,3								FA512904
C(1)	× 0.0								FAST2905

244

245

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	00 150 1-1.3	54673004
		F#312900
120		FAST2907
	CALL PATHINN, STR, X (CINSTIST, NRGINSC)	FAST2908
	511 = 0.0	FAST2909
	DO 160 T=1,6ST	FAST2910
	J = NRG[[]	FAST2911
	IF(ISV(J).G1.0)60 TC 170	FAST2912
160	STT = STT + ST(1)	FAST2913
165	CONTINUE	FAST2914
	NST = 0	FAST2915
	GD TO 300	FAST2916
170	NTT = 1	FAST2917
	PTOT = 0.0	FAST2918
	XMPT = 0.0	EAST2919
	STX = STT	F4512920
	DD 220 1=htt,NST	FAST2921
	J = NRG(1)	FAST2922
	$K = \{S_{Y}(j)\}$	FAST2923
	L = HTL(J)	EAST2024
	SGR = ATC+RH0(J)+SSH(JZERC)	FAST2075
	IFIL-GT-01SGR = SER + ATC#SGT1.JZERO.L1	EAST 2024
	XMPP = SGR#ST/[]	F4512720
	IEIK-67-0100 TO 190	F4312921
	IN(1) = 0.0	FAS12928
	CO TO 210	FA312424
180	CALL APPOLITY STY & O DIASTALLY C YES	FAS12930
100	LIPEC - K	FA512931
		FA512932
	CACE 3156010110113101	FAS12933
	CALL ADDOW 17.517 + 0 ENETTING VEN	FAST2934
	CALL ARROW TATSTA + 0.3+31111,0,851	F4ST2935
	00H - 00000	
		FAST.2937
	TRATTI = PUR+SUV(R)+EXP(-XMPT)	FAST2938
	ARGARG E U.U	FASAZ939
	LFITPOB PCHI.GI.U.O) ARGARG = ALUG(PEB/PDH)	FASB2939
	1+151111.61.C.UI SGR = SGR + 2.0+ARGAR5/ST(1)	FASC2939
	TRB(I) = SGR	FAST2940
	1PtSGR.NE.0.0JGU TO 190	FAST2941
	XA(1) = ST(1) * TRA(1)	F45T2942
	GU TU 200	FAST2943
190	XM(1) = TRA(1)*(1.0 - EXP(~SGR*ST(1)))/SGR	FAST2944
200	PTDT = PTDT + XH(1)	FAST2945
210	XMPT = XMPT + XMPP	FAST2946
220	STX = STX + ST(1)	FAST2947
	PDS = PTOT+RANNC(NMP)	FAST2948
	DO 230 1=NTT,NST	FAST2949
	[F[XM(1].GT.PD5)G0 TO 240	FAS12950

PDS = PDS - XM(1) FAS 230 ST = STI + ST(1) FAS 1 = NST FAS 1 = STI + ST(1) FAS 1 = STAT + ST(1) FAS 1 = STAT + STA(1) FAS 1 = FOS/TARC FAS 0 = TO ZAO FAS 0 = TO ZAO FAS 0 = POT + POT/TARC FAS 0 = TO ZAO FAS 0 = TO TARC FAS 0 = TO TARC FAS 0 = TO TARC FAS 0 = NT + STI(1) FAS				
230 STT = STT + ST(1) FAS 1 = NST FAS 240 NN = NRC(1) FAS LLREC = LSVINNI FAS NST FAS NST FAS NST FAS NST FAS NST FAS SGR = ISVINNI FAS SGR = TRB(1) FAS SGR = TRB(1) FAS SGT = POJ/TAR(1) FAS PDT = POJ/TAR(1) FAS ST(1) = POS/TAR(1) FAS SGT = TALGIARG/TAR(1)/SGR FAS SGT = ALGCIARG/TAR(1)/SGR FAS SGT = ALGCIARG/TAR(1)/SGR FAS SGT = ALGCIARG/TAR(1)/SGR FAS SGT = ALGCIARG/TAR(1)/SGR FAS DO TO TOPTOPTOPTOPTOP FAS DO TO TAR FAS SO TH = ST + ST(1) FAS DO TO TARA FAS SO TH = ALGCIARG/TAR(1)/SGR FAS DO TO TARA FAS SO TH = ST + ST(1) FAS SO TH = ST + ST(1)			PDS = POS - XH(1)	FAST2951
1 - NST FAS 20 NN = NRG11 FAS LLREG = ISVINNI FAS NNT = 0 FAS NT FAS NT FILT FAS FAS NT FULREC.LE.00 GU TO 300 NT FILT FEISGR.ME.O.01GO TO 25G FAS STILI > POS/TRAILI FAS GO TO 26O FAS 220 CONTINUE FAS ARG = TALANC FAS 230 STI = STI + STILI FAS POT = POI/TAGLIJST**2 FAS 200 TI = CALCARC/TAALIJ/SGR FAS 200 TRUN FAS FAD FAS DOT = POI*POIT#ST**2 FAS FAD FAS DOT RETURN FAS FAD FAS DOT INE MARDMERS.S.C.C.YI FAS DOT INE STIL * STILI FAS FAD FAS DOT INE STIL * STILI FAS CONNTINE MARDMERS.S.C.C.YI FAS DOT INE STIL * STILI FAS		230	STT = STT + ST(1)	FAST2952
240 NN = MRG(1) FAS LLREG = ISY(NN) FAS NST = 0 IF(LLREG.LE.0) GU TO 300 NST = 1 FAS IF(LLREG.LE.0) GU TO 300 FAS NST = 1 FAS IF(STARL) FAS POT = POT/TARL1) FAS OT 02 200 FAS ST(1) = POS/TARL1) FAS OT 02 200 FAS ST(1) = POS/TARL1) FAS OT 02 200 FAS ST(1) = -ALGGLAGC/TARL1)/SGR FAS POT = POT/FARC FAS POT = POT/FARC FAS SO DE TS TS TS 11 FAS OT 10 STAR (NARDAK X, S(C, Y) FAS D DE RETURN FAS O D 10 L= L-3 SUBROUTINE ARRDM X, S(C, Y) FAS D O 10 L= L-3 SUBROUTINE ARRDM X, S(C, Y) FAS O TO 10 STAR X MYA FAS FAS I O TUTI = X(1) + SUCI1)	•		L= NST	
LLREG = 15YINN) NST = 0 IF(LLREC.LE.0) GU TO 300 NST = 1 SGR = TRELID SGR = TRELI		240	NN = NRG(1)	FAST2953
NST = 0 FALL NST = 0 FALL IFILIERC.LE.0.0 GU TO 300 FAS SGR = TB611 FAS IFICSGR.ME.O.OLGG TO 25C FAS STI1 > POSTRALI1 FAS PO TO			LIREG * ISVENNI	FAST2954
TFILLREC.LC.0) GU TO 300 NST = I FAS SGR = TR8(11) FAS SGR = TR8(11) FAS SGR = TR8(11) FAS SGT = ZOTFARL1) FAS GU TO ZOTFARL1) FAS ARG = TRA(11 - PDS*SGR FAS STIT = ST + ST + STL1 FAS JOD RE TURNE FAS JOD TO LE L-3 FAS JOT TO TO TO STAR TWARDAL X,S,C,Y1 FAS D TO TO TO LE L-3 FAS JOD TO TO TO STAR TWARDAL X,S,C,Y1 FAS COMMON FAS START ***********************************			NSF = 0	
NST = 1 FAS SGR = TB0(1) FAS SGR = TB0(1) FAS IF(SGR, ME.O.O)GO TO 25G FAS ST(1) = POS/TBA(1) FAS POT = PO1/TAG(1) FAS 25G GT TA FAS POT = PO1/TAG(1) FAS POT = PO1/AGC FAS DO T = ATT + STI(1) FAS DO T = CHAN FAS SIBFIC GANON HA, SCICTIAN FAS DO T = L3 FAS DO T = L3 FAS FAS COMON H 11 SCIL			1E(1)REC.1E.01 G0 TO 300	
SGR = TRB(11) [FAG IF(SGR + ME(-0.0)GO TD 25G FAG ST(1) = POS/TRA(1) FAG POT = POT/TRA(1) FAG 250 AGG TD 1260 FAG 250 AGG TRA(1) = POS*GGR FAG AGG = -ALGG(AGG/TAA(1)/SGR FAG POT = POT/AAG FAG POT = POT/AAG FAG POT = POT/AAG FAG POT = POT*POTAGC FAG POTAGC FAG POT = POT*POTAGC FAG POT = POT = PO			NST = 1	FAST2955
TETSGR.HE.0.0100 TD 250 FA3 STIL1 = PDSTRAT1) FA3 PDT = PDTTRAT11 FA3 GD TO 260 FA3 250 CDMTINUE FA3 ARC = TAT/ARC FA3 STIL1 = PDSTSGR FA3 ARC = TAT/ARC FA3 250 CDMTINUE FA3 ARC = TAT/ARC FA3 250 STI = STIL + STIL1 FA3 250 STI = STIL + STIL1 FA3 30D RETURN FA3 END PDT = PDT+PTDT4STT+*2 FA3 0 TATIL + STIL1 + STIL1 FA3 0 TATIL + STIL + STIL1 FA3 1 TATIL + STIL1 + STIL1 FA3 1 TATIL			SGR = TRB/II	FAST2956
STITL = POSTRATIS POT = POTTAALIS FOT = POTTAALIS GO TO 260 FOT = POTTAALIS GO TO 260 FOT = POTTAALIS FOT = FOT = FOT = FOT FOT =			1E(SGB-NE-0-0)60 TO 250	FAST2957
PDT = PDT/TRAILI FA3 GD TO Z60 FA3 250 CUMTINUE FA3 ARG = TRAILI - PDS*5GR FA3 PDT = PDT/TAGE FA3 200 STL1 = -ALCGENC/TRAILI)/SGR FA3 200 RETURN FA3 DIFECARROWK N94/22,XRT FA3 SUBROUTINE ARROWIX,S.C.VI FA3 DIFECARROWK N94/22,XRT FA3 ID VILI = XLL1 + S*CLII FA3 RETURN FA3 ID VILI = XLL1 + S*CLII FA3 FUNC TING STARINN,X.CL FA3 COHMON/LINITX/NSTORE, MERDR,NSPAX ,NARAX ,NEMAX ,NEMAX ,NSTMAX, FA3 COHMON/LINITX/NIAX ,NVMAX ,NKMAX ,NKMAN, NHMAX ,NEMAX ,NSTMAX, FA3 2 NUNITX,NIAX ,NVMAX ,NKMAX ,NKMAN, NHMAX ,NTMAX ,NTMAX , FA3 3 NUMAX ,NGMAD,NDENT,NDUN ,NUMAX ,NEMAX ,NTMAX , FA3			STILL = PDS/TRA(1)	FAST2958
00 TO 260 FA3 250 CONTINUE FA3 ARG = TRAILI - PDS*5GR FA3 PDT = PDT/ARG FA3 STIL + STIL + STIL + FA3 260 STI = STI + STIL + FA3 260 STI = STI + STIL + FA3 300 DT = NDT*PC FA3 260 STI = STI + STIL + FA3 300 DT = NDT*PCIPT*PC FA3 300 DT = L3 FA3 10 YTI = XTI + STIL + S*CTIN FA3 10 YTI = XTI + S*CTIN GT INTIAL CIRECTION VECTOR FOR FASTER*T_JORDANFAS RETURN FA3 COMMON SELECTION GT INTIAL CIRECTION VECTOR FOR FASTER*T_JORDANFAS 1 NETAN FA3 COMMON THI ARADON SELECTION OF INTIAL CIRECTION VECTOR FOR FASTER*T_JORDANFAS 2 NUNTTX_NITANIARX NYMAX NAMAX NEMAX NEMAX NEMAX NEMAX NEMAX FA3 3 NMAX NYMAX NYMAX NAMAX NEMAX NEMAX NEMAX NEMAX NEMAX FA3 3 NMAX NYMAX NYMAX NAMAX NEMAX NEMAX NEMAX NEMAX NEMAX FA3 4 NONANA NYMAY NYMAX NAMAX NEMAX NEMAX NEMAX NEMA			PDT = PDT/TRAIL	FAST2959
250 CONTINUE FA3 ARG = TRAILI - PDS+SGR. FA3 PDT = PDT/ARG FA3 PDT = PDT/ARG FA3 STIT = STT + STIIJ FA3 260 STT = STT + STIIJ FA3 300 RETURNESTINGE FA3 00 RETURNESTING RANDUK S,S,C,Y1 FA3 00 TO TO TA L3 FA3 00 TO TO TA L3 FA3 00 TA CTARX FA4			60 10 260	FAST2960
AGC = TRAILI - PDS*SGR FAG PDT = PDT/ARG FAG ST(1) = -ALG(JARG/TAAILI)/SGR FAG ST = STI + SI(1) FAG PDT = PDT/ARG FAG SDD RETURN FAG SUBROUTHE ARGON(X,S,C,Y) FAG D IG TIAL FAG O IG TIAL STACON PAG FAG O IG TIAL STACON FAG FAG O ICKENSION X SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*T.JORONHAR FAG FAG COMMON LINITS/NSTORE, MERDRO, NSPAN, NAMAX, NRMAN, NBMAX, NSTMAX, FAG COMMON HILINITS/NSTORE, MERDRO, NSPAN, NAMAX, NRMAN, NBMAX,		250	CONTINUE	FAST2961
PDT = PDT/ABC FAS ST(1) = ~ALGGARG/TAAL11/SGR FAS 200 STT = STT + SI(1) FAS PDT = PDT+PTGFST**2 FAS 300 RETURN FAS 0 IMENDATINE ARROW(X,S,C,Y) FAS 0 TATA FAS 0 TATA FAS 0 TO IO I= 1,3 FAS 0 TO IO STARINA, SCILL FAS CORHON HILL CORH			ARG * TRAILI - PRSESCR	FAST2962
ST(1) = -ALCC(ARG/TAA(1)/SGR FAS 200 STI = STI + S			PDT * PDT/ARG	FAST2963
240 STT = STT + ST(1) FA3 POT = POT PPTOTASTT++2 FA3 300 RETURN FA3 SUBPCTURE ARROWLX,S,C,Y1 FA3 0 THENSION X 10, (51, Y13) FA3 0 THENSION X 10, (51, Y13) FA3 10 F10; F10; F10; F10; F10; F10; F10; F10;			ST(1) = -A1CG(ARG/TRAT1))/SGR	FAST2964
POT = POT + POT + STOR + STAR PAG PAG PAG PAG PAG PAG PAG PAG PAG SUBROUTINE ARROWIX,S.C.Y1 PAG DOT ABLEWA PAG OUTINE ARROWIX,S.C.Y1 PAG RETURN FAG RETURN FAG RETURN FAG COTARX P94/27,XR7 FAG FAG		260	STT = STT + ST(1)	FAST2965
300 RÉTURN FA3 100 RÉTURN FA3 518FC LARROWV M94/2,XRT FA3 518FC LARROWV M94/2,XRT FA3 0 ITRENSION X(3),C(3),Y(3) FA3 0 TRENSION X(3),C(3),Y(3) FA3 0 TRENSION X(3),C(3),Y(3) FA3 0 TITL = X(1) + SPC(1) FA3 10 YITL = X(1) + SPC(1) FA3 10 STAN M94/2,XRT FA3 FA3 50 SUBROUTIKE ARRONG SUECTION OF INITIAL CIRECTION VECTOR FOR FASTER+T, JURDANFA3 F00 TITL STATER, MERDE, NEPAX, NARAX, NEMAX, NEMAX, NETMAX, FA3 COMMON SUECTION OF INITIAL CIRECTION VECTOR FOR FASTER+T, JURDANFA3 1 DECTION OSTAR (NN,X,C) FA3 1 NCRAX, NVMAX, NNHAX, NARAX, NEMAX, NEMAX, NEMAX, NEMAX, FA3 2 NONITIX, NIMAX, NAMAX, NARAX, NEMAX, NEMAX, NEMAX, NEMAX, FA3 3 NOVA, NVMOD, NOTINT, MODER, MEDDIN, TRODE, MEDDIN, TROMS, NEMAX, FA3 4 NONA, NVMOD, NOTINT, MODER, MEDDIN, TRODELU, MODELU, FA3 5 NOVARA, NVMOD, NOTINT, MODER, MEDDIN, NELLS, HTALS, FTA3 6 NORINT, NUMITS, NUMPER, MAILOBE, MAILOBE, MAILOBE, MAILOBE, FA3 1			PDT = PDT+PTOI+STT++2	FAST2966
END FAG SIBTC ARROWY M94/2,XRT FAG SIBTC ARROWY M94/2,XRT FAG O ICK SID,X13,(12),Y13 FAG O ICK SID,X13,(12),Y13 FAG O IO IO I=1,3 FAG O ICK SID,X13,(12),Y13 FAG O ICK SID,X13,(12),Y13 FAG O ICK SID,X13,FCI,IX FAG CRTMAX XII > *5C(I) FAG RETURN XII > *5C(I) FAG COTAX M94/2,XRT FAG COTHON FINITIAL CIRECTION VECTOR FOR FASTER*T, JORDAFAS FUNCTION GSTARING X, XCI FAG COMMON HIL FAG		300	RETURN	FAST2967
118FCT_ARKOWV M94/2, NRT FAS SUBBOUTINE ARROWN KS, G, YI FAS 0 INFENSION X(3), (13), Y(3) FAS 0 INFENSION X(3), (13), Y(3) FAS 10 Y(1) = X(1) + S*C(1) FAS NETLORN FAS COSTAR VM94/2, XR7 FAS COMMON SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*T, JORDAWFAS FAS COMMON HILITS/NSTORE, MERDR, NSPAX, NNMAX, NNMAX, NNMAX, NSTMAX, FAS FAS COMMON/LINITS/NSTORE, MERDR, NSPAX, NNMAX, NNMAX, NNMAX, MAMAX, HTAA, FAS FAS 3 NMMAX, NCMAX, NNMAX, NNMAX, NNMAX, MAMAX, HTAA, FAS FAS 4 NUNTITA, INFAX, NNMAX, NNMAX, NNMAX, MAMAX, HTAA, FAS FAS 5 NUNTITA, MAXA, NNMAX, NNMAX, NNMAX, NNMAX, HTAA, FAS FAS 6 NPRINT, MUNTIS, NUMPER, MAILOBEL, NODEL, FAS 6 NPAN, NUMPER, MA			END	FAST2968
SUBROUTINE JARDDYLX,S,C,YI FAS DIMENDIAL STATUS FAS DO IO I=1,3 FAS CONNO FAS RIDAN FAS COSTARX M94/2,XR7 FAS CONHON HIII CONHON/INTX, HITS/HARAX, HANAX, HORDAN, HORDAN, HINAKA, HINAX, HANAX, HORDAN, HORDAN, HANAS, HANAX,	\$ 1	RETO	ABROWY M94/2-X87	FAST2969
DIRENSION X(3),(13),(13) DI 01 E1,3 FAS 10 YII = X(1) + S*C(1) RETURN EXTERN CORMAN X FM472,X87 CGSTAR FRANDOM SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*T.JORDAN FAS COMMON HIL COMMON FLINTS/NSTORE, MERDOR, NSPAX, NAMAX, NBMAX, NSTMAX, FAS COMMON HIL COMMON/LINITS/NSTORE, MERDOR, NSPAX, NAMAX, NBMAX, NSTMAX, FAS COMMON HIL COMMON/LINITS/NSTORE, MERDOR, NSPAX, NAMAX, NBMAX, NSTMAX, FAS 1 NMAX, NGMAX, NFAX, NYMAX, NAMAX, NBMAX, NSTMAX, FAS 2 NUNITY, NIMAX, NAMAX, NAMAX, NBMAX, NBMAX, NSTMAX, FAS 3 NMAX, NGMAX, NFAX, NYMAX, NAMAX, NBMAX, NTAN, FAS 4 NDMAX, NGMO, NDPENI, MONDO, NCMAX, HEAK, HITAX, FAS 5 NMPRINT, NUNITS, NIMPERI, ALIDDELD, NDDEL, NGL, NGEL, FAS 5 NMPRINT, NUNITS, NIMPERI, ALIDDELD, NDSCL, NGEL, FAS 5 INTE, ILSY, IMTL, IRMU, JIA, JIL, FAS 3 INTG, IELF, IFGW, ITOS, ILSY, INT, ILSY, ISS, IJOS, INF, JISS, FAS 5 INT, ILSY, IATN, IASY, IASS, IAS, JIAS, JIAS, ISS, IJOS, INF, FAS 5 INT, ILSY, IATN, IASY, IASS, IAS, JIAS, INF, ISS, IASS, FAS 5 INT, ILSY, IATN, IASY, IASS, IAS, JIAS, INF, ISS, IASS, IASS, INT, ISS, IASS, INT, IASS, IASS, INT, FAS 5 INT, IALY, IALY, IATN, IASS, IASS, INT, ISS, IASS, INT, FAS 5 INT, IALY, IALY, IATN, IASS, IASS, INT, INS, INT, ISS, IASS, IASS, INT, ISS, IASS, INT, ISS, IASS,			SUBROUTINE ARROW(X.S.C.Y)	FAST2970
D0 10 1-11-3 FA3 D0 10 1-11-3 FA3 RETURN FA3 END. FA3 STAFT FA3 STAFT FA3 STAFT STAFT STAFT<			DIMENSION X(3).C(3).Y(3)	FAST2971
ID YITI'- XITI' \$ \$*CITI RETURN END. STOR STARX #94/2,XA7 STARX #94/2			00 10 I=1.3	FAST2972
RETURN FAS END. FAS SIBFIC QSTARX M94/2,XR7 GEND. FAS SIGFIC QSTARX M94/2,XR7 GENDRON SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*T,JORANFAS FAS FUNCTION GSTARINN,X.CI FAS COMMON/LINITS/NSTORE, MERROR, MSPAX, MAMAX, MRAMAX, MERAD, MXSECT, MUNITO, FAS FAS 1 NEMAX, MMMAX, MAMAX, MARAX, MERAD, MXSECT, MUNITO, FAS 2 NMMAX, MMMAX, MARAN, MARAN, MERAD, MXSECT, MUNITO, FAS 3 NMMAX, MMAX, MARAN, MARAN, MERAD, MXSECT, MUNITO, FAS 4 NOMAX, MONOT, MINT, MONTO, MINT, MINTAX, MTAKA, FAS 5 NUMAX, MCHORI, MONOD, MCMAY, MINAK, MITAKA, FAS 6 NPRINT, MUNTS, MUNDER, MALDO, MCMAY, MINAK, MITAKA, FAS 6 NPRINT, MUNTS, MUNDER, MALDO, MCMAY, MINAK, MITAKA, FAS 6 NUMAX, MCHORI, MONOD, MCMAY, MINAK, MITAKA, FAS 7 JOBAK, MUNDER, MALDO, MCMAY, MINAK, MITAKA, FAS 6 NUMAX, MCHORE, MALDO 7 JOBAK, MUNDER, MALDO 7 JOBAK, MUNDER, MALDO 8 IVID, ILOT, ILOT, ILOY, ILOK, I		10	y(1) = x(1) + S = C(1)	FAST2973
END. END. SIPTC QSTARX M94/2,XR7 FASCQSTAR *RANDOK SELECTION QF INITIAL CIRECTION VECTOR FOR FASTER+T, JDRDAMFAS FUNCTION GSTARING, ALL COMMON HIL COMMON COMMON CINESTARING, ALL COMMON HIL COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON COMMON			RETURN	FAST2974
SIBFTC GSTARX M94/2,XR7 FA3 SCAR MARANDON SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*I,JURANFAS FA3 CORMON SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*I,JURANFAS FA3 CORMON HILI FA3 CONMON/LINITS/NSTORE,MEROR,NSPAX, NAMAX, NRMAX, NBMAX, NSTMAX, FA3 FA3 CONMON/LINITS/NSTORE,MEROR,NSPAX, NAMAX, NRMAX, NBMAX, NSTMAX, FA3 FA3 CONMON/LINITS/NSTORE,MEROR,NSPAX, NAMAX, NRMAX, NBMAX, NSTMAX, FA3 FA3 1 NCMAX, NVMAX, NXMAX, NAMAX, NBMAX, NBMAX, NSTMAX, FA3 2 NUMITIX,NIMAX, NNMAX, NAMODER,NDUAN, NELLS,NTRAHS, FA3 3 NOMAX,NVMOD,NOINT, MONDER,NDUAN, NELLS,NTRAHS, FA3 4 NOMAX,NVMOD,NOINT, NOMER,NDUAN, NELLS,NTRAHS, FA3 5 NUDMAX,NVMODER,NDINT, MODEL,NDODELU, MODELU, MODELU, FA3 6 NRTIN, NUMITS,NUMORER,NDIER,NDUAN, NELLS, FA3 1 JELME, IAZ ISIN IDE 2 LINTA, ISUV, IAIN, IAIN, IAIN, IES ISIS, IJEN, FA3 3 INTG, IELF, IFAG, ITOS, INPC, IJSN, ISIS, IEL, FA3 IAIG, IELF, IFAG, ITOS, ISIN, IDE 4 IVIL, ICOT, IZCT, IRSI, IAIN, IAIN, ISIS, ISI, ISIN, FA3 ISIN, ISIN, ISIN, ISIN, ISIN, FA3 5 IAIN,			END,	FAST2975
CGSTAR *RANDOM SELECTION OF INITIAL CIRECTION VECTOR FOR FASTER*T.JORDANFAS FINCTION GSTARINA.X.C) FAS CONMON H11 CONMON H11 CONMONZIANT START AND	\$ 1	8FTC	QSTARX M94/2+XR7	FAST2976
FUNCTION GSTARINN,X.C) FAS COMMON HII COMMON/LINITS/NSTORE,MERDR,NSPAX,MAMAX,NRMAX,NBMAX,NSTMAX, FAS COMMON/LINITS/NSTORE,MERDR,NSPAX,MAMAX,NRMAX,NBMAX,NSTMAX, FAS 1 NKMAX,NVMAX,NKMAX,MSHEAX,NCHOD,MXSECT.NUNITO, FAS 3 NKMAX,KCMAX,NFMAX,MSHEAX,NCHOD,MXSECT.NUNITO, FAS 3 NKMAX,KCMAX,NFMAX,MSHEAX,NTMAX,HITAX,FAS 5 NKUNAX,NKUMOD,HOTIM,MODELD,MCDELD,MODELU,MODELV, 6 NKPINT,NUMITS/NLMDRER,MALIDE,HODELD,MODELU,MODELV, FAS 1 NLGAX,INYUMOD,HOTIM,MODER,MALIDE,SISSH,JDEN,FAS 3 INTG,IELF,IFGW,ITOS,IIAY,IIAY,IISS,JSH,JDEN,FAS 5 INTG,IELF,IFGW,ITOS,IIAY,IVA,IISS,JSH,JDEN,FAS 3 INTG,IELF,IFGW,ITOS,IIAY,IVA,IISS,JSH,JDEN,FAS 5 IAIM, IALV,IAIM,IA,SI,AL,VVA,IISS,JSH,JDEN,FAS 5 IAIM,IALV,IAIM,IA,SIS,IAE,VVA,IISS,FAS 5 IAIM,IALV,IAIM,IA,SIS,IAE,VVAD,ICIN,FAS 5 IAIM,IALV,IAIM,IA,SIS,IAE,VVAD,ICIN,FAS 6 ISS,JSH,IAT,IAF,IAS,IAE,SISSH,JDEN,FAS 6 ISS,JSH,IAT,IAF,IAS,IAE,SISSH,JDEN,FAS 6 ISS,JSH,IAF,IASS,IAS,SISSH,IDE,IAS,FAS 7 ISSS,FEXT,IAFP,ISGR,JSG,FIDE,IDI,FAS	C G	STAR	*RANDOM SELECTION OF INITIAL DIRECTION VECTOR FOR FASTER*T.JORDAN	FAST2977
CONHON HII) CONHON/LINIIS/NSTORE,NEEROR,NSPAX,NARAX,NRHAX,NBHAX,NSTHAX, FAS LONHON/LINIIS/NSTORE,NEEROR,NSPAX,NARAX,NEHOD,MXSECT,NUNITO, FAS 2 NUNIX,NIMAX,NAHAX,NGHOD,NXSECT,NUNITO, FAS 3 NUMAX,NGHAX,NFHAX,NVHOD,NCHAX,NIHAX,NTHAX, FAS 4 NUMAX,NGHAX,NFHAX,NVHOD,NCHAX,NIHAX,NTHAX, FAS 5 NUDAX,NVHOD,NDINI,MUHOLEN,HODELD,NGDALU,HODELU, 6 NUMAX,NUHOD,NDINI,MUHOEK,ALUE 6 NUMAX,NUHODEK,ALUE 7 LISUS, NITO, FAS, STATUS, NITO, STATUS, FAS 3 NUHAX,NYHODEK,ALUE 6 NUMAX,NYHODEK,ALUE 6 NUMAX,NYHODEK,ALUE 1			FUNCTION OSTARINN.X.CI	FAST2978
COMMON/LINITS/NSTORE,MERFOR,MSPAX,MARAX,NEMRAX,MSHAX,NSTAX,FAS LOHMON/LINITS/NSTORE,MERFOR,MSPAX,MARAX,NEMDA,XSTECT.NUNITO,FAS NUNITY,MIMAX,NUNAX,MSUNGDER,NDDUN,INELAS.NTANAS,FAS NUNAX,NGMAX,NFAX,MVADA,NUNGDER,NDDUN,INELAS.NTANAS,FAS MORAX,NGMAX,NFAX,MVADA,NDDER,MODEL,NDDUL,MDDELY, MORAX,NGMAX,NDHEN,MDUDE,MJCHODEL,NDDUL,MDDELY, COMMON/INDEX/INTP ,IAZ ,IISY ,IMTL ,IRMO ,IXR ,IELL ,FAS LOHMON/INDEX/INTP ,IAZ ,IISY ,IMTL ,IRMO ,IXR ,IELL ,FAS Z			COMMON H(1)	FAST2979
I NEMAX INVMAX INXMAX INXEMAX INEMAD INXSECTINUITOF FAS 2 NUNITXIHAX INTAKA INXEMAX INTAGAN NODUM INTELSA NITAANS FAS 3 NNMAX INGMAX INFAA INVMOD INCHAX INTAKA ITAA 4 NDMAX INGMAX INFAA INVMOD INCHAX INTAKA ITAA 5 NUDAX INGMOD INDENI TIMODELP INODELO, MODELU, MODELU 6 NPRINT INUNITSINUPBERIALDE 6 NOTINI INTALIA INTO INTI INDEENI INTO INTI INTI INTI INTI INTI INTI IN			COMMON/LINITS/NSTORE.NERROR.NSPAX .NAMAX .NRMAX .NBMAX .NSTMAX.	FAST2980
2 NUNITY, NIMAX, NAMAX, NUNDER, NDDNH, INELAS, NITAANS, FAS 3 NUMAX, NGMAX, NHAX, NYAO, NCHAX, NIMAX, NITAA, FAS 4 NDMAX, NGMO, NDERI, NDMO, NEDAKA, NTMAX, FAS 5 NUDAX, NGMO, NDERI, NDMO, NEDAKA, NEDAGU, NDEL, AGOEU, NDELY, FAS 6 NUMAX, NUMMO, NUNIT, NDELF, NDEL, NDEL, NDEL, NDELY, FAS 6 COMMON/INDEX/INIT, NUTS, NUNEAR, NITA, NITA, FELL, FAS 7 COMMON/INDEX/INIT, NUTS, NUTS, NUTS, NITA, NITA, NITA, FAS 8 NUTS, NITA, NUMAY, NITA, NUTS, NITA, NITA, NITA, NITA, FAS 8 NUTS, NITA, NUTS, NUTS, NITA, NITA		t	NEMAX .NVMAX .NXMAX .NXEMAX.NEMOD .NXSECT.NUNITD.	FAST2981
3 NNMAX INGRAX INFAX INVIGO INCHAX INLAX INTAX FAX 4 NDMAX INGRAX INFAX INVIGO INCHAX INLAX INTAX FAX 5 NUDAX.NUDRDINFIINGAL, NDDAX,NUDRDONSNSAX, FAX 5 NUDAX.NUDRDINFIINGEI, ALDE 6 NPFINI, NUNITS.NUDFER, ALDE 7 ISU ILI ISU INTE ILI FAX 1 INT INUNITS.NUDFER, ALDE 1 ILI ISU INFI ILI FAX 2 ILI ISU ILI ISU INTE ILI FAX 3 INTG IELF IGU IISU ILI ISU INFC IJSI ILI FAX 4 IVGL IELF IGU IISU ILI ISU INFC IJSI ISI ISI FAX 5 ISI ISU ILI ISU ILI ISU INFC IJSI ISI ISI FAX 5 ISI ISU ILI ISU INFC ISI ISI ISI ISI ISI ISI ISI ISI 5 ISI ISI ISI ISI ISI ISI ISI ISI ISI IS		2	NUNITX-NIMAX .NNMAX .NGRDER.NDDWN . [NELAS-NTRANS.	F4512982
4 NDMAX INGADD INDIKITINDADD NIPDMAX, PEDRODINSDMAX, FAS 5 NUDMAX INGADD. NDIKITINDADD NIPDMAX, NEDRODINSDMAX, FAS 6 NDFINITINUTSNDJERIALIDE CDMMON/INDEXS/INTINITSNDJERIALIDE 1 INTINITSNDJERIALIDE 1 INTINITSNDJERIALIDI 1 INTINITSNDJERI 1 INTINITS		3	NNMAX NGMAX NEFAX NVHOD NCMAX NEMAX NTHAX .	FAST2983
5 NUDHAX, NUDHOL, NODIN, MODELP, HODELO, MODELU, MODELU, FAS 6 NPRINT, MUNITS, NUDBER, MAILDE FAS COMMON/INDEXS/INTP 1AZ .IISV (MRL ,IRMO ,IXR ,IELL , FAS 1 .ILW ,IAE ,INE (MRL ,IRMO ,IXR ,ILSX ,FAS 2 .IIXR ,ISUV ,IATN ,IATN ,IESD ,ISSN ,IDSN , FAS 3 .INTG ,IELF ,IGW ,ITOS ,IIOV ,IIOX ,IDS ,FAS 4 . IVOL ,ICOT ,IXCT ,IRSI ,IALP ,VVD ,ICIN , FAS 5 .IXFN ,ISOF ,IDS ,ISOT ,VVE ,IVA ,ISS 6 . ISGS ,MEXT ,IXPP ,ISGR ,INS ,IES ,INC , FAS		4	NDMAX NGNOD BOKENT NDMOD NDDMAX NPDMOD NSDMAX.	FAST2984
6 NPRINT, NUNITS, NUPBER, ÅLIDE FAS COMMON/INDEXS/INTP (AZ 115V (MTL 1RHO 1IXR 1ELL FAS I 1 IELH 1AE INE (MSG 1NPC IJSK 1ISX FAS 2 IXTR 1SV (MTL 1ESM 1SSH 1ISX FAS 3 INTG 1ELF INE (MSG 1NPC IJSK 1ISSK FAS 4 INT (IXTN 1ATK 1ESM 1SSH 1DSK FAS 5 INTG 1ELF INGK 1IDS (IAF) (IAF) (IAF) (IAF) (IAF) 5 IAIH 1ALH 1ALH 1A (IAF) (IALF 1VPO IGIN FAS 6 ISFN 1SPE IATO 1RSS 1IST (IEE IVAL FAS 7 ISGS NEXT (IXP) ISGR 1WS 1ES , IMS 1ES 1WC FAS		Ś	NYDMAX . NYDMOD . NPO INT . MODEL P .M DDELO . MODELU . MODEL V .	FAST2985
COMMON/INDEX/INTP ILAZ IISV IMTL IENO IXR IEL P FAS 1		é	NPRINT, NUNITS, NUMBER, KALIDE	FAST2986
1 - IELW IAE THE INSC INFC IJSK IJSK FAS 2 IXTR ISUV IATN IATW IJESB ISSK IJDEN FAS 3 INTC IELF IFGW ITDS IIESB ISSK IJDEN FAS 4 IQU IELF IFGW ITDS IIAD ITTS IIESB ISSK IJDEN FAS 5 IQU IELF ITCGW ITDS IALP IVMO IGIN FAS 5 IAIH IALH IALH IAI IAS INFE IVEE IVAL FAS 6 ISFW ISPE IATD IRSF ISCT INCE INTE IFF ISCT FILS 7 ISCS NEXT IXMP ISCR INS IES INC FAS			COMMON/INDEXS/INTP .1AZ .IISV .IMTL .IRHO .IXR .IELL .	FAST2987
2 IXTR ISUV IATN IATW IESB ISSN IDDN F FAS 3 INTG IELF FIGH ITOS IDDV ITON FIDS F FAS 4 IVQL ICOT IXCT IRSI IALP IVMO ICIN F FAS 5 IATN IALP IALH IA IAS IVEE IVAL FAS 6 ISPN ISPF IATO IRSP ISGT ITOF ITOI F FAS 7 ISOS IFENT IATP ISGN INS FES INC F FAS		1	L .IELW .IAE .IBE .INSG .INPC .IJSN .IJSX .	FAST2988
3 INTG JELF, IFGN JITOS IIDV JITOR JITOS F FAS 4 IVOL ILOTY JIKTY IRAS JIALP JIVN JIGIN F FAS 5 IAIH JIALH JIALH JIA JIAS IVEE JIVAL F FAS 6 ISPN JSPE JIATO JRSP JISCT IIDE IIDI F FAS 7 ISGS JREAT JIXHP JISGR JIWS JIES JIWC F FAS		ż	LXTR ISUV LATH LATH JESB ISSH IDEN	FAST2989
4 IVOL JICOT JIXCT JIRSI JIALP JIVNO JICIN , FAS 5 IAIN JIALP JIALH JIA JINS JIVEE JIVAL , FAS 6 ISPN JISE JIALH JIA JIST JILOE JIDI , FAS 7 ISGS JNEAT JIXAP JISGR JINS JIES JINC , FAS		3	INTG , IELF , IFGW , ITDS , I IDV , I IDR , I IDS .	FAS12990
5 IAIM IALM IALM IAI INS IVEE IVAL FAS 6 ISPN ISPE IATO INSP ISGT IIDE IIDI FAS 7 ISGS NEXT IXPP ISGR INS IES INC FAS		4	IVOL .ICDT .IXCT .IRSI .IALP .IVND .IGIN .	FAST2991
6 ISPN ,ISPE ,IATO ,IRSP ,ISGT ,IIDE ,IIDI , FAS 7 ISGS ,NEXT ,IXMP ,ISGR ,INS ,IES ,INC , FAS		5	IATH , TALF , TALH , TA , THS , TVEE , TVAL ,	FAST2992
7 ISGS ,NEXT ,IXMP ,ISGR ,INS ,IES ,INC , FAS		6	ISPN ,ISPE ,IATO ,IRSP ,ISGT ,IIDE ,IIDI ,	FAST2993
		1	ISGS , NEXT , IXMP , ISGR , INS , IES , INC ,	FAST2994
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Laboratory	Astronuclear

1	8	IEC	, IND	, 10	, I V	• E W	• I S I	, 151 .	FAST2995
	9	INRG	, INSC	+ISTP	. INRP	, I NCP	+ IFXP	, IFXS	FAST2996
	1	IFXI	, 1F XE	+IFXA					FAST2997
	QSTAR = QSTDUM	ILNN,X,	C.VXHY	X,5,1,H	11501,6	I([NPC).	HIIVEE)	.H(1VHD)	I, FAST2998
	1	HIIAL	P]+H[[XTR),H(I	NSG))				FAST2999
	RFTURN								FAST3000
	END								FAST3001
\$IBFT	C QSTDH1 M94/2	, XR7							FAST3002
COSTD	UN#RANDOM SELEC	TION 0	F INIT	IAL CIRE	CTION V	ECTOR F	OR FAST	ER +T . JOP	DANFAST 300 3
	FUNCTION OSTDU	H (NN + X	, C, L1,	67,63,85	SV , NPC , V	/EE,VND,	ALP .XTR	+NSG1	FAST3004
	DIMENSION X(3)	.C(3)							FAST3005
	DIMENSION ISVI	11+NPC	15,1),	VEE111,L	2,131,1	ND (5+1)	,ALPIS,	1),	FAST3006
	L XTR (3,11,N	56(1)						FAST3007
	DIMENSION VB(5	1.0(3)	,2(3),	ROT(3,31					FAST3008
	COMMON/OTHERS/	RADIUS	• XCT (3	},DELTA	, BDC (3)	+A T A	+ATB	ATC ,	FAST3009
	1	ATD	+ A T	,B1	, A S	+B S	, JHIN	JHAX ,	FAST3010
	2	KNIN	*КНАХ	, JBAR	, NZERO				FAST3011
	COMMON/LLSREG/	LLREG							FAST3012
	N = [SV(NN)]								FAST3013
	N =-LLREG								FAST3014
	PDA = 1.0								FAST3015
	00 10 1=4.5							1	FAST3016
	J = NPC(I,N)								FAST3017
10	PDA = PDA+SAMP	LEIVEE	(1,1,N),VEE(J,	1,01,08	DE L.N.	ALP([,N	1.VB([])	FAST3018
	D(3) = V8(5)								FAST3019
	SPH = SQRT(1.0	- C13]**Z}						FAST3020
	D(1) = SPH*COS	(V8(4)	1						FAST3021
	$D{2} = SPH*S1N$	{V8{4})						FAST3022
	IF(NSG(N).GT.O	160 TO	30						FAST3023
	DO 20 I=1.3								FAST3024
20	C(1) = D(1)								FAST3025
	GU TO 90								FAST3026
30	DO 40 [≤L,3								FAST3027
40	2(1) = X(1) -	X TR (I , I	N 1						FAST3028
	MAX = NSG(N) +	1							FAST3029
	ARE = 0.0								FAST3030
	DD 50 1=1,HAX								FAST3031
50	ARE = ARE + Z(1)++2							FAST3032
	ARE = SORTIARE	1							FAST3033
	IF (MAX.EQ.3)GO	TO 60							FAST3034
	CPH = 1.0								FAST3035
	SPH = 0.0								FAST3036
	GO TO 70								FAST3037
60	CPH = 2(3)/ARE								FAST3038
	SPH = SQRT(1.0	- CPH	•+5)						FAST3039
	ARE = SPH+APE								FAST3040
70	CTH = Z(1)/ARE								FAST3041

STH = Z{2}/A	RE								FAST3042
CALL ROTATE(СРН. SPH	.CTH.ST	H.80T)						FAST3043
00 80 1=1.3									FAS T3044
((1) = 0.0									FAST3045
DO 80 J=1.3									FAST3046
BO(C(1) = C(1)	+ nr.i)+	ROTIAL	1						FAST3047
90 OSTOUN = PDA									FAST3048
RETURN									FAST3049
END									FAST3050
SIRFIC USTARX N94	/2.XR7								FAST3051
CUSTAR SRANDOM SEL	ECTION	OF SCAT	TERING	POINT FO	DR PROGR	RAM FAST	FER + T.J	ORDA	NFAST3052
FUNCTION UST	ARITT.	XXX . YYY	ZZZ	H.ST.NR	G)				FAST3053
DIHENSION ZZ	2(1). 77	Y(1).XX	XIII.CP	(3)					FAST3054
CONBON	H(3)								FAST3055
COMBON / DURUS	1/517	.515	.PSI	- 510	-NST	.PDT			FAST3056
COMBON/LINET	S/NSTOR	F.NFRRO	R.NSHAX	NAMAX	NRMAX	NRMAY	.NSTMA	×.	FAST3057
,	NERAX	.NVNAX	-NXMAX	NXEMA	X-NENOD	NXSEC	NUNTT	n.	FAST3058
2	NUNIT	X-NIHAX	NHHAX	NORDE	R-NOOWN	. INEL AS	S-NTRAN	s.	FAST3059
à	NNMAX	NGNAX	.NFHAX	NVHOD	NCHAY	NI HAY	NTHAT	·.	FAST3060
4	NOMAX	NGNOD	NOPEN	T.NDHOD	-NPDHA	NPDHO	NSDHA	x.	FAST30A1
ś	NYDHA	Y-NVDRO	D.NPCIN	T. HODEL	P-NODEL	. KONEL	I. NODEL	v.	FAST3062
6	NPRIN	T.NUN1T	S-NUMBE	R.KALTO	F				FAST3063
COMMON/INDEX	SITNTP	. 1 4 7	.115V	. [#7]	.1 RHO	-IXR	. TELL		FAST3064
1	TELV		185	THSG	INPC	. T.I.SN			FAST30A5
2	IXTR	TSUV	TATN	TATH	ALES8	ISSH	TOEN	1	FAST3066
1	INTO	TELE	TEGH	1105	1104	TIDE	1105		FAST3047
í.	TVOI	1003	TYCT	IRSI	TALP	TVHD	TOTH		FAST3068
· • •	TATH	TATH	TATH		INS	TVEE	TVAS		FAST30A9
,	ISPH	ISPE	TATO	TRSP	1 567		1101		FAST3070
7	1505	NEXT	TYMP	1569	1 45	TES	. 1 90		EAST3071
ė	160	. IND		1.0	.16	151	Ter		EAST3072
å	INDC	TASE	1510	TNPP	TNCP	TEYO	TEVE		EAST3072
7	TEXT	TEVE	. 16 14	11110	re nor	111.46		•	EAST3074
NCT - WWW									54513075
517 - VECTOR	1.444	**.693							CAST3075
STS - ST7##7									EACT2077
313 - 312++2	Gtca . 77	718577							CAST3070
	NEWOR.1				111 111	CT1 01	1 10 1		FAST3070
	UPTUD - U	IICIN C	1 1003			3017161			FA313019
TTT - 510			1 #rikor						PAST3080
NWN - NCT									EASTROOD
									FAST3082
OSTAR - PUL									FA515083
END									CA515084
TRETC USTONI NOA	15 202								FA313085
	SETTON		10110					-	FA313086
SUBDOUTINE II	STOUMO	1.12.84	0.554.8	TI .SCT.	YN. TPA.	T08.ST.	1007104	UNUF	SACT2000
		/ * B /1							

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	,											
	DI HENSION	57(1	l],NRG	(1),RHO	11.SH	11),MYL4	L) .SGT	L1.L2)	TRALL	, '	FAST3089	,
	1.	TRB	[1],XM	(1)							FAST3090)
	COMMON/DU	MUST/	1512	,sts	*P\$1	, STC	•N ST	+ PDT			FAST3091	i
	COMMON/OT	HERSI	RADIU	S+XCT(3)),DELTA	,800(3)	ATA	+ATB	,ATC		FAST3092	è
	1 7		ATD	, AT	•BT	, AS	•B S	. JNEN	JHAX	1	FAST3073	i
	2		KMIN	.KHAX	.JBAR	NZERD			· .		FAST3094	i
	COMMON/L1	MI 15/	INSTOR	E, NERRO	RANSPAX	, NAMA X	NRNAX	, NBRAX	NSTRA	x,	FAST3095	5
	1		NEMAX	,NVMAX	+NXMAX	*NXEMA)	.NEKOD	+NX SECT	F, NUNITI	D.	FAST3096	5
	2		NUNIT	X,NIMAX	+NHPAX	.NORDER	*NDOWN	+INEL AS	NTRANS	Ś.	FAST3097	i
	3		NNNA X	, NGMAX	*NF#AX	• NVHOD	NCMAX	. NE MAX	.NTHAX		FAST3098	,
	4		NOMAX	+ NGMOD	+NOPEN1	******	+NPDMAX	. NPOHOD	J-NSCHA:	x.	FAST3099	,
	5		NVORA	X, NYDMOE	NPGINT	, MODELP	-HODELC	ADDELL	J, MODEL 1	v.	FAST3100	,
	6,		NPRIN	T, NUNITS	NUFBER	KALIDE					FAST3101	i.
	IF(MODELU	EC:0) GO (TO 89							FAST3102	
	STD8 = SQF	21651	51								FAST3103	
	XHTT = ,0.0	כ									FAST3104	
	XMST = 0.0	0									FAST3105	5
	TRAB ≈ 1()									FAST3106	
	STT = 0.0										FAST3107	ŕ
	FMP = 0.0										FAST3108	ı.
	002 = .1.0/	'STS									FAST3109	,
	IF (NPOINT.	.GT.0	1 60	10 5							FAST3110	
	DOZ = 1.0										FAST3111	
	IFISTOB.LE	. OEL	TA) GI	CTC5							FAST3112	
	DOZ = 10.5	S*DEL	TA/STI	083**2							FAST3113	
	DOZ = DOZ4	11.0	+ DO.	23							FASTILLA	
5	DOH = DOZ										F45T3115	
	XHBB ⇒, D.C)									FASTBLIA	
	DO 20 N=1,	NST									FAST3117	
	I = NRG(N)										FASTBLIR	
	J = NTL(1)										FAST3119	
	SGR # RHD	11+5	SHIJB	AR }							FAST3120	
	1F(J.GT.0)	SGR	= SG1	R + SGT(JBAR, J1						FAST3121	
	STN = ST(h	•									FAST3127	
	STT * STT	+ ST	N								FAST3123	
	STDS = STS	: + S	TT+(2.	.0*PSI +	511)						FAST3124	
	STDA > STD	8									F15T3125	
	STDB = SQR	TIST	051								FAST3126	
	XMST = XMS	it + .	AT+SGR	ROSTN						i i	FAST3127	
	XHTT = XHT	T + I	BT+SGS	ROLSTOR	- STDAI						FAST3128	
	XMAA × XNB	8				•				i i	EAST3120	
	XHBB = XHS	T + 3	TTRX								FAST3130	
	TRAA = TRA	в									FACT3131	
	DOH = 1.0/	STCS									EASTALAT	
	IF INPOINT .	GT.O) GO 1	ro e							ENCTATA	
	DOM = 1.0										FASTRIA	
	IFISTD8.LE	.DEL	TA) GE	3 10 8							CICT2126	

	DDM = {0.5+DELTA/STEB}+2	FAST3136
	DOH = DOH + (1.0 + DOH)	FAST3137
8	TRAB = DOH+EXP1-XHST - XHTT3/DOZ	FAST3138
	XMN = 0.0	FAST3139
	IF((SGR+STN),EQ.0.0) GB TO 10	FAST3140
	TRA(N) = SGR+TRAA	FAST3141
	IF(TRA(N).EC.0.0) GO TO 10	FAST3142
	ARGU = TRAB/TRAA	FAST3143
	IF(ARGU.GT.0.0) GO TO 9	FAST3144
	TRBN = (XHAA - XHBB)/STN	FAST3145
	XMN = TRA(N)+(EXP(XMAA - XMBB) - 1.0)/TRBN	FAST3146
	60 10 11	FAST3147
9	TRBN = ALOG(ARGU)/STN	FAST3148
	XHN = SGR+(TRAB - TRAA)/TRBN	FAST3149
11	TRBINI = TRBN	FAST3150
10	XH(N) = XHN	FAS13151
20	FAP * FAP + XAN	FAS13152
		PASISISS
50		FA313139
	00 40 N+t-NCT	FASI31355
	LEIVENING E-ENAL CO TO SO	EAST3167
		FASTINA
40	FNR = FNR - XN(N)	FAST3159
50	NST * N	FAST3160
	ARG = EMP	FAST3161
	TRAN = TRA(N)	FAST3162
	TRBN = TR8(N)	FAST3163
	YARG = FM8+TR8N + TRAN	FAST3164
	STP = ST(N)'	FAST3165
	XYZ = VARG/TRAN	FAST3166
	IF(XYZ.GT.0.0) STP = ALOG(XYZ)/TRBN	FAST3167
	STC = STT + STP	FAST3168
	SGP = 1.0	FAST3169
	I=N	FAST3170
	60 10 170	FAST3171
89	CUNTINGE	PASTBLTZ
	PSIS*1.0	FAST31/3
		FA313174
	TRALLY = 514	CAS131/3
	FRT = 0.0	FAST3177
90	FMP = 0.0	FASTALTR
	DD 120 N#1.85T	FAST3179
	1 = NRG(N)	FAST3180
	J + HTLEES	FAST3181
•	SGR. # RHO([]+SSH(JBAR)	FAST3182



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	1F{J.GT.D}SGR = SGR + SGT(JBAR.J)	FAST3183
	IF(NGT.GT.0)GO TO 100	FAST3184
	IF(SGR.EQ.0.0160 TO 110	FAST3185
	XM(N) = ST(N)+SGR+ANG	FAST3186
	GO TO 120	FAST3187
100	STT = STT + ST(N)	FAST3188
	TRA(N+1) = SQRT(STS + STT+(Z.O+PSI + STT+PSIS))	FAST3189
	TRB(N) = 0.0	F 15T3190
	IF(SGR.EQ.0.0160 TO 110	F4ST3191
	TRB(N) = BT+SGR+(TRA(N+1) TRA(N))	FAST3192
	FBT = FBT + TRB(N)	FAST3193
	XM(N) = TRB(N) + AT+SGR+ST(N)	FAST3194
	GO TO 120	FAST3195
110	XM(N) = 0.0	FAST3196
120	FMP = FMP + XH(N)	FAST3197
	IF(FMP.GT.0.0)GD TO 125	FAST3198
95	NST = 0	FAST3199
	GO TO 195 .	FAST3200
125	AAA = EXP(-FMP)	FAST3201
	ARG = L.O - AAA	FAST3202
	VARG = 1.0 - ARG#RANNO(NMB)	FAST3203
	FNA = -ALOGIVARGI	FAST3204
	FKB = FNA-	FAST3205
	FHC = 0.0	FAST3206
	STC = 0.0	FAST3207
	DO 140 I=1,NST	FAST3208
	IF(FNB.LE.XM(1))GO TO 150	FAST3209
	FHB = FHB - XH([]	FAST3210
	STC + STC + ST(1)	FAST3211
140	FAC = FAC + TRB(1)	FAST3212
150	NN = NRG(I)	FA5T3213
	MA = MTL(NN)	FAST3214
	NST=E	FAST3215
	SGP = RHO(NN)+SSH(J8AR)	FAST3216
	IF(MM.GT.O)SGP = SGP + SGT(JBAR+MM)	FAST3217
	IF(NGT.GT.D)GO TO 160	FAST3218
	SGP = ANG+SGP	FAST3219
	DDX = (FHP#AAA/ARG + FNA - 1.0)/ANG	FA5T3220
	STP = FHB/S6P	FA5T3221
	STC = STC + STP	FAST3222
	GO TO 170	FAST3223
160	SGA = AT+SGP	FAST3224
	SCB = BT+SCP	FAST3225
	CQ = (FMB + SGA*STC + SGB*TRALII)/SGB	FAST3226
	AQ = SGA/SGB	FAST3227
	FST = AQ++2 - PSIS	FAST3228
	BQ = (AQ*CQ + PSI)/FST	FAST3229

HH = (8C**2 - (CQ**2 - STS)/FST) FAST3230 1F(HH.LT.0.0) HH=0.0 . HH=SQRT(HH) FAST3231 FAST3232 HH=SQRT(HH) STO = BQ - HH IF(STO_LT_STC)STO = BQ + HH STP = STO = STC STC = STO AKE = CO - AQ*STC FKC = FKC + SCD*(ARE - TRA(I)) FKC = FKC + SCD*(ARE - TRA(I)) FK = (FSI - STS) - STS(STC)/ARE AKE = NCC*SC ST(1) = STP FAST3233 FAST323 F4573235 FAS 13236 FAST3237 FAST3239 FAST3240 FAST3241 FAST3242 170 ST(1) = STP PDT = ARG+STC++2/(SGP+VARG+12,566371) FAST3243 FAST3244 195 RETURN FAST3245 FAST3246 END FRANCE FOR FOR THE NUMBER AND OF FOR THE FAST STATUS FRANCE FOR THE FOR TH END 6 NPRINT, NUNITS, NUMBER, KALIDE FAST3256 FAST3257 1 (MUDELY = 1) 5,10,15 5 CONTINUE VSTAR = VSTOUNICC,CP,C,BS,AS) GO TO 20 10 VSTAR = VSTOUNICP,CC,C,AS,BS) GO TO 20 15 VSTAR = VSTOURICP,CC,C,AS + BS,0.0) FAST3258 FAST3259 FAST3260 FAST3261 FAST3262 FAST3263 20 RETURN FAST3266 20 RETURN END SIBETC V31DM1 M94/2,xR7 FUNCTION V31DUM1CP,CC.C.AS,B51 DATA P/73.141593 DIMENSION CF131.cC(1),C(1),R01(3,31,D(3) CONTACTOR (1),D(1),F0(1),D(2),C013,D31 CONTACTOR (2),F011 FAST3265 FAST3266 FAST3267 FAST3268 FAST3269 **FAST3270** FAST3271 00 10 I=1,3 0(1) = 0.0 FAST3272 FAST3273 DO 10 J=1,3 10 D(1) = D(1) + ROT(1,J)*CC(J) TH2 = 0.0 FAST3274 FAST3275 FAST3276 IF((ABS(01) + ABS(02)).GT.0.0) THZ * ATAN2(02.01) FAST3277

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SINZ * SQRT(1.0 - D3++2)	
PDA = SAMPLE(-1.0,1.0,-1.0,AS,D3)	
SINE - SQRT(1.0 - D3++2)	
PDA = PDA+SAMPLE[-PI,PI,0.,-85+SINZ+SINE,THE]	
THE = THE + THZ	
D1 = S(NE+COS(THE)	
D2 = SINE*SIN(THE)	
DO 20 I=1.3	
C(11) = 0.0	
DO 20 J=1.3	
20 C(1)" = C(1) + D(J)+ROT(J,1)	
VSTDUM = RDA	
RETURN	
END -	
\$18FTC SAMPLR M94/2, XR7	
CSAMPLE*RANDOM SELECTION OF VARIABLE	
FUNCTION SAMPLE(VMN+VMX+VMO+ALP+VEE)	
IF(VHX.GT.VHN)GO TO 10	
C DELTA FUNCTION (OR ERROR)	
PDF = 1.0	
VEE - VHN	
GO TO 30	
10 R = RANNO(NMB)	
1F(ALP.NE.0.01G0 TO 20	
C UNTFORM DISTRIBUTION	
POFE VHX - VHN	
VEE > VHN + R#PDF	
GD TO 30	
C EXPONENTIAL DISTRIBUTION	
20 PLT = EXPTALPOINT - VMN11 - 1.0	
PGT = EXP[ALP+(VHX - VMD]] - 1.0 + PLT	
PMD = PLT/PGT	
r = -1.0	
1F(R,GT,PMD)T = 1.0	
R = 1.0 + T+(R+PGT - PLT)	
VEE = VHD + T#ALOG(RI/ALP	
POF = PGT/(R*ALP)	
30 SAMPLE = PDF	
RETURN	
END	
- STBETC RANDUM M94/2,XR7	
FUNCTION RANNO(NM8)	
COMMON/CDC1EM/IBMCDC	
DATA N.NNN/O.LLLLL/	
IF(IBHCDC.GT.O) GC TO 10	
R = RANF(NNN)	
GO TO 20	

10		
	IFIN-EQ.	(0) R = RANF(NNN)
	R = RANE	÷(0)
20	CONTINUE	
	N = N +	1
	RANNO =	R *
	NMB = N	
	RETURN	
	END	
\$18MAP	RANL	
*	RANDOM	NUMBER GENERATOR
	ENTRY	RANF
RENE	100	L16
	MPY	L17
	LLS	4
	ALS	4
	LRS	4
	STO	L-16
	ADD	116
	STO	L-16
	ARS	4 .
	ORA	120
	FAD	L20
	TRA	1.4
116	DCT	002312421637
117	OC T	000000001737
1 20	OCT	200000000000
	END	
SDATA		:
		\$

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FAST3325 FAST3326 FAST3327 FAST3328 FAST3329 FAST3330 FAST3331 FAST3332

AST 3279 PAST 3279 PAST 3270 P