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TECHNICAL MEMORANDUM NO. 98

THE FIRST CONFERENCE OF USERS OF THE MAGIC AND SAM-C PROGRAMS

R. A. Marking

May 1971

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
ARMY MATERIEL SYSTEMS ANALYSIS AGENCY
ABERDEEN PROVING GROUND, MARYLAND

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13. ABSTRACT

This report contains the proceedings of the first conference of the users of the MAGIC and SAM-C computer programs held August 6, 7, and 8, 1969, at the Army Materiel Systems Analysis Agency, Aberdeen Proving Ground, Maryland. The purpose of the conference was to determine which subprograms constitute the MAGIC and SAM-C programs, to create program source decks, to create benchmark test problems, and to discuss problems of mutual interest.

Also included are the addresses, in expanded form, of the principal users of the two programs. These addresses included corrections and improvements to the two codes.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Nuclear fluence, flux, dose, or dose rate analysis						
Radiation transport benchmark problems						
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MAGIC Conference						
SAM-C Conference						

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Security Classification

A R M Y   M A T E R I E L   S Y S T E M S   A N A L Y S I S   A G E N C Y

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A B E R D E E N   P R O V I N G   G R O U N D ,   M A R Y L A N D

ARMY MATERIEL SYSTEMS ANALYSIS AGENCY

TECHNICAL MEMORANDUM NO. 98

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Aberdeen Proving Ground, Md.

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THE FIRST CONFERENCE OF USERS OF
THE MAGIC AND SAM-C PROGRAMS

1. INTRODUCTION AND PURPOSE

This report presents the proceedings of the first large-scale conference of the users of the MAGIC and SAM-C computer programs. The conference convened at 0915 on August 6, 1969, in Building 328 at Aberdeen Proving Ground, Maryland. Early in the afternoon of the 7th the conferees divided themselves into two groups: those interested in the MAGIC code and those interested in the SAM-C. The conference closed shortly after noon on Friday the 8th.

The following sections contain abridged versions of the announcement letter and of the opening address.

1.1 Copy of Conference Announcement (Abridged).

"AMXRD-AWF

"SUBJECT: Conference for Users of the MAGIC/SAM-C Computer Programs

"1. References:

a. The MAGIC SAM-C Target Analysis Technique, AMSAA Technical Reports 4, 10, 11, 13, and 14.

b. A Geometric Description Technique Suitable for Computer Analysis of Both the Nuclear and Conventional Vulnerability of Armored Military Vehicles, MAGI-6701 (AD 847576).

c. UNC-SAM-2: A FORTRAN Monte Carlo Program Treating Time-Dependent Neutron and Photon Transport Through Matter, UNC-5157 (AD 647470).

"2. The SAM-C Monte Carlo radiation transport program and the MAGIC conventional projectile ray-tracing program were developed by MAGI (Mathematical Applications Group, Inc) under Contract No. DAAD05-67-C-0041 for this agency (ref. a). MAGIC is the computer code that assembles data along selected rays through a target by employing the MAGI originated Combinatorial Geometry technique (ref. b) which utilizes combinations of certain basic solids such as boxes, wedges, *etc.*, to describe the target. SAM-C is the UNC-SAM-2 Monte Carlo nuclear radiation transport code (ref. c) with the original geometry routines replaced by those of the Combinatorial Geometry technique. These programs have been disseminated to a number of interested government agencies for their use and will be made available to others upon request.

"3. Recent activity with MAGIC has resulted in several advances including the addition of new "library" solids, additional input checking, and faster input processing. These advances are clearly applicable to SAM-C as well and are thus of general interest to both groups. On the other hand, recent activity with SAM-C indicates that the flux-at-a-point routine is incorrectly coded, versions for different computing systems have non-trivial differences in logic/organization, and the computational procedure for carrying out a complete set of calculations is unacceptably complicated.

"4. As a result of the many questions, comments, and suggestions from the personnel involved in using SAM-C/MAGIC, it is clear that everyone involved can benefit from an informal discussion of problem areas and a concerted attack on areas of mutual interest. It is the purpose of this letter to announce an informal, unclassified conference to define and solve problems in the MAGIC and SAM-C computer codes developed under the auspices of this agency.

"5. It is envisioned that the conference will begin on 6 August 1969 at 0900 hours in the Conference Room of ARDC Building 328 under the chairmanship of Mr. R. A. Marking of AMSAA. At this writing it is envisioned that 2 days will be required with a third day allotted only to provide a buffer period.

"6. The first day will be devoted to introductory, informal discussions of individual problems, solutions, and changes to the various codes plus presentations (on MAGIC by Mr. Larry Bain, Methodology Office, AMSAA, and on SAM-C by Dr. Wayne Coleman, Nuclear Physics Branch, NEL) of information gathered too late for inclusion into the reports of reference a. The item, "Introduction of Participants," is envisioned as an opportunity for each participant to identify which program(s) his agency is using, what problems have been encountered, any solutions that have been created, and what specific problem areas he would like to see addressed during the conference period. About 20 minutes will be allotted for each individual.

"7. The second day is planned for the creation of ad hoc working groups to achieve solutions of the problems defined on the first day. An additional day is scheduled to allow an orderly conclusion of the working group projects and the conference as a whole if necessary; the form and content of a conference report will be decided on the last day.

"8. Two items have been of special interest to all those contacted thus far: (1) the establishment of FORTRAN source decks for MAGIC and SAM-C that are not subject to the vagaries of day-to-day changes and are available to be copied by new user agencies or in the event that serious problems develop with an existing source deck; and (2) the creation of "benchmark" test problems that will provide valid tests of all features/options operational using the "archival" or "library" source deck. It is expected that these two items can be introduced in the afternoon of the first day of the conference.

"9. Participation in the conference is encouraged to promote the utility of the SAM-C and MAGIC programs. Representation from your organization is invited. The distribution list is not considered exhaustive and interested personnel within government may be invited to attend by contacting Mr. Marking. Participants are encouraged to bring listings of the current working versions of their program(s).

"10. It is intended that the meeting will result in documented improvements in the SAM-C and MAGIC source programs and/or implementation procedures. This documentation is expected to be in the form of a letter or technical note and copies will be sent to all participants.

"11. The desirability of scheduling similar meetings at regular intervals will be discussed as a means of maintaining lines of communications between MAGIC-SAM-C users."

12. (Administrative)

13. (Administrative)

FOR THE DIRECTOR:

/s/ Morgan G. Smith
MORGAN G. SMITH
Chief, Ground Warfare Division

1 Incl
as
(CF)

PROPOSED CONFERENCE AGENDA

DAY 1

"Introduction and Purpose

Introduction of Participants

Recent AMSAA Activity with MAGIC

Recent NEL Activity with SAM-C

Definition of MAGIC and SAM-C Capabilities and

Creation of Appropriate Source Decks

Creation of Benchmark Problems

DAY 2

Conclusion of the Creation of Archival Source Decks and Benchmark Problems

Formation of Sub-groups to Solve the Problems Defined on Day 1

Discussion and Drafting of Documentation

Consideration of Future Meetings

DAY 3 (If Necessary)

Conclusion of Unfinished Business"

Incl 1 to ltr

1.2 Opening Address.

"Welcome to the 1st Conference of Users of the MAGIC and SAM-C Programs.

"As stated in the Conference letter-announcement, this is to be an informal, unclassified conference of the users of the MAGIC and/or SAM-C computer programs (as well as any of the peripheral programs that might be of mutual interest).

"The purpose of this conference is three-fold:

- to find out where we stand with respect to the actual operation of both SAM-C and MAGIC
  - who is using what
  - on what machines are the codes operating
  - what changes of substance (e.g., packing into 36-bit v. 48-bit words) have been made
  - what kinds of problem areas are being considered (e.g., deep penetration as opposed to close-in transport problems, penetrator fragmentation, x-ray or thermal neutron problems, etc.)
  - what sort of functional and/or theoretical problems are being encountered in operating these codes (e.g., functional identifiers of "0", incorrect evaluation of the uncollided flux, improper coding of SAM-C for inelastic scattering, etc.)
- to define what SAM-C and MAGIC should be capable of
  - there are a number of versions of SAM-C several of which are different enough to require separate operating manuals
  - changes have significantly increased the speed of MAGIC thus making here-to-fore impractical applications worth considering
  - should SAM-C be modified along the lines of UNC-SAM-3 (ENDF/B cross-sections and a non-common energy mesh)
  - should MAGIC calculate vulnerable areas
  - should the geometry processing routines (e.g., GENI, RPPIN, ALBERT, etc.) be called MAGIC and the "driving" or controlling routines such as VOLUM and GRID be handled as separate "packages"
  - should MAGIC employ packing and what effect would its absence have on SAM-C

- to create benchmark problems
  - compatibility of geometric input between MAGIC and SAM-C
  - should they be mathematical tests of all the options or tests of physical acceptability of some combination of both...."

2. INTRODUCTION OF PARTICIPANTS

At the beginning of the Conference the individual participants indicated (1) which program they were using, (2) on which computers was it routinely used (or intended to be used), (3) what were the nature and complexity of the problems treated, (4) what program innovations had been made, and (5) what problems or errors had been encountered. Additionally, it was requested that participants indicate specific program problems to discuss during the Conference.

To accomplish these introductions in an orderly manner, a form covering all of the obvious points of interest was used. Since some of the agencies were represented by more than one person, representatives from the same group using the same program caucused to present a unified picture of their work and problems.

The participants' introductions follow the list of agencies; they are in alphabetical order.

List of Agencies Represented

Aeronautical Systems Division
(Wright-Patterson)

Air Force Armament Laboratory
(Eglin)

Air Force Weapons Laboratory
(Kirtland)

Ground Warfare Division (AMSAA)
(Aberdeen)

Methodology Office (AMSAA)
(Aberdeen)

Naval Weapons Laboratory*
(Dahlgren)

Nuclear Effects Laboratory (BRL)*
(Edgewood)

*No Participant Introduction Form available.

List of Agencies Represented (Cont'd)

SMUPA-DW6*
(Picatinny)

SMUPA-SS
(Picatinny)

SMUPA-TW3
(Picatinny)

SMUPA-VC1
(Picatinny)

RSIC (ORNL)
(Oak Ridge)

Signature & Propagation Laboratory**
(Aberdeen)

Terminal Ballistics Laboratory (BRL)*
(Aberdeen)

Vulnerability Laboratory (BRL)
(Aberdeen)

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*No Participant Introduction Form available.

**Observer only, no Participant Introduction Form included.

PARTICIPANT INTRODUCTION FORM

Agency: USAF, ASD (ASBRS), WPAFB, Ohio 45433

Name(s) of Representative(s): Gerald Bennett (ASBRS)
Roy Hilbrand (ASVCP)

Program Used: MAGIC

Purpose: To provide target descriptions for use in aircraft vulnerability analyses.

Computer(s) Used: Name IBM Direct Coupled 7044/7094 Word Size 36 bits

Memory Size: Total 32768 Available Unk

Tape Drives: No. 16 No. of Channels 4 1401-Compatible? Yes

Program Requirements: Storage 28K Packed Word Size 35 bits

Tape Drives 2 Links? Yes, 1

Dependence on Assembly Language None

Planned Program Usage: To generate target description for aircraft vulnerable area computation.

Planned Program Changes: Addition of plotting, presented area, and volume subroutines; modifications as required to generate and store data for efficient processing in vulnerable area computation program; further simplifications, as possible, to input descriptive data.

Program Innovations: The use of any body as a target volume subdivision (i.e., as an RPP); the streamlining of MAGIC by stripping out about 16 of the subroutines and recoding of others; restructuring of the Master-Aster array (M-A) deleting some items from the M-A array; recoding and repacking for 36 bit words, viz., 35 bits and one sign bit; changed grid cell generation; changed printout; allowing the attack plane to be outside of the enclosing volume; and disposal of random number generator requirement.

Program Problems/Errors: Core storage (too large); complexity in preparation of data. (Various program errors have been corrected and the corrected listings have been forwarded to AMSAA.)

Program Changes of Immediate Interest: Addition of an airfoil shape to the solid library; a more extensive ARB of perhaps 10 to 12 sides; introduction of "canned" standard aircraft component descriptions (e.g., a pilot).

PARTICIPANT INTRODUCTION FORM

Agency: Air Force Armament Laboratory

Name(s) of Representative(s): Sue Gibson

Program Used: MAGIC

Purpose: To be used with a vulnerable area program to produce vulnerable area program to produce vulnerable areas of foreign targets.

Computer(s) Used: Name CDC 6600 Word Size 60 bits

Memory Size: Total 100,000 Available 32,000

Tape Drives: No. 16 No. of Channels Unk 1401-Compatible? No

Program Requirements: Storage 32,000 Packed Word Size 36 bits

Tape Drives 7 Links? Yes, 4

Dependence on Assembly Language None

Planned Program Usage: Describe foreign air and ground targets in terms of line of sight data.

Planned Program Changes: Complete conversion from IBM 7094 to CDC 6600. Omit TESTG and other unnecessary subroutines to allow room for addition of new figure subroutines.

Program Innovations: Point Burst subroutine has been added and is being checked.

Program Problems/Errors: Lack of storage due to amount of storage allowed to each user, not to the total amount of storage in the CDC 6600.

Program Changes of Immediate Interest: Addition of new figures and reduction of amount of storage required.

PARTICIPANT INTRODUCTION FORM

Agency: AFWL, Kirtland AFB, New Mexico 87117

Name(s) of Representative(s): Michael J. Paul - AFWL (WLRAS)
A. Kris Widdison - AFWL (WLCP-M)

Program Used: SAM-C

Purpose: Both deep-penetration (in air) and close-in transport (concrete) problems, primarily neutrons, but including prompt and secondary gammas.

Computer(s) Used: Name CDC 6600 Word Size 60 bits

Memory Size: Total 300K (w/o extended core) Available $1M_8$ (w/extended core) $\cdot 325K_8$ (w/o extended core)

Tape Drives: No. 10 No. of Channels 9 1401-Compatible? Unk

Program Requirements: Storage generally 120K Packed Word Size 45 or 60 bits
Tape Drives 1-3 Links? None
Dependence on Assembly Language some, but easily changed

Planned Program Usage: Hard-rock silo configurations and state-of-art neutron and gamma transport problems.

Planned Program Changes: Complete revision of input to be more understandable and logical and easier to punch. Combined time-energy-angular dependent source input (allowing input of flux from a preliminary discrete ordinates code).

Program Innovations: Free-form reading routine (eliminates need for formatting input). Cut down flux printing by 50% by eliminating extraneous lines (e.g., ΔE). Eliminate need to change NXS = ... and NDQ.... cards (e.g., add a parameter, say ENDM, to end of master array (COMMON DUM (250), MASTER (30000), ENDM), then NDQ = LOCF (ENDM) - LOCF (Master)).

Program Problems/Errors: None.

Program Changes of Immediate Interest: ENDF/B cross sections, inelastic scattering improvements; graphic geometry display; better geometry checking.

PARTICIPANT INTRODUCTION FORM

Agency: AMSAA, Ground Warfare Division (GWD); Methodology Office (MO)
Aberdeen Proving Ground, Maryland 21005

Name(s) of Representative(s): L. Bain (MO)
R. Lake (GWD)
J. Brewer (GWD)

Program Used: MAGIC

Purpose: Conventional vulnerability by 4" cells and/or areas for combat vehicles and aircraft.

Computer(s) Used: Name BRLESC I & II Word Size 68 bits

Memory Size: Total 96K Available 48K

Tape Drives: No. 8 No. of Channels 4 1401-Compatible? Yes

Program Requirements: Storage 48 Packed Word Size 30

Tape Drives 4 Links? No

Dependence on Assembly Language Yes but easily avoided

Planned Program Usage: Conventional vulnerability of combat vehicles and aircraft (both rotary and fixed wing types).

Planned Program Changes:

1) Thirty bit packing for triplets and scalars.
2) Shielded areas.

Program Innovations: Rewrite program flow to minimize presence of unnecessary steps, extraneous comments, and blank cards.

Program Problems/Errors: None.

Program Changes of Immediate Interest: No genuinely pressing problems.

PARTICIPANT INTRODUCTION FORM

Agency: Picatinny Arsenal, Dover, N. J.

Name(s) or Representative(s): Robert Kesselman - VC-1
John Saarmann - VC-1
Robert Barnas - SS
John Burgio - TW3

Program Used: SAM-C NEL Version

Purpose: To obtain running version on IBM 360 for radiation transport and shielding calculations.

Computer(s) Used: Name IBM 360 Word Size 32/64 bits

Memory Size: Total Unk Available 200K

Tape Drives: No. 8 No. of Channels 9 1401-Compatible? Yes

Program Requirements: Storage 200K Packed Word Size 64 bits

Tape Drives 3 Links? Unk

Dependence on Assembly Language one subroutine

Planned Program Usage: Transport and Shielding

Planned Program Changes: In January 1970 Picatinny Arsenal will start using CDC 6500; therefore, the debugging effort on the conversion has been suspended.

Program Innovations: (See comment above.)

Program Problems/Errors: (See comment above.)

Program Changes of Immediate Interest: (See comment above.)

PARTICIPANT INTRODUCTION FORM

(Observer)

Agency: Radiation Shielding Information Center
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, Tennessee 37830

Name(s) of Representative(s): Robert W. Roussin

Program Used: SAM-C

Purpose: For distribution to anyone who wants the program. (RSIC operations are sponsored by the AEC, DASA, and NASA.) We have the CDC 6600 version for distribution (but no 6600 at ORNL).

Computer(s) Used: Name Word Size

Memory Size: Available

Tape Drives: No. of Channels 1401-Compatible?

Program Requirements: Storage Packed Word Size

Tape Drives Links?

Dependence on Assembly Language

Planned Program Usage:

Planned Program Changes:

Program Innovations We are Interested in:

1) IBM 360 version.
2) Version with ENDF/B cross sections.

Program Problems/Errors:

Program Changes of Immediate Interest:

PARTICIPANT INTRODUCTION FORM

Agency: BRL, Vulnerability Laboratory, Aberdeen Proving Ground, Md. 21005

Name(s) of Representative(s): M. J. Reisinger

Program Used: MAGIC

Purpose: Currently being used to debug target descriptions for Electronics Command, Army Tank Automotive Command, Missile Command, Munitions Command, Weapons Command, Nuclear Effects Laboratory, Test & Evaluation Command and Falcon Research & Development.

Computer(s) Used: Name BRLESC Word Size 68 bits

Memory Size: Total 120K Available 80K

Tape Drives: No. 3 No. of Channels 7/9 1401-Compatible? Yes

Program Requirements: Storage 48 Packed Word Size 30

Tape Drives 4 Links? No

Dependence on Assembly Language Depends on version

Planned Program Usage:

1) "Graphic Program" being developed from NASA program by L. Bain and M. J. Reisinger.
2) Recognition of heat projectile improper detonation from target description.
3) Point burst program with emphasis on components.

Planned Program Changes: Generalized Ellipsoid (i.e., not restricted to ellipsoids of revolution). Elimination of enter-leave table philosophy in favor of a more direct approach which is intended to reduce tracking time.

Program Innovations: Graphics Package.

Program Problems/Errors: A more detailed description of targets than done in the past (example, M60A1 with approximately 2500 bodies) is rapidly approaching our computer system time and size limit: a 1300 body description is using 64K, will 2500 bodies use less than the available 80K? Computer time on our system forces partial runs for graphics (need about four hours, large memory). Summation: need better computer.

Program Changes of Immediate Interest:

1) Development of support subroutines such as generalized components (wheels, ammunition, engine, etc.) that require location, orientation, and relative size that lead to computer generated bodies (solids).

2) Development of programs that would construct the optimized solid for a body from an input consisting of point data read directly from engineering drawings.

3. RECENT ACTIVITY WITH MAGIC AND SAM-C

The three sections that follow consist of the material presented verbally at the conference plus one or two minor additions or modifications.

3.1 Recent Activity with MAGIC at AMSAA. (Presentation by Larry Bain)

The recent activity with MAGIC at AMSAA falls into one of two categories: program changes or proposed plans. Each category is discussed separately.

3.1.1 Changes to MAGIC. This category is divided into three subtopics:

- Additions.
- Modifications.
- Corrections.

a) Additions. Of primary interest, three new solids have been added:

- TEC (Truncated Elliptic Cone).

  i) Height vector does not need to be perpendicular to the base ellipse.

  ii) Specify (Table 3.1)

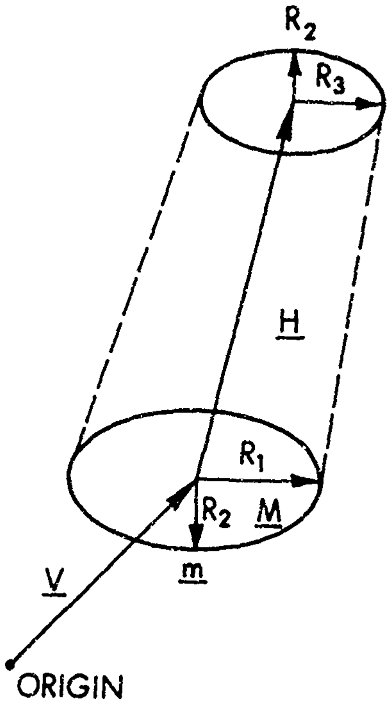
  - V - vertex of base ellipse,
  - H - height vector,
  - M - semimajor axis of base ellipse,
  - m - semiminor axis of base ellipse, and
  - R - ratio (base ellipse/top ellipse), viz., R = (R1/R3) = (R2/R4).

(The normal height vector is computed in GENI; $\underline{n} = \underline{M} \times \underline{m}$; it is necessary to change the sign of $\underline{n}$ if $\underline{H} \cdot \underline{n} < 0$.)

TABLE 3.1 CARD INPUT FOR THF NEW SOLIDS

Body Type	3-Letter ID 4 - 6	11-20	21-30	31-40	41-50	51-60	61-70	No. of Cards Needed
Truncated Elliptic Cone	TEC	V_x	V_y	V_z	H_x	H_y	H_z	1 of 3
		M_x*	M_y*	M_z*	m_x*	m_y*	m_z*	2 of 3
		R						3 of 3
Torus	TOR	V_x	V_y	V_z	N_x	N_y	N_z	1 of 2
		R1	R2					2 of 2
Arbitrary Curved Surface	ARS							
		M	N					1 of n
		X(1,1)	Y(1,1)	Z(1,1)	X(1,2)	Y(1,2)	Z(1,2)	3 of n
		. . .						
		X(1,N)	Y(1,N)	Z(1,N)				N+2 of n
		X(2,1)						
		. . .						
		X(M,1)						
		. . .						
		X(M,N)	Y(M,N)	Z(M,N)				

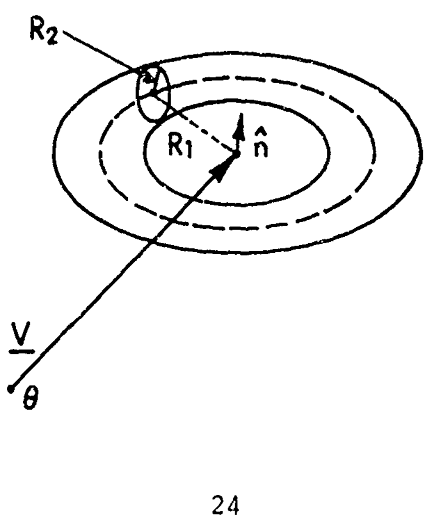
*M → semimajor axis
m → semiminor axis



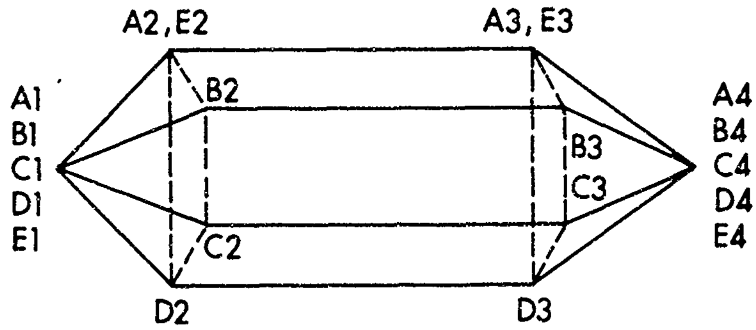
• TOR (Torus)

Specify (Table 3.1)

- V - vertex,
- n - normal vector (normal to the plane bisecting the torus),
- R1 - radius from V to the mid-point of the torus' cross section, and
- R2 - cross sectional radius (R1 $\geq$ R2).



- ARS (Arbitrary Surface)
  - i) Specify M curves of N points (see Table 3.1).
  - ii) The number of words of memory is 92 + M*N*4.
  - iii) An ARS can be described in more than one way.



Example (using the figure above).

One Approach (Solid Lines)		Another Approach (Dashed Lines)	
M = 5	N = 4	M = 4	N = 5
curve 1 pt	A1, A2, A3, A4	curve 1 pt	A1, B1, C1, D1, E1
curve 2 pt	B1, B2, B3, B4	curve 2 pt	A2, B2, C2, D2, E2
curve 3 pt	C1, C2, C3, C4	curve 3 pt	A3, B3, C3, D3, E3
curve 4 pt	D1, D2, D3, D4	curve 4 pt	A4, B4, C4, D4, E4
curve 5 pt	E1, E2, E3, E4		

Figure closed by duplicate curve
Note: pt A1 = B1 = C1 = D1 = E1
pt A4 = B4 = C4 = D4 = E4

Figure closed by duplicate points
pt A2 = E2
pt A3 = E3

The addition of these new solids has required the addition of auxiliary subroutines:

- QRTIC to solve 4th degree equation.
- CUBIC to aid QRTIC.

- CROSS to compute vector cross products.
- DOT to compute dot products.
- UNIT to compute unit vectors.
- ARIN to process the ARS input.

Additional coding is also similarly required in subroutine CALC to compute normals and in GENI, G1, and WOWI.

Quite apart from the new solids, coding has been incorporated in Geni to increase input checking as follows:

- Checks of vector perpendicularity in BOX, RAW, REC, and TEC.
- Checks of TRC radii to ensure that $R_B \neq R_T$.
- Checks of TOR radii to ensure that R1 is not less than R_2 (v.s.).

Schematically, an option has been added to suppress tape 8 (the monitor output) output (except for error messages) when writing tape 1.

Finally, two control subroutines have been created to assess quantities other than line-of-sight thickness:

- AREA to compute presented areas (the ray is traced to its first contact).
- MOMENT to compute moments of inertia (and as a by-product, the center of gravity, total weight, total volume, mean angle of incidence, and the mean cosine of incidence are also computed).

b) Modifications. Seven modifications have been made:

- The ELL input has been optimized.
  - i) Present input (cc 7-10 = 0 on card 1) is both foci plus the length of the major axis.
  - ii) Optimal input (cc 7-10 $\neq$ 0 on card 1) requires the vertex, a vector representing the semimajor axis, and the scalar length of the semiminor axis.
- Computer word packing has been converted from 45 bits/word to 30 bits/word (it is estimated that 30 bit packing runs about 30 percent faster on BRLSEC I and II).

- The solid input section has been revised by eliminating FLOCON and DIGCON and substituting the F-type format specification.
- SENSESWITCH settings have been eliminated and their control data read in on punch-cards.
- The data output coding in TRACK has been revised to eliminate SETUP and ISIGN by using I and F-type format specifications.
- A version of MAGIC has been written in "standard" FORTRAN (incidentally, this version runs slower on the BRLESCs than any of the versions already mentioned).
- The control logic in the main program has been modified so that VOLUM can be run without reading in the Identification Table.

c) Corrections. Four major subroutines were found to have more or less subtle errors:

- VOLUM faltered when G1 tried to combine regions of the same "item" code because VOLUM requires that each region be processed separately; a special exit was added to G1 to correct this condition.
- TESTG suffered a similar fate but to a greater extent since the item data was not loaded into core prior to the execution of TESTG; an additional special exit was added to G1 to rectify this condition.
- GENI computes data for the normal vector to the base ellipse in the TEC but failed to ensure that the normal was an inward rather than an outward normal; a check was added so that if $\underline{H} \cdot \underline{n}$ is negative the direction of $\underline{n}$ is reversed.
- CALC was unable to correctly calculate normal thickness through adjacent regions with the same item code (cf., VOLUM and TESTG); a modification to the existing exit in G1 to compare the item code of the next region with the item code of the previous region was made to allow continuing the normal ray.

3.1.2 Proposed Plans for MAGIC. Activity in four areas is being carried on:

- Compatibility with SAM-C - let MAGIC do some of the geometry processing for SAM-C.
- Eliminate part or all computer word packing.

- Couple the target description ray tracing directly to outputs such as vulnerable area, kill probabilities, etc.
- Addition of a graphics capability via plotters, lineprinters, CRT displays, or all three.

3.1.3 Concluding Remarks. The actual changes required to implement the three new solids are discussed in the MAGI report, A Description of Three Additional Bodies for the MAGIC Conventional Vulnerability Program, by J. R. Davis and M. Moskowitz (MAGI report MR 6902, May 1969). An abridged version of this report consisting of the main portion of the text appears as Appendix B.

In any direct dealings with the coding of the MAGIC program, a knowledge of the core storage layout, input data requirements, etc., is essential. Figures 3.1 through 3.4 supply the requisite data:

- Figure 3.1 is a map of the MASTER/ASTER array showing storage for the processed geometry data. Both 45-bit and 30-bit packing versions are shown. Variable names beginning with L are the locations of each set of data in the MASTER/ASTER array.
- Figure 3.2 concludes the map of the MASTER/ASTER array showing storage of the identification table and the "working" storage used at run time.
- Figure 3.3 is a map of the pointers to the location of the solid data.
- Figure 3.4 is the map of the storage for the arbitrary surface (ARS).

Finally, to appreciate the relationships between various routines, Figure 3.5 displays the many auxiliary routines of MAGIC and their relationship to the main of "driver" routines.

3.1.4 Additional Information. In October, 1969, several runs were made using the AMSAA "Revised Standard MAGIC" (Appendix D) on a number of different computing systems. The geometry input consisted of a description which we shall call the "December '68 Master Target." This target is comprised of 701 solids and 904 regions; none of the three new solids were used. About 5 man-months were required to create the description. The following driver routines and their input were used:

GRID	0^o Az 0^o Elev	1015 cells
VOLUM	Head-on	1015 cells
AREA	Head-on	4189 cells
TESTG	------	2 rays

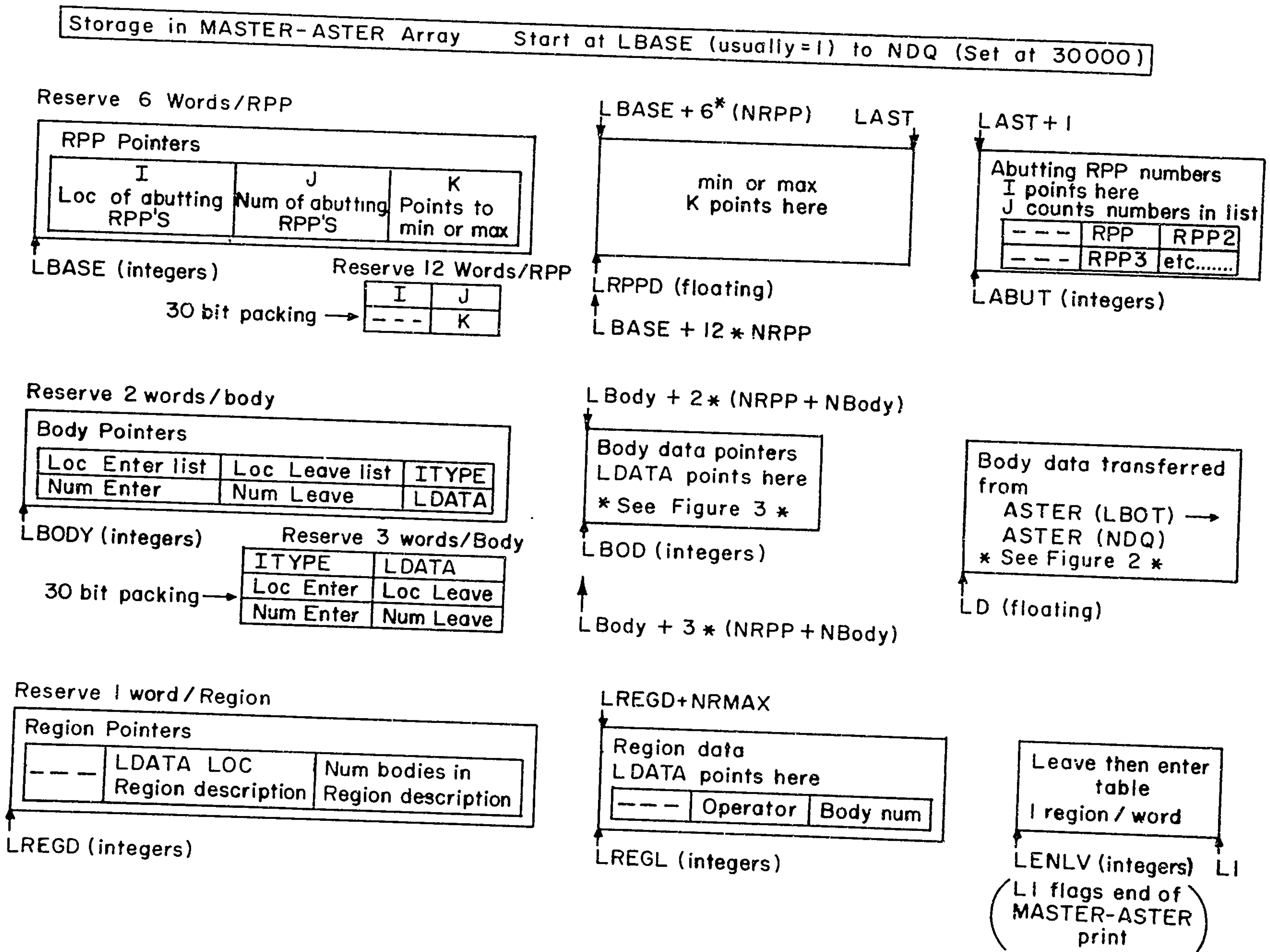


Figure 3.1 Partial Map of the MASTER-ASTER Array

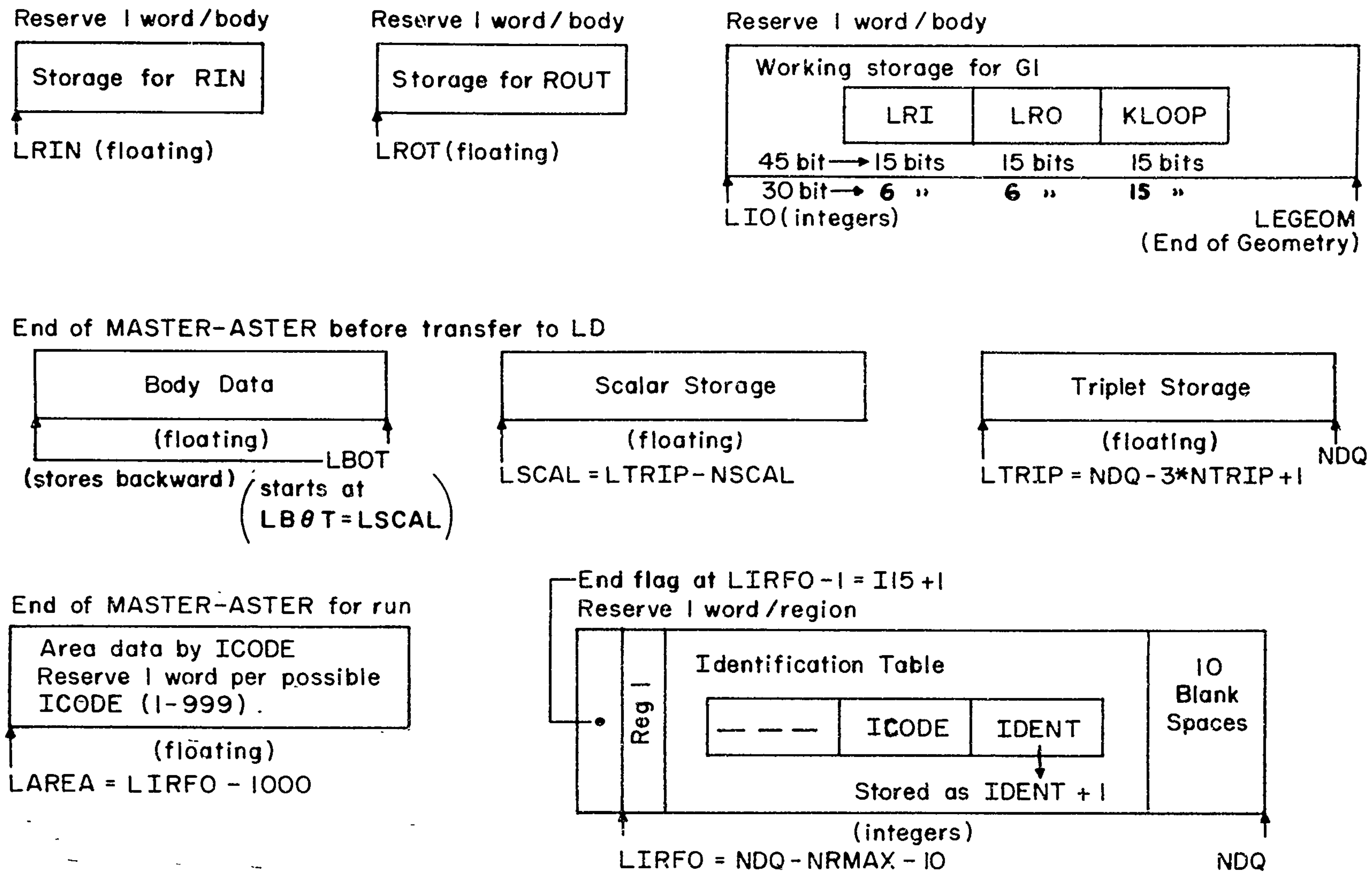


Figure 3.2 Map of the Remainder of the MASTER-ASTER Array

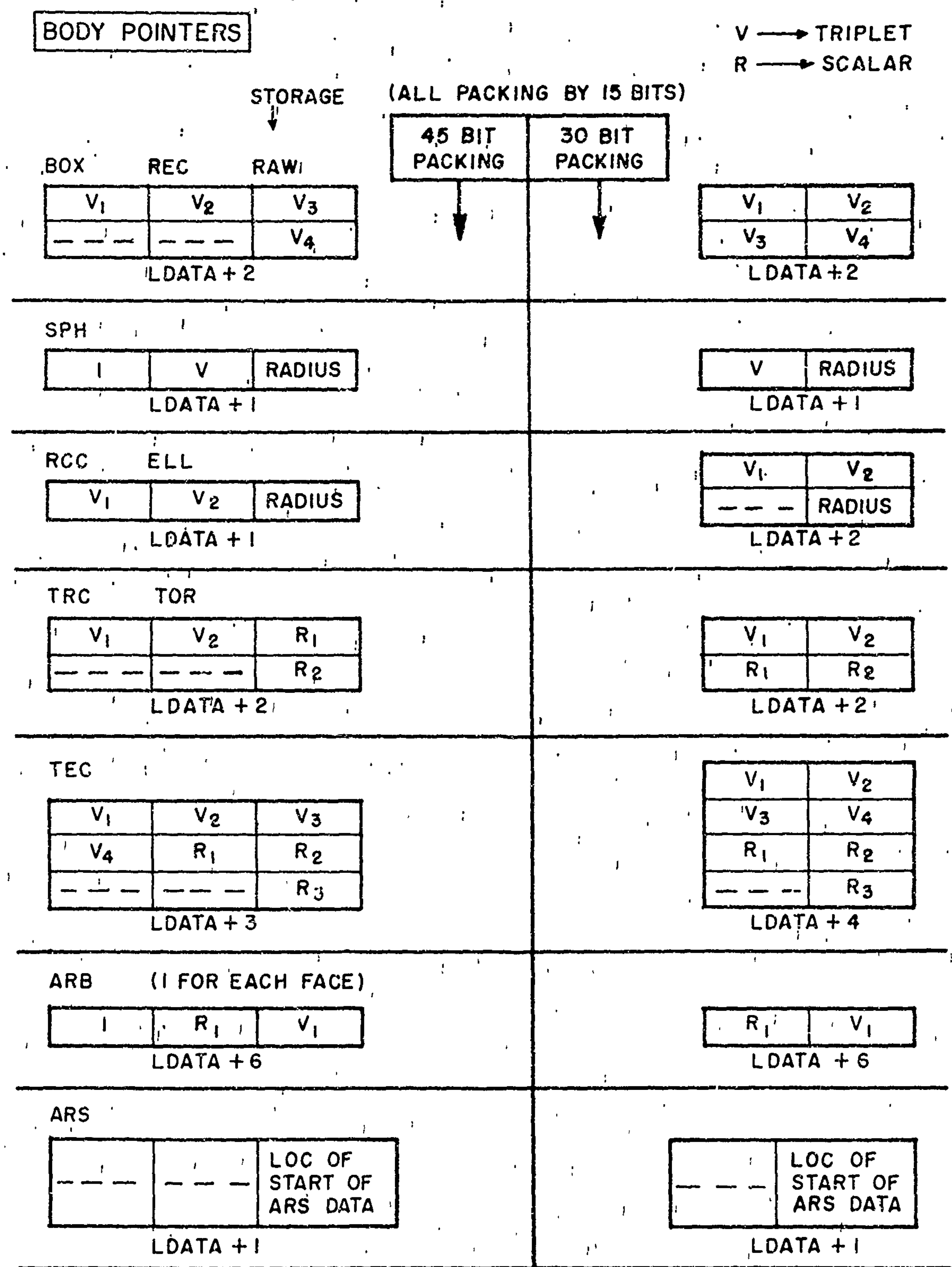


Figure 3.3 Map of Pointers to Solid Data

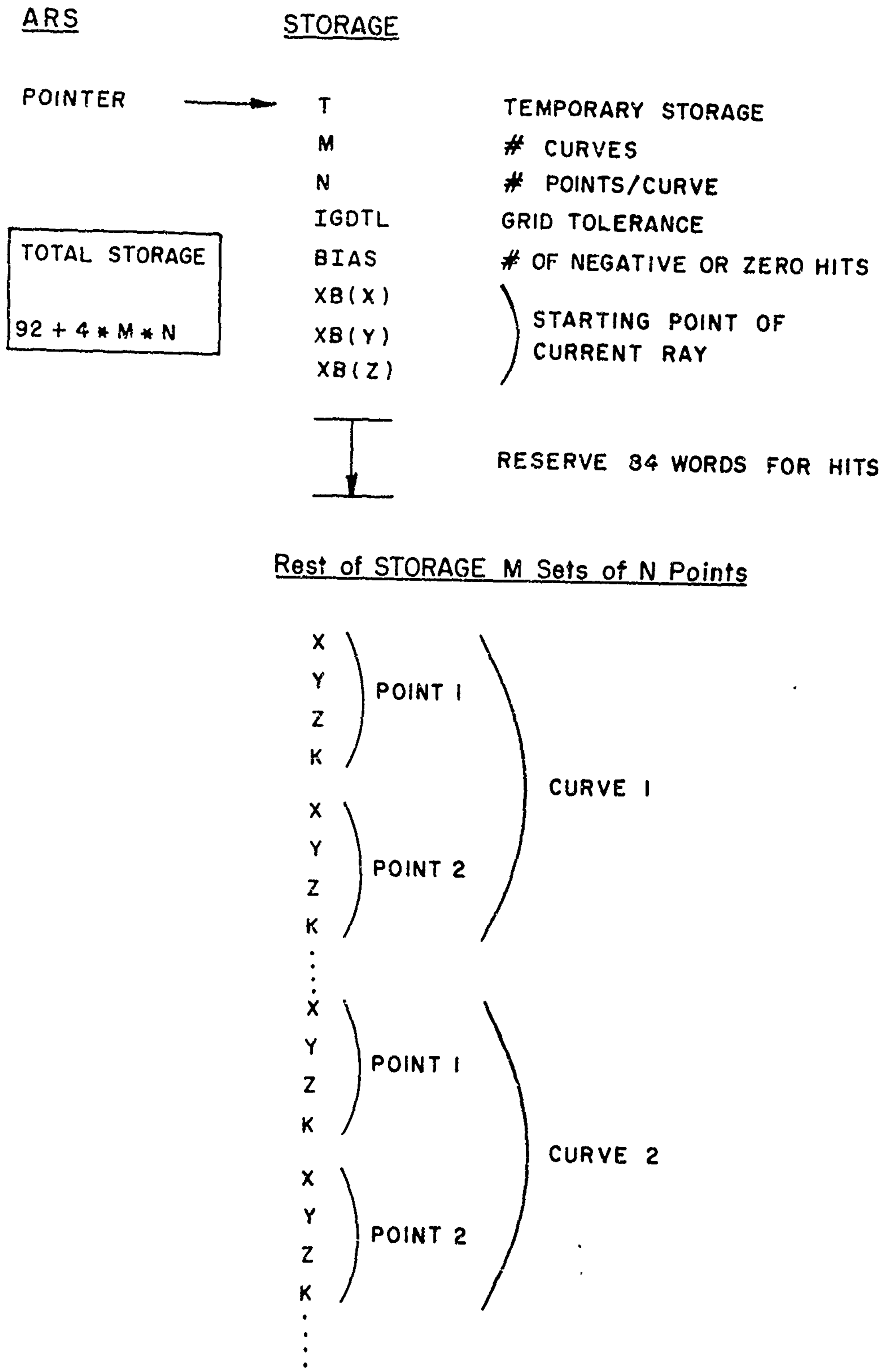


Figure 3.4 Storage for the ARS

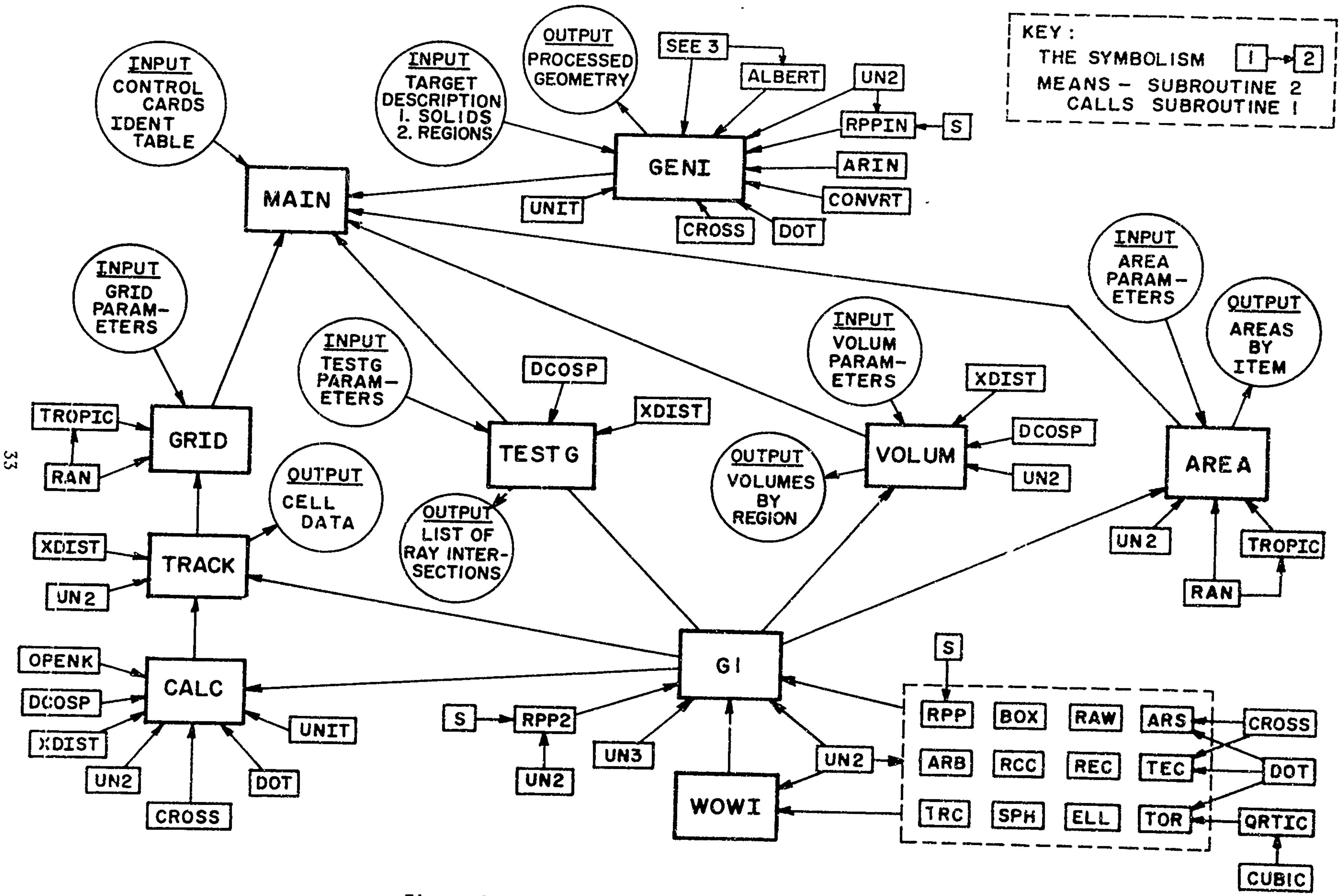


Figure 3.5 Interrelationships of MAGIC Routines

Table 3.2 presents the results of the various computer runs.

TABLE 3.2 COMPUTER SYSTEM TIME REQUIREMENTS

System	Location	Time (in minutes)	Ratio
BRLESC I	ARDC, APG, Md	133	1
BRLESC II	ARDC, APG, Md	55*	.41
CDC 6600	New York Univ	15	.11

*Using the on-line printing capability instead of "dumping" onto tape for off-line tabulation.

3.2 Recent Activity with SAM-C at NEL. (Presentation by Wayne Coleman)

The recent activity with SAM-C at NEL falls into one of three categories: recent calculations completed using SAM-C, completed corrections and improvements to the SAM-C code, and plans for the future.

3.2.1 Recent Calculations. This category is divided into three subtopics:

- Calculation of the energy dependent gamma flux at 3 feet above an infinite Co-60 "fallout" field.
- Calculation of the energy dependent and total neutron fluence at various positions within the Ralph J. Truex (Tandem Van de Graff) accelerator at the Nuclear Effects Laboratory (Edgewood Arsenal).
- Calculation of the energy dependent neutron fluence in an environment simulating that used in Operation HENRE.

a) Infinite Fallout. Although these calculations did not constitute a comprehensive test of the geometric capabilities of SAM-C, very good agreement with the known solution of this problem was obtained.

b) Accelerator. These calculations include the most complex geometries that have been simulated to date at NEL and were included for that reason. The physical results unfortunately cannot be compared directly to any results of experiments or any other calculations.

c) HENRE. This problem demonstrates how, under certain restrictions, ad hoc changes can be made to produce results for source angular distributions other than 4π-isotropic or monodirectional. The results compared favorably with unfolded flux spectra from experimental activation measurements when the SAM-C results were used as an "input guess spectrum" in the unfolding calculations.

3.2.2 Corrections/Improvements. Corrections are indicated by "C" while changes that are more in the category of improvements are indicated by "CI." C/CI's are by order of their appearance in the program.

a) Variable Dimensioning (CI). On machines that assign priority based on memory requirements, adjustable sizes of blank common and labeled common CROSA are an operational necessity. Variable dimensioning in SAM-C is accomplished by creating an artificial "main" program in which dimensioning is accomplished.

b) SEEK (C). Change E = 1 to I = 1 in TUNC and MONTE.

c) SOUCAL (C). Set "KKMAX = K-1" between FORTRAN statement numbers (S.N.) 780 and 925.

d) CARLO (C). The calculation of flux-at-a-point following an inelastic collision is incorrect. See the August RSIC Newsletter (No. 57) for details.

e) SOUPIC (C/CI). Volume source additions may be made by modifying the coding shortly after FORTRAN S.N. 800.

f) ARB (C). T was inadvertently used as a variable name to represent time in a labeled common and temporary storage in the routine (S.N. 50 and 50 + 1).

g) FAP (CI). The coding for identifying point flux contributions by region appears here.

h) FAP (C). To correctly calculate flux-at-a-point add COMMON/LSU/LSURF.

i) GE (C). (1) The scattering problem look-up for neutrons was referencing the wrong area of common for neutron anisotropic scattering; cf., the RSIC version. (2) The third argument in the call to SEEK (S.N. 185) should be 10 and not 11. (3) Format 106 ends incorrectly - replace "10" with any desired E- or F-type format.

j) SUBED (C). Change "NRMAX" to "NDET" at S.N. 121.

k) SOUCAL (C). Change Format 402 (not all versions). (CI) finally changes to compute statistics on the total flux or fluence for flux-at-a-point would be desirable.

3.2.3 Improvements in Progress. Modifications to calculate flux at a point as a function of angle or direction as well as energy are well underway at NEL.

3.2.4 Planned Improvements. Neutron cross section representation is earmarked for extensive study. Key inputs or approaches to this subject include UNC-SAM-3, an ENDF/B cross-section processor, and a thorough examination of the representation of neutron elastic, angular scattering distributions. Total, elastic, and non-elastic cross section data are also expected to be involved.

3.3 Coordination of MAGIC and SAM-C.

Both MAGIC and SAM-C process card-image target description data and store the results in the MASTER/ASTER array. Both can compute volumes. If the conventional component/space code table has been created, a trivial program (Program COMPAS) exists to convert this data to a region/chemical composition assignment table. The following two sections describe the changes required so that target descriptions can be utilized by either MAGIC or SAM on a wide variety of computational equipment with a minimum of difficulty. The goal, of course, is to permit the creation of a library of target descriptions which can serve two purposes: they can reduce duplication of effort and they can lend insight into what a given agency considers an adequate degree of descriptive detail.

3.3.1 Discussion. This category is divided into two subtopics: a description of the proposed tape's contents and a discussion of how the tape should be created.

a) Description of the Tape Contents. The first step is to identify the data available for the library tape; these data are displayed in Table 3.3.

TABLE 3.3 TARGET DESCRIPTION DATA AVAILABLE

MAGIC	SAM-C
"Processed" (GENI) Target	Output Data (MASTER-ASTER*)
Region Identification Table	Composition Assignment Table
Volumes (Optional)	Chemical Composition Definitions
Region Weights (Optional)	"Processed" (BAND/BEDIT) Cross Section Data (MASTER-ASTER)
Moment of Inertia (Optional)	Volumes (ASTER)
Target Description Title	
"Raw" (Card-Image) Target Description Solid & Region Data	

*The SAM-C program stores these data in a location different from that used by MAGIC.

TABLE 3.4 LIBRARY TAPE CONTENTS: PARTS 1 AND 2

"Block" 1. <u>Identification</u> (80A1)

Target Description Title

"Block" 2. <u>Table of Contents</u>

(1) Solid/Region Table Format (cc 1-5)

0 : GENI Input form

≠ 0 : GENI Output form

For (2) through (8), 0 means the category was not included while a non-zero entry indicates that the data was included

(2) Region Identification Table (cc 6 - 10)

(3) Composition Assignment Table (cc 11 - 15)

(4) Volumes (cc 16 - 20)

(5) Chemical Composition Data (cc 21 - 25)

(6) Region Total Weights (cc 26 - 30)

(7) "Organized" Cross-Section Data (cc 31 - 35)

(8) Moment of Inertia Data (cc 36 - 40)

(9)-(10) (Spares) (cc 41 - 50)

cc 51-52 Unit Systems (Examples: IP for inches, pounds (& seconds), CG for centimeters, grams, seconds, <u>etc.</u>)

cc 53 Coordinate System "Handedness" L = left, R = right

cc 54-80 Location of Geometric Origin with respect to the Reference Origin (e.g., for "tanks" the reference origin is frequently the intersection of the turret datum line and the vehicle centerline) (3E9.2)

The second step is to determine the data to be loaded and in what order. Clearly, the target description title plus some type of flagging to indicate the data categories available should appear near the start of the tape to minimize the time spent in identifying the tape contents. It is therefore proposed that the first tape "block" consist of ten flag words as described in Table 3.4. Beyond these two points, any data that describe the target are suitable for inclusion on the tape.

b) Approach. It was the consensus of the program users that, while all library tapes should be in BCD format for transmittal, the basic target description solid and region data should be in card-image rather than in "processed" (GENI output) form; except for a few installations, the computer time spent in reprocessing the "raw" data is negligible compared with the time that would be used to convert the data into the form required by those of a different installation. It was also agreed that the raw data approach would place the least number of restrictions on the internal operating procedures of any given MAGIC or SAM-C program user.

3.3.2 Program Changes. Some coding changes of a very minor nature will be required. The routines affected are:

a) MAGIC. The main program plus GENI, VOLUM, the moment of inertia, and the vulnerable area routines will require modification.

b) SAM-C. TUNC, GENI, DR, and VOLUM are involved. In SAM-C, VOLUM will generally only require an additional output statement.

4. DEFINITION OF MAGIC AND SAM-C; CREATION OF SOURCE DECKS

This provided the first opportunity of the conference for the conferees to determine the course of action to be followed. The two sections that follow present the consensus achieved by the conferees in defining what the capabilities of the two programs should be and in determining how these capabilities should be achieved.

4.1 MAGIC.

The following sections represent the major areas discussed at the conference together with the results of these discussions.

4.1.1 Standard Version. A consensus was achieved in four areas:

a) Input. The input to MAGIC will consist of

- RPP Data,
- Solid Description Data, and
- Region Description Data.

b) Subprograms. The subprograms are characterized as "geometry processing" (including some testing):

- GENI,
- ALBERT,
- RPPIN, and
- ARIN,

or "ray tracking" (but not in the sense of GRID which is considered a "driver routine"):

- G1,
- WOWI/RPP2,
- RPP/body routines + TOR, ARS & TEC, and
- Auxiliary body routines such as QRTIC, UNIT, etc.

c) Program Features.

- No packing.
- It should be possible to use an RPP to subdivide the target, itself.
- Drop TESTG.
- Drop FLOCON and DIGCON.
- Output the processed geometry which should consist of titling data, the geometry data, and the functional identification table.

d) Tests. It was agreed that TESTG as a random but supposedly complete test of the description is inefficient and should be dropped; in its place, a driver routine of interest - such as GRID - should be used. Input testing was considered valid and at least the following tests should be available:

- Legitimacy of solid names.
- Vector perpendicularity for boxes, RAW's, and the REC.
- Equal radii in the TRC.
- Region checking (on an optional basis).
- "4-points-in-a-plane" in the ARB.
- Degenerate plane in the ARB.

- Proper ordering of RPP input.
- Proper structure creation by contiguous RPP's (since the structure that would enclose all RPP's must be in the shape of an RPP).

4.1.2 Ad Hoc Problems. Although there was not enough time for the formal formation of working groups to solve ad hoc problems, the following problems were defined for solution by any interested groups or individuals.

- The creation of a technique for the arbitrary designation of solids to have the special characteristics currently displayed by the RPP.
- The identification of methodological differences in the routines that form MAGIC between versions held by the several agencies using MAGIC.
- The establishment of a methodology for creating "library" routines (for such configurations as wheels, people, etc.) which can be processed as a unit rather than a set of distinct subsolids.
- The establishment of a uniform system of flags for transmittal of the processed geometry.

4.2 SAM-C.

SAM-C was not the subject of serious discussion until late in the afternoon of the second day. Because the SAM-C program is so large and complex, our attitude toward it is considerably different than our attitude toward MAGIC. In the first place (and of overriding importance), there are few computing facilities capable of efficiently executing the SAM-C programs; secondly, a substantial amount of understanding of the code and the manner in which it attempts to solve problems, and of the problems themselves, is required to achieve any sort of successful solution. Keeping these points in mind, the following sections present the consensus reached.

4.2.1 Standard Version. For the time being at least, the standard version of SAM-C will be that obtainable from RSIC at Oak Ridge. In brief, this version features Combinatorial Geometry inputs identical to those of Standard MAGIC with one important difference: triplet and scalar inputs will be allowed.

4.2.2 Ad Hoc Problems. Although time was again insufficient, the following study/problem areas were defined:

- The abolishment of computer word packing to the greatest practical extent.

- The incorporation of ENDF/B cross sections - preferably using a noncommon energy mesh.
- Bonafide time dependence: time dependence currently assumes the source is a separable function of time.
- Simplification of input preparation.

5. CREATION OF BENCHMARK PROBLEMS

Although time constraints precluded the actual creation of test problem input, it was possible to indicate what the benchmark problems should include.

5.1 MAGIC.

The test problem input should meet five conditions:

- Use only the solids generally available; place the three new solids at the end of the solid table for possible deletion.
- Use all three region operator symbols (+, -, OR).
- Use 1 RPP to enclose the target (Wright-Patterson AFB will use a BOX).
- Employ solids in such a way that they present overlaps and contiguities.
- Similarly, ensure that at least one situation arises where more than one following region has the same functional identification code as the region in front (to ensure that the correct normal thickness is being computed).

In addition, it is desirable to introduce a few deliberate errors to ensure that internal error checks are operative.

5.2 SAM-C.

It was decided that more than one benchmark problem should be created to enable checking the modeling of the physical solution and the execution of the code. Two benchmark problems were agreed upon:

- The "infinite" fallout problem (RSIC Benchmark Problem No. 4), and
- AFWL "Rocket" Geometry.

Physical/code input for these problems is presented in Appendix C.

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APPENDIX A. MAGIC/SAM-C CONFERENCE PARTICIPANTS

	Name	Agency	City, State
1.	Robert E. Barnas	Picatinny Arsenal	Dover, New Jersey
2.	Sue Gibson	AFATL	Eglin AFB, Florida
3.	Larry Bain	AMSAA (Methodology)	APG, Md.
4.	Matthew J. Reisinger	BRL (VL)	APG, Md.
5.	John A. Zook	AMSAA (ASA)	APG, Md.
6.	Thomas Jankunis	Picatinny Arsenal	Dover, New Jersey
7.	Jesse W. Brewer	AMSAA (ASA)	APG, Md.
8.	Donald W. Mowrer	BRL (VL)	APG, Md.
9.	Robert E. Walther	BRL (VL)	APG, Md.
10.	Lewis G. Gotze	BRL (VL)	APG, Md.
11.	John Saarmann	Picatinny Arsenal	Dover, New Jersey
12.	Michael J. Paul	AFWL (WLRAS)	Albuquerque, N. M.
13.	A. Kris Widdison	AFWL (WLDC-PD)	Albuquerque, N. M.
14.	Kenneth Richer	BRL (S&PL)	APG, Md.
15.	George H. Connor, Jr.	BRL (NEL)	Edgewood Arsenal, Md.
16.	Robert W. Roussin	ORNL - RSIC	Oak Ridge, Tennessee
17.	Wayne A. Coleman	BRL (NEL)	Edgewood Arsenal, Md.
18.	W. B. Beverly	BRL (NEL)	Edgewood Arsenal, Md.
19.	Janet Lacetera	BRL (NEL)	Edgewood Arsenal, Md.
20.	Richard Saum	BRL (NEL)	Edgewood Arsenal, Md.
21.	William Ralph	NWL	Dahlgren, Virginia
22.	Robert E. Gray	NWL	Dahlgren, Virginia
23.	Roy R. Hilbrand	ASD	Dayton, Ohio
24.	Gerald Bennett	ASD	Wright-Patterson AFB, Ohio
25.	Robert Kesselman	Picatinny Arsenal	Dover, New Jersey
26.	Joe Burgio	Picatinny Arsenal	Dover, New Jersey
27.	Norman S. Banks	BRL (TBL)	APG, Md.
28.	Robert Lake	AMSAA (ASA)	APG, Md.
29.	Ronald Marking	AMSAA (ASA)	APG, Md.

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APPENDIX B MAGI REPORT MR 6902 (ABRIDGED)

CONTENTS

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B.1 ORGANIZATION OF THE NEW MAGIC PROGRAM

The general organization of the MAGIC program remains as before. The following subroutines were changed: CALC, GENI, G1, WOWI. The following routines were added: TEC, TOR, ARS, DOT, CROSS, UNIT, QRTIC, CUBIC, ARIN. A description of the changes to existing subroutines and the new subroutines follows:

B.1.1 Changes to CALC.

CALC - Statement 18 - Change the computed "go to" by adding locations for computing the normals in the new bodies.

Statement 500

This section computes the normals to the elliptic cone. If the point of intersection was the top or bottom the normal is the same as the normal received as input. If the point is on the side of the cone the following equation is used.

$$\text{(1)} \qquad \overline{W}_B = \frac{(\ )_1}{\tau} \overline{A}^* - \frac{\overline{H}\cdot\overline{A}^*}{\overline{H}\cdot\overline{\eta}} \overline{\eta} + \frac{(\ )_2}{1} K^* - \frac{\overline{H}\cdot\overline{K}^*}{\overline{H}\ \overline{\eta}} \overline{\eta} - m(r_4 - r_2) \frac{\overline{\eta}}{\overline{H}\cdot\overline{\eta}} ,$$

where $(\ )_1 = (\overline{X} - \frac{\overline{X}\cdot\overline{\eta}}{\overline{H}\cdot\overline{\eta}} \overline{H} - \overline{V} + \frac{\overline{V}\cdot\overline{\eta}}{\overline{H}\cdot\overline{\eta}} \overline{H}) \ .\overline{A}^*$, and

$(\ )_2 = (\ )_1$ with $\overline{K}^*$ instead of $\overline{A}^*$

The terms are defined as follows:

$\overline{H}$ = height vector of cone,

$\overline{A}^*$ = unit vector - direction of major axis,

$\overline{K}^*$ = unit vector - direction of minor axis,

τ = ratio of major to minor axis squared,

$$m = \frac{(\overline{X}-\overline{V})}{\overline{H}\cdot\overline{\eta}} \cdot\overline{\eta}\ (r_4 - r_2) + r_2$$

$\overline{X}$ = point of intersection,

$\overline{\eta}$ = normal to cutting plane, and

$\overline{V}$ = center of base ellipse.

The derivation is shown on the following page.

The equation for the ellipse parallel to the base ellipse and through the point of intersection $\overline{X}$ is

(2) $$\frac{((\overline{X}-\overline{V}-\gamma\overline{H})\cdot\overline{A}^*)^2}{\tau m^2} + \frac{((\overline{X}-\overline{V}-\gamma\overline{H})\cdot\overline{K}^*)^2}{m^2} = 1 ,$$

(3) $$\gamma = \frac{(\overline{X}-\overline{V})\cdot n}{\overline{H}\cdot\overline{n}} , \text{ and}$$

(4) $$m = \gamma r_4 + (1-\gamma)r_2 \cdot$$

NOTE: γ and τ and $\overline{X}$ are known.

Expanding we get

$$0 = \left(\frac{\overline{X}-\frac{\overline{X}\cdot\overline{n}}{\overline{H}\cdot\overline{n}}\overline{H}-\overline{V}\frac{\overline{V}\cdot\overline{n}}{\overline{H}\cdot\overline{n}}\overline{H}}{\tau}\cdot\overline{A}^*\right)^2 + \left(\frac{\overline{X}-\frac{\overline{X}\cdot\overline{n}}{\overline{H}\cdot\overline{n}}\overline{H}-\overline{V}\frac{\overline{V}\cdot\overline{n}}{\overline{H}\cdot\overline{n}}\overline{H}}{1}.\overline{K}^*\right)^2 - m^2.$$

Differentiating, with respect to X, Y, and Z, and taking the unit vector of the result gives us Equation (1).

Statement 550

The section computes the normal to the torus at the point of intersection. The equation used is:

(1) $$\overline{W}_B = \frac{\overline{X} - (\overline{C}+r_1\overline{d}^*)}{r_2} .$$

where $\overline{X}$ is point of intersection,

$\overline{C}$ is center of torus,

r_1 is distance from center to the locus of mid-point of circular cross section

$\overline{d}^*$ = unit $\{\overline{d}\}$,

$\overline{d} = \{\overline{n}X(\overline{X}-\overline{c})\}\ X\ \overline{n}$ = direction of r_1 in plane, and

r_2 is radius of circular cross section.

Statement 575

This coding examines the intersection with the arbitrary surface (XI), selects the proper normal from those left in the MASTER/ASTER array by ARS, and places this normal into WB. See write-up of ARS routine to determine details of computation.

B.1.2 Changes to GENI.

GENI - Change all computed GO TO's involving body type to add three new bodies. Add conversion routines to store TORUS and Elliptic Cone data in either floating point or triplet and scalar form. Add coding to store Arbitrary Surface in floating point format. (Subroutine ARIN).

B.1.3 Changes to G1.

G1 - For a new ray, processing remains the same, except for changing the computed GO TO to check the new bodies. For continuation of a ray, a check is made for TORUS or ARBITRARY SURFACE. If the body is neither of these, the previously computed value is used. However, if the body type is one of these a check is made to see if the distance we have traveled is greater than ROUT. If it is not then we use the existing values for RIN and ROUT. Otherwise, we reenter the body routine and compute the next RIN/ROUT set (if any).

B.1.4 Changes to WOWI.

WOWI - The same changes as were made to G1 apply here. A description of the new routines follow.

B.1.5 Addition of TEC.

TEC - Body routine for truncated elliptic cone. Computes RIN, ROUT, LRI, LRO for intersection of ray and cone. Uses DOT, CROSS, and SQRT.

B.1.6 Addition of TOR.

TOR - Body routine for torus. Computes RIN and ROUT; LRI and LRO are 1. If four roots are found it selects the first pair greater than DIST as RIN and ROUT. Uses QRTIC and CUBIC.

B.1.7 Addition of QRTIC.

QRTIC (A,B,C) - Solves quartic polynomial equation with unit leading coefficient, $X^4 + C_1X^3 + C_2X^2 + C_3X + C_4 = 0$.

Method is from J. V. Uspensky, "Theory of Equations," pp 94-95. Used by TOR.

A = Array of coefficients

B = Array of roots

C = Number of real roots

B.1.8 Addition of CUBIC.

CUBIC (A,B,C) - Solves cubic polynomial equation with unit leading coefficient, $X^3 + C_1X^2 + C_2X + C_3 = 0$.

Method is from J. V. Uspensky, "Theory of Equations," pp 84-93. Used by TOR.

A = Array of coefficients

B = Array of roots

C = Number of real roots

B.1.9 Addition of DOT.

DOT (A,B) - Computes the dot product of vectors $\overline{A}$ and $\overline{B}$.

B.1.10 Addition of CROSS.

CROSS (A,B,C) - Computes the cross product of vectors $\overline{B}$ and $\overline{C}$ and stores result in vector $\overline{A}$.

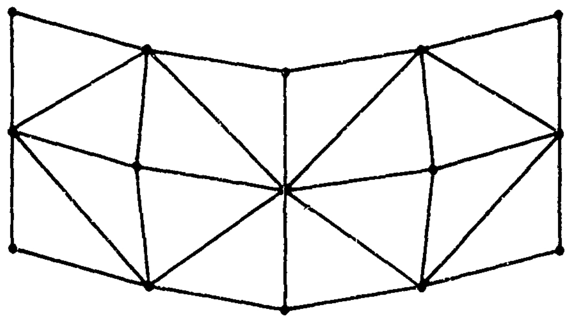
B.1.11 Addition of UNIT.

UNIT (A) - Computes unit vector of $\overline{A}$ and stores back in $\overline{A}$.

B.1.12 Addition of ARS.

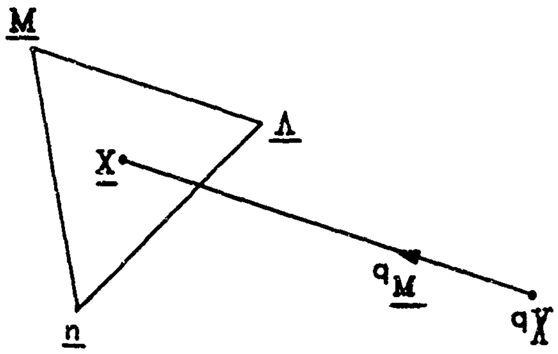
ARS - Body routine for arbitrary surface. Computes RIN, ROUT. LRI and LRO are always 1.

For the purposes of determining intersections and normals, the routine constructs a series of triangles, as below, and utilizes these triangles to determine intersections and the associated normals.



When entered for a new ray, the intersections are stored in the MASTER/ASTER array, together with the normals at these points. Upon reentry for the same ray, the RIN, ROUT pair appropriate to DIST are selected and returned to the calling routine.

To determine the intersection and normals, the ray is tested against each triangle for which at least one point of the triangle lies within the projection of the grid square. The calculation is done as follows:



By the rules of convex figures in 2-space, for $\overline{x}$ within the triangle, there must exist α,β,γ such that

(1) $$\alpha\overline{u} + \beta\overline{v} + \gamma\overline{w} = \overline{x} = \overline{x}_b + s\overline{w}_b$$

$$\alpha + \beta + \gamma = 1; \ \alpha,\beta,\gamma > 0 \ ;$$

then

$$\gamma = 1 - \alpha - \beta \ ,$$

(2) $$\alpha\overline{u} + \beta\overline{v} + (1-\alpha-\beta)\overline{w} = \overline{x}_b + s\overline{w}_b \ , \text{ and}$$

(3) $$\alpha(\overline{u}-\overline{w}) + \beta(\overline{v}-\overline{w}) - s\overline{w}_b = \overline{x}_b - \overline{w} \ .$$

These are simply three equations in three unknowns.

Using determinants to solve this set of simultaneous equations we obtain α,β,γ, and s. After verifying that $\alpha + \beta + \gamma = 1$ and $\alpha,\beta,\gamma \geq 0$, we record the s value as well as a unit normal to the triangle. If α,β,γ fail to meet these requirements, the ray missed this triangle.

After performing the calculations for each triangle, the resulting s values and normals are placed in the MASTER/ASTER array. Sufficient space is provided for up to ten pairs of RIN and ROUT. The variable DIST is used to determine which pair of RIN and ROUT should be returned to the calling routine.

B.2 DESCRIPTION OF INPUT PARAMETERS

B.2.1 Truncated Elliptic Cone.

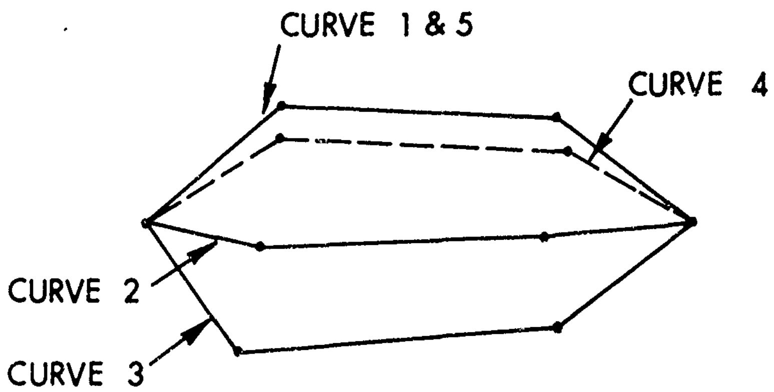
Specify a vertex V at the center of the larger ellipse, the height vector H, expressed in terms of its x,y,z components, the direction of the major axis A, the direction of the normal N, and three scalars - R1, the length of the major axis of the larger ellipse, R2, the length of the minor axis of the larger ellipse, and P, the ratio of the larger to the smaller ellipse.

B.2.2 Torus.

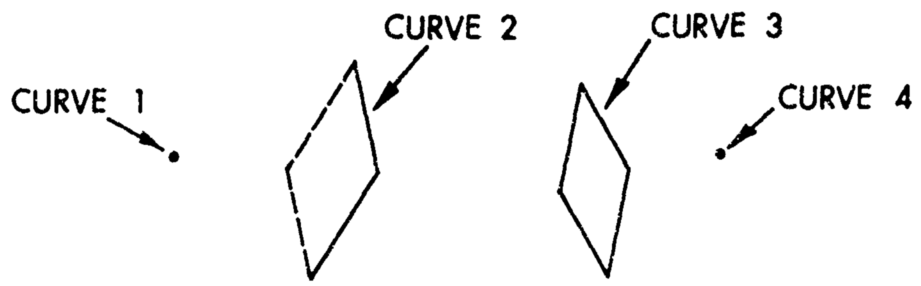
Specify a vertex V at the center of the torus, the normal to the plane in which the locus of mid-points of the circular cross sections lie, N, and two scalars - R1, the distance from the center to the mid-point of circular cross section, and R2, the radius of circular cross section.

B.2.3 Arbitrary Surface.

Specify the number of curves (M) to be specified and the number of points (N) which will be specified on each curve. A surface is constructed between curve 1 and curve 2, between curve 2 and curve 3, etc. The user must be careful that the described figure is closed and solid.



In the previous example, the first and last point of each curve is identical, and the first curve is identical to the last, and one can see that the figure is solid.



In this example, curve 1 consists of the same point repeated five times, curve 2 of five points (the first and fifth point being the same), curve 3 is defined similar to curve 2, and curve 4 similar to curve 1. It can also be seen that this figure is solid.

To further illustrate this figure, note in the figure that

M = 4	N = 5
Curve 1	pt. A_1
	B_1
	C_1
	D_1
	E_1
Curve 2	pt. A_2
	B_2
	C_2
	D_2
	E_2

M = 4	N = 5	
Curve 3	pt.	A_3
		B_3
		C_3
		D_3
		E_3
Curve 4	pt.	A_4
		B_4
		C_4
		D_4
		E_4

is identically the same figure as

M = 5	N = 4	
Curve 1	pt.	A_1
		A_2
		A_3
		A_4
Curve 2	pt.	B_1
		B_2
		B_3
		B_4
Curve 3	pt.	C_1
		C_2
		C_3
		C_4

M = 5	N = 4
Curve 4	pt. D_1
	D_2
	D_3
	D_4
Curve 5	pt. E_1
	E_2
	E_3
	E_4

The user should use this isomorphism as a check on whether the figure defined is truly closed and solid.

B.3 BODY CARDS

The data describing each body must be input using the format described in Table B.1. This table is similar to Table 3.1 (page 37 in the original document) and should be viewed as an extension of that table.

B.4 NEW VARIABLES IN COMMON

Variable Name	Labeled Common	Definition
IGRID	DAVIS	The grid square of the origin of the current ray (XBS)
LOOP	DAVIS	Set by G1 upon entry to a body routine to reflect ray number of last ray fired at the body.
INORM	DAVIS	Set by G1 to indicate if the ray is being fired normal to a surface (normal is computed by CALC)

B.5 NEW ERROR STOPS

Routine	Message	Explanation
CALC	ARS DID NOT FIND NORMAL	Data in MASTER/ASTER Array inconsistent. Some routine has destroyed portions of MASTER/ASTER.

TABLE B.1

Body Type	3 Letter ID	11-20	21-30	31-40	41-50	51-60	61-70	No. of Cards Needed
Truncated Elliptic Cone	TEC	V_x	V_y	V_z	H_x	H_y	H_z	1 of 3
		N_X^*	N_Y^*	N_Z^*	A_X^*	A_Y^*	A_Z^*	2 of 3
		R1	R2	P				3 of 3
Torus	TOR	V_x	V_y	V_z	N_x	N_y	N_z	1 of 2
		R1	R2					2 of 2
Arbitrary Curved Surface	ARS							
		M	N					1 of n
		X(1,1)	Y(1,1)	Z(1,1)	X(1,2)	Y(1,2)	Z(1,2)	3 of n
		⋮						
		X(1,N)	Y(1,N)	Z(1,N)				
		X(2,1)						N+2 of n
		⋮						
		X(M,1)						
		⋮						
		X(M,N)	Y(M,N)	Z(M,N)				

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APPENDIX C

SAM-C BENCHMARK PROBLEM INPUT

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C.1 SHIELDING BENCHMARK PROBLEM 4.0 (Abridged)

Gamma-Ray Dose Above a
Plane Source of ^{60}Co on an
Air/Ground Interface

Original Submitted by:

Charles W. Garrett
Radiation Research Associates, Inc.*
8404 Westmont Court
Bethesda, Maryland 20034

2 December 1968

Accepted by BPG:

December, 1968

This Abridged Version prepared September, 1969

*Corporate offices located in Fort Worth, Texas.

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"1. INTRODUCTION

The dose rate three feet above an air/ground interface contaminated with gamma-ray emitting isotopes is often used as a basic normalizing parameter in fallout radiation environment studies and fallout shielding methodology. For example, the dose rate three feet above a fallout field is the basic quantity to which geometric and barrier factors are applied in the currently-used "Engineering Method" (References 1,2*). This technique predicts shield effectiveness in fallout situations. There have been experimental measurements of the dose above fallout fields in several weapons test (References 3,4) and several calculations (References 1,5) of the same quantity have been made.

"However, because of the obvious difficulties associated with measurements of actual fallout, many studies have concerned themselves with the radiation environment above interface planes contaminated with a single isotope. In particular, ^{137}Cs and ^{60}Co have been extensively used in these investigations.

"2. THE AIR/GROUND INTERFACE PROBLEM

This benchmark problem is concerned with the theoretical computation of various quantities above an ideal air/ground interface uniformly contaminated with ^{60}Co. A discussion of experimental results is also included for comparative purposes.

"2.1 Problem Geometry

Figure C1 illustrates the geometry for the theoretical benchmark. A receiver (detector) point is located three feet above the air/ground interface which is assumed to be smooth and infinite in extent. ^{60}Co is uniformly distributed on the interface. Although ^{60}Co emits one 1.17 MeV photon and one 1.33 MeV photon per disintegration, many studies assume an average photon energy of 1.25 MeV. This assumption introduces negligible errors, and the benchmark data are normalized to a source strength of one 1.25 MeV photon emitted isotropically per cm^2 of interface area per second. [For SAM C the photon energy of 1.33 MeV was used.]

*References are not included in this abridged version. Ed.

BASED ON ORNL-DWG 69-2121 IN SHIELDING BENCHMARK PROBLEM 4.0.

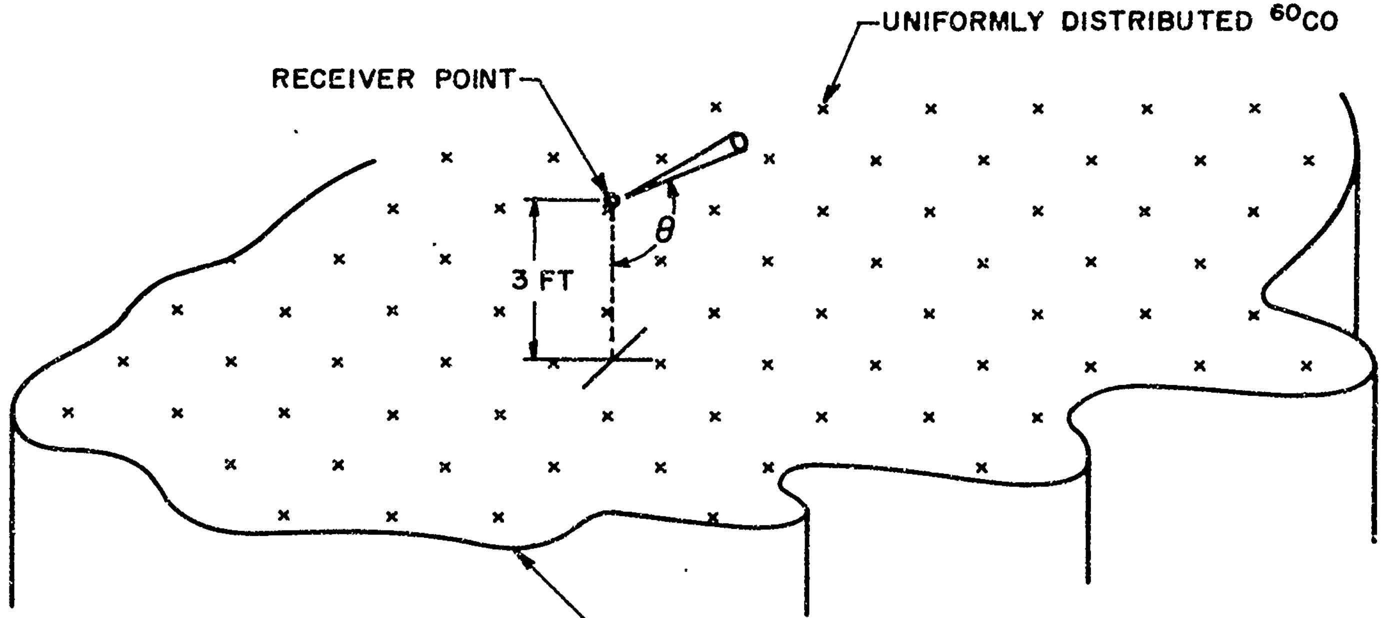


Figure CI. Air Over Ground Geometry

"Table I lists the constituents of the air and ground. The air density is 1.29×10^{-3} g/cm^3; the ground is assumed to have a composition similar to Nevada Test Site soil (Reference 6).

TABLE I AIR AND GROUND COMPOSITIONS

	Element	Atomic Concentration (atoms/cm^3)
Air*	Nitrogen	4.19×10^{19}
	Oxygen	1.13×10^{19}
	Argon	2.53×10^{17}
Ground	Hydrogen	8.55×10^{21}
	Oxygen	2.27×10^{22}
	Aluminum	2.01×10^{21}
	Silicon	9.53×10^{21}

*There has been a slight change in format. Ed.

"2.2 Quantities Calculated

Quantities calculated at the receiver point are: (1) the total kerma rate,** T, in air; (2) the kerma rate,** D, in air from uncollided photons; (3) the dose buildup factor, B; and (4) the differential angle and energy distribution of the number flux density, $\Phi(E,\theta)$, where θ is the receiver polar angle (Figure C1). The number flux density energy spectrum, I(E), [is the only quantity calculated by SAM C] ...."[calculated results appear in Tabular Form in Table IV and in graphical form in Figure C2].

** For the photon energies and geometry of this problem, the numerical difference between kerma rate and absorbed dose rate in air is small and can be ignored. Other studies quote kerma rate in tissue, and adjustments should be made to compare the results of such studies with this benchmark.

TABLE IV* SCATTERED PHOTON KERMA RATES THREE FEET ABOVE AN INFINITE ^{60}Co CONTAMINATED PLANE

Energy Interval (MeV)	K(E) (ergs=cm^2/g)	Flux Density (Photons/cm^2-sec)	Kerma Rate (ergs/g-sec)
.02 - .03	1.06(-8)	1.47(-3)	1.56(-11)
.03 - .04	5.28(-9)	1.55(-2)	8.18(-11)
.04 - .06	3.06(-9)	9.32(-2)	2.85(-10)
.06 - .10	3.06(-9)	2.10(-1)	6.43(-10)
.10 - .18	5.56(-9)	2.99(-1)	1.66(- 9)
.18 - .30	1.08(-8)	2.94(-1)	3.18(- 9)
.30 - .50	1.89(-8)	1.93(-1)	3.65(- 9)
.50 - .75	2.92(-8)	1.08(-1)	3.15(- 9)
.75 - 1.00	3.97(-8)	8.31(-2)	3.30(- 9)
1.00 - 1.25	5.00(-8)	1.69(-1)	8.45(- 9)
	TOTALS:	1.47(0)	2.44(-8)

NOTE: Read 1.06(-8) as 1.06×10^{-8}

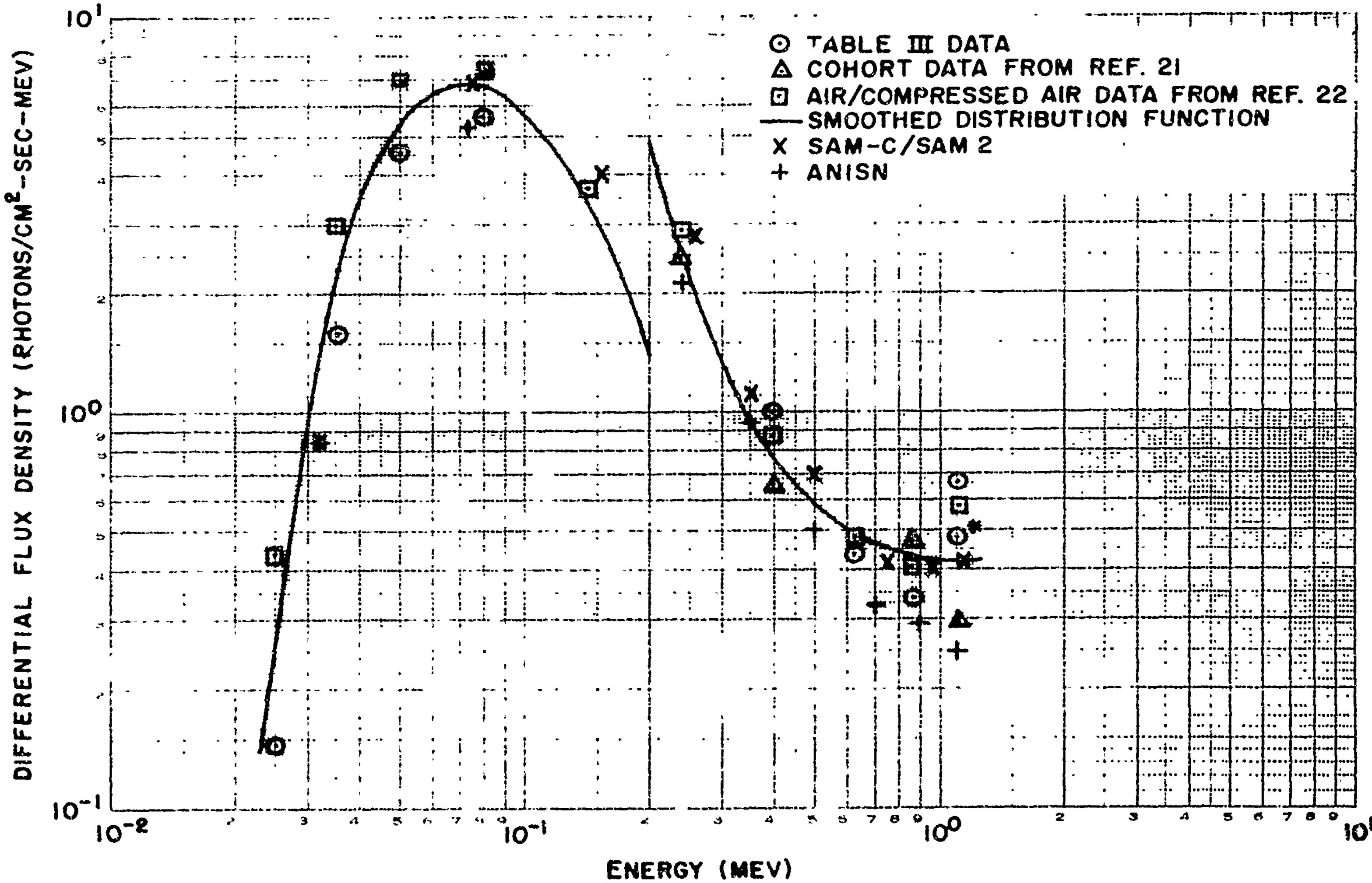
*Tables II and III have been omitted in this version. Ed.

[Results]

"On Figure C2 (Figure 6 in original document), differential scattered photon flux density energy spectra are plotted for the two cases shown on Figure 4,* along with data from a 7,000 history air/ground COHORT Monte Carlo study by French (Reference 21). Although neither the Table III or the COHORT data was smoothed in any way prior to constructing Figure 5, adjustments had to be made in the three lowest energy groups of the air/compressed air case. In that case, a severe fluctuation (visible on Figure 4) occurred in the 30° - 40° angle interval in each of the three energy bins. The solid curve on Figure 5 was obtained by intuitively smoothing all available data and, in addition, making use of two known facts; the magnitude of the discontinuity at the first scattering cutoff energy (0.212 MeV) and the value at the source energy (1.25 MeV). As described in Reference 24, these values can be easily and accurately computed. The value computed for the energy spectrum at 1.25 MeV is 0.43 photons/cm^2-sec-MeV, and the magnitude of the discontinuity is 3.40 photons/cm^2-sec-MeV.

*Figures 2, 3, 4, and 5 of original document have been omitted. Ed.

BASED ON ORNL-DWG 69-3429 IN SHIELDING BENCHMARK PROBLEM 4.0



* Plotted Incorrectly on Original.

Figure C2 Monte Carlo Scattered Flux Density Energy Spectra.

"In conclusion, it is to be emphasized that the differential data and smoothed curves presented on Figures 3, 4, and 5 contain rather large uncertainties, and must not be taken as absolute standards...."

C.2 AIR FORCE WEAPON LAB "ROCKET" GEOMETRY

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FORTRAN CODING FORM AND DATA SHEET

PROGRAM SAMC GEOMETRY INPUT

PROGRAMMER A KRIS WIDDISON

```
   TEST GEØMETRY --  INCLUDES ALL TYPES ØF SØLIDS
         1           1          1          11          11
      -250 0       150 0      -50 0       450 0                  0       [illegible]
       -50 0       250 0      450 0
         2.0
*  RAW           0 0        0 0        0.0        0 0        0 0        20 0
                 0 0       60.0        0.0      100 0        0 0         0 0
*  BØX           0.0        0 0        0 0        0 0        0 0        20 0
                 0 0       60 0        0 0      -80 0        0 0         0 0
*  REC        -100 0       30 0        0.0        0.0        0 0        20 0
                 0 0       15 0        0 0       10 0        0 0         0 0
*  RCC         -30.0       40.0       20.0        0 0        0 0       150 0
                10.0
*  TRC         -30.0       40 0      170.0        0.0        0 0        10 0
                10 0        0 0
*  ARB         -20 0        0 0       20.0      -20 0       20 0        20 0
               -20 0        0 0      220 0      -20 0       20.0       220 0
               -60 0        0 0       20.0      -60 0       20 0        20 0
               -60 0        0 0      220.0      -60.0       20 0       220 0
          1234  2684  6578  1375  3487  1562
*  SPH         -30.0       40.0      172.0        1.0
*  ELL         -30.0       40.0      140.0      -30.0       30.0       150 0
                20.0
*  SPH         -30.0       40.0       30.0        5.0
```

FORTRAN CODING FORM AND DATA SHEET

PROGRAM: SAM-C GEOMETRY (CONT.)

PROGRAMMER: A. KRIS WIDDISON

PHONE: | LAB: | DATE: | PAGE: of

0 = ZERO, Ø = ALPHA O; 1 = ONE, I = ALPHA I; 2 = TWO, Ƶ = ALPHA Z

```
STATEMENT  C
NUMBER     O  FORTRAN STATEMENT                                                   IDENTIFICATION
12345      6  7..........................................................72     73........80
   SPH                  1          1
*  ARB             -19.0      29.0      140.0     -41.0      29.0      140.0
                   -41.0      29.0      165.0     -19.0      29.0      165.0
                   -48.0     252.0      445.0     -52.0     252.0      445.0
                   -52.0     252.0      455.0     -48.0     252.0      455.0
              1234  4378  5678  1265  1485  2376
    1     +  1  -  2  -  3  -  4  -  5  -  6  -  7  -  8  -  9
          -  10 -  11 -  12
    2     +  2  -  3
    3     +  3  -  2  -  5  -  7
    4     +  4
    5     +  5  -  3  -  6  -  9  -  10
    6     +  6  -  5  -  8
    7     +  7  -  3
    8     +  8
    9   ØR   9ØR   10
   10     +  11
   11     +  12 -  5  -  6  -  7  -  8  -  9  -  11
   -1
```

AMXRD-C Form 15 20 May 70 (Replaces AMXRD-C Form 13 9 Mar 66)

APPENDIX D

LISTING OF THE AMSAA OCTOBER REVISED STANDARD MAGIC PROGRAM

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```
C
      DIMENSION MASTER(30000),A(6)
      COMMON ASTER(30000)
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/TEMPOR/XS(6),X(6),IX(8),IT(10),IA(9),IN(9)
      COMMON/WALT/LIRFO,NGIERR
      COMMON/CONTRL/ITESTG,IRAYSK,IENTLV,IVOLUM,IWOT,ITAPE8,NO,IYES
      COMMON/ENGEOM/LEGEOM
      COMMON/SIZE/NDQ
      COMMON/ERR/IERR)
      COMMON/RANDM/IRANDM
      EQUIVALENCE (ASTER,MASTER)
C
  901 FORMAT(1H1,32HTHIS IS THE 11 APR 69 VERSION OF /
     1        1H ,32HTHE BRLESC MAGIC PROGRAM  ****** //)
  902 FORMAT(16H BEGIN EXECUTION)
  903 FORMAT(8I10)
  904 FORMAT(1H0,10X,42HTHE TAPE 4 USED FOR THIS RUN HAS THE TITLE /
     1  10A6/)
  905 FORMAT(1H0,10HENTER GENI)
  906 FORMAT(1H0,12HLEAVING GENI)
  907 FORMAT(1H0,35HTERMINATION ON GEOMETRY INPUT ERROR,5X,5HIERR=,I5)
  908 FORMAT(1H1,15HTESTG IS CALLED)
  909 FORMAT(1H0,13HLEAVING TESTG)
  910 FORMAT(1H1,24HREGION TYPE DATA FOLLOWS, 8X,6HLIRFO=,I10/
     1        1H ,6HREGION,6X,4HCODE,6X,4HTYPE,6X,11HDESCRIPTION/)
  911 FORMAT(3I10,10X,6A6)
  912 FORMAT(I6,I10,I9,7X,6A6)
  913 FORMAT(1H0,23HNO ROOM FOR IDENT TABLE,5X,7HLEGEOM=,I7,5X,
     1     6HLIRFO=,I7)
  914 FORMAT(1H0,32HWRITE TAPE 1 OPTION IS SPECIFIED)
  915 FORMAT(I5,10X,10A6)
  916 FORMAT(1H1,11HENTER VOLUM)
  917 FORMAT(1H0,13HLEAVING VOLUM)
  918 FORMAT(1H ,6H 999.9)
  919 FORMAT(1H1,11HEND OF CASE,I5)
  925 FORMAT(1H1,32HNUM OF ASPECT ANGLES FOR GRID IS,I5)
  927 FORMAT(10I5)
  928 FORMAT(1H1,32HNUM OF ASPECT ANGLES FOR AREA IS,I5)
  929 FORMAT(1H0,31HNUMBER OF GI ERRORS ENCOUNTERED,I5)
  930 FORMAT(1H0,31HNUMBER OF  0  ITEMS ENCOUNTERED,I5)
  999 FORMAT(1H0,10HEND OF RUN)
C
      IRANDM=0
      WRITE (6,901)
      WRITE (6,902)
C
      I15=2**15
      I30=2**30
      PINF=1.0E50
      NO=0
      IYES=1
      IERR=0
      LBASE=1
      KLOOP=0
      NDQ=30000
C
      READ (5,903)IRDTP4,IWRIP4,ITESTG,IRAYSK,ICARDI,IENTLV,IVOLUM
```

```
      IF(IRDTP4.NE.0)IRDTP4=IYES
      IF(IWRTP4.NE.0)IWRTP4=IYES
      IF(ITESTG.NE.0)ITESTG=IYES
      IF(IRAYSK.NE.0)IRAYSK=IYES
      IF(ICARDI.NE.0)ICARDI=IYES
      IF(IENTLV.NE.0)IENTLV=IYES
      IF(IVOLUM.NE.0)IVOLUM=IYES
C
      IF(IRDTP4.EQ.NO) GOTO 10
      READ (4) DUMMY,ASTER,LBASE,PINF,IERR,NRPP,NTRIP,NSCAL,
     1  NBODY,NRMAX,LTRIP,LSCAL,LREGD,LDATA,LRIN,LROT,LIO,LOCDA,
     2  LBODY,LIRFO,SCALE,LRI,LRO,PINF,IT
      WRITE (6,904)(IT(I),I=1,10)
      GOTO 20
C
C      PROCESS GEOMETRY
C
   10 DO 11 I=LBASE,NDQ
      ASTER(I)=0.
   11 CONTINUE
C
      WRITE (6,905)
      CALL GENI
      WRITE (6,906)
      IERR=0
      IF(IERR.LE.0)GOTO 12
      WRITE (6,907)IERR
      STOP
C
   12 IF(IWRTP4.EQ.NO)GOTO 20
      WRITE(4) DUMMY,ASTER,LBASE,PINF,IERR,NRPP,NTRIP,NSCAL,
     1  NBODY,NRMAX,LTRIP,LSCAL,LREGD,LDATA,LRIN,LROT,LIO,LOCDA,
     2  LBODY,LIRFO,SCALE,LRI,LRO,PINF,IT
C
C     TEST G
C
   20 IF(ITESTG.EQ.NO)GOTO 30
      WRITE (6,908)
      CALL TESTG
      WRITE (6,909)
      ITESTG=NO
C
C     VOLUM
C
   30 IF(IVOLUM.EQ.NO)GOTO 40
      WRITE (6,916)
      CALL VOLUM
      WRITE (6,917)
      IVOLUM=NO
C
C     REGION TYPE DATA           / ICODE / IDENT /
C
C     IRN   = REGION NUMBER
C     ICODE = ITEM CODE
C     IDENT = SPACE CODE AND SPECIAL IDENTIFICATION
C          0 NO IDENT CODE
C          10,20,30,40,50,60,70,80,90 SPECIAL IDENTIFICATION
C               SKIRT=10    ARMOR=20     TARGET=30
C          -1,1-9,11-19,21-29,.......,91-99 SPACE CODES
C
```

```
   40 LIRFO=NDQ-NRMAX-10
      IF(LIRFO.GT.LEGEOM)GOTO 41
      WRITE(6,913)LEGEOM,LIRFO
      STOP
   41 WRITE (6,910)LIRFO
      MASTER(LIRFO-1)=I15+1
C
   42 READ(5,911)IRN,ICODE,IDENT,(A(I),I=1,6)
      IF(IRN.LE.0)GOTO 50
      WRITE (6,912)IRN,ICODE,IDENT,(A(I),I=1,6)
      IDENT=IDENT+1
      K=LIRFO+IRN-1
      MASTER(K)=ICODE*I15+IDENT
      GOTO 42
C
C     NOAA  = NUM OF ASPECT ANGLES FOR GRID
C     ITAPE8 IS THE SUPRESS PRINTER OPTION
C     IWOT IS WRITE OPTION FOR TAPE 1
C     NAREA = NUM OF ASPECT ANGLES FOR AREA
C
   50 READ (5,927)NOAA,IWOT,ITAPE8,NAREA
      IF(IWOT.NE.0)IWOT=IYES
      IF(ITAPE8.EQ.0)GOTO 51
      ITAPE8=NO
      GOTO 52
   51 ITAPE8=IYES
   52 IF(IWOT.EQ.NO)GOTO 60
      REWIND 1
      WRITE (6,914)
      WRITE(1,915)NOAA,(IT(I),I=1,10)
C
C     GRID
C
   60 IF(NOAA.LE.0)GOTO 70
      WRITE (6,925)NOAA
C
      DO 61 I=1,NOAA
      CALL GRID
      IF(IWOT.EQ.IYES)WRITE(1,918)
      WRITE (6,919)I
      WRITE (6,929)IERR
      WRITE (6,930)IERRO
      IERR=0
      IERRO=0
   61 CONTINUE
C
C     AREA
C
   70 IF(NAREA.LE.0)GOTO 99
      WRITE (6,928)NAREA
C
      DO 71 I=1,NAREA
      CALL AREA
      WRITE (6,919)I
      IERR=0
   71 CONTINUL
C
   99 WRITE (6,999)
      STOP
      END
```

```
C                                                                       MAIN 181
C                                                                       MAIN 182
      SUBROUTINE UN2(L,J1,J2)                                           ****   1
C        UNPACKS 2 ITEMS FROM THE MASTER-ASTER ARRAY                    UN2    2
      COMMON MASTER(30000)                                              UN2    3
      I3=MASTER(L)                                                      UN2    4
      J1=I3/32768                                                       UN2    5
      J2=I3-J1*32768                                                    UN2    6
      RETURN                                                            UN2    7
      END                                                               UN2    8
C                                                                       UN2    9
C                                                                       UN2   10
      SUBROUTINE UN3(L,J1,J2,J3)                                        ****   2
C        UNPACKS 3 ITEMS FROM G1 STORAGE                                UN3    2
      COMMON MASTER(30000)                                              UN3    3
      I3=MASTER(L)                                                      UN3    4
      I2=I3/32768                                                       UN3    5
      J1=I2/64                                                          UN3    6
      J2=I2-J1*64                                                       UN3    7
      J3=I3-I2*32768                                                    UN3    8
      RETURN                                                            UN3    9
      END                                                               UN3   10
C                                                                       UN3   11
C                                                                       UN3   12
      SUBROUTINE OPENK(L,J1,J2,J3)                                      ****   3
      COMMON/GTRACK/D1,D2,KHIT,LMAX,TR(200),XBS(3),IRSTRT,IENC,         OPENK  2
     1     ITR(200),CA,CE,SA,SE                                         OPENK  3
C                                                                       OPENK  4
C     UNPACKS 3 ITEMS FROM COMPONENT LINE OF SIGHT STORAGE ITR          OPENK  5
C     / SURFACE NUM / BODY NUM / NEXT REGION /                          OPENK  6
C                                                                       OPENK  7
      I3=ITR(L)                                                         OPENK  8
      I2=I3/4096                                                        OPENK  9
      J1=I2/4096                                                        OPENK 10
      J2=I2-J1*4096                                                     OPENK 11
      J3=I3-I2*4096                                                     OPENK 12
      RETURN                                                            OPENK 13
      END                                                               OPENK 14
C                                                                       OPENK 15
C                                                                       OPENK 16
      FUNCTION RAN(M)                                                   ****   4
      COMMON/RANDM/IRN                                                  RAN    2
C        GENERATES RANDOM NUMBERS                                       RAN    3
      RAN=URAN31(IRN)                                                   RAN    4
      RETURN                                                            RAN    5
      END                                                               RAN    6
C                                                                       RAN    7
C                                                                       RAN    8
      FUNCTION URAN31(I)                                                ****   5
      IF(I)20,10,20                                                     URAN31 2
   10 I=11111111                                                        URAN31 3
   20 J=I                                                               URAN31 4
      J=J*25                                                            URAN31 5
      J=J-(J/67108864)*67108864                                         URAN31 6
      J=J*25                                                            URAN31 7
      J=J-(J/67108864)*67108864                                         URAN31 8
      J=J*5                                                             URAN31 9
      J=J-(J/67108864)*67108864                                         URAN3110
      A1=J                                                              URAN3111
      I=J                                                               URAN3112
```

```
      URAN31=A1/67108864.                                               URAN3113
      RETURN                                                            URAN3114
      END                                                               URAN3115
C                                                                       URAN3116
C                                                                       URAN3117
      SUBROUTINE CROSS(ANSWER,FIRST,SECOND)                             ****   6
      DIMENSION ANSWER(3),FIRST(3),SECOND(3)                            CROSS  2
C         COMPUTES CROSS PRODUCT      ANSWER = FIRST X SECOND           CROSS  3
      ANSWER(1) = FIRST(2)*SECOND(3) - FIRST(3)*SECOND(2)               CROSS  4
      ANSWER(2) = FIRST(3)*SECOND(1) - FIRST(1)*SECOND(3)               CROSS  5
      ANSWER(3) = FIRST(1)*SECOND(2) - FIRST(2)*SECOND(1)               CROSS  6
      RETURN                                                            CROSS  7
      END                                                               CROSS  8
C                                                                       CROSS  9
C                                                                       CROSS 10
      FUNCTION DOT(FIRST,SECOND)                                        ****   7
      DIMENSION FIRST(3),SECOND(3)                                      DOT    2
C         COMPUTES DOT PRODUCT      DOT = FIRST . SECOND                DOT    3
      DOT = FIRST(1)*SECOND(1)+FIRST(2)*SECOND(2)+FIRST(3)*SECOND(3)    DOT    4
      RETURN                                                            DOT    5
      END                                                               DOT    6
C                                                                       DOT    7
C                                                                       DOT    8
      SUBROUTINE UNIT(V)                                                ****   8
      DIMENSION V(3)                                                    UNIT   2
C         COMPUTES UNIT VECTOR                                          UNIT   3
      TEMP = SQRT(DOT(V,V))                                             UNIT   4
      V(1)=V(1)/TEMP                                                    UNIT   5
      V(2)=V(2)/TEMP                                                    UNIT   6
      V(3)=V(3)/TEMP                                                    UNIT   7
      RETURN                                                            UNIT   8
      END                                                               UNIT   9
C                                                                       UNIT  10
C                                                                       UNIT  11
      SUBROUTINE QRTIC(C,R,NRE)                                         ****   9
C                                                                       QRTIC  2
C     SOLVES A POLYNOMIAL EQUATION OF THE TYPE                          QRTIC  3
C       X**4 + C(1)*X**3 + C(2)*X**2 + C(3)*X + C(4) = 0                QRTIC  4
C     THE COEFFICIENT OF X**4 IS ASSUMED TO BE 1                        QRTIC  5
C     R CONTAINS THE ROOTS                                              QRTIC  6
C     NRE CONTAINS THE NUMBER OF REAL ROOTS                             QRTIC  7
C     IF THERE ARE TWO REAL ROOTS THEY WILL BE IN R(1) AND R(2),        QRTIC  8
C       WITH THE COMPLEX ROOTS R(3) +- R(4)*I                           QRTIC  9
C     IF THERE ARE NO REAL ROOTS, THE COMPLEX ROOTS ARE                 QRTIC 10
C       R(1) +- R(2)*I AND R(3) +- R(4)*I                               QRTIC 11
C                                                                       QRTIC 12
      DIMENSION C(4),R(4),CP(3),Y(3)                                    QRTIC 13
      C1SQ=C(1)**2                                                      QRTIC 14
      CP(1)=-C(2)                                                       QRTIC 15
      CP(2)=C(1)*C(3)-4.*C(4)                                           QRTIC 16
      CP(3)=(4.*C(2)-C1SQ)*C(4)-C(3)**2                                 QRTIC 17
      CALL CUBIC(CP,Y,NRE)                                              QRTIC 18
      A=C1SQ/4.-C(2)+Y(1)                                               QRTIC 19
      B=.5*C(1)*Y(1)-C(3)                                               QRTIC 20
      D=.25*Y(1)**2-C(4)                                                QRTIC 21
      IF(A.GT.0.)GOTO 10                                                QRTIC 22
      E=0.                                                              QRTIC 23
      GOTO 20                                                           QRTIC 24
   10 E=SQRT(A)                                                         QRTIC 25
   20 IF(D.GT.0.)GOTO 30                                                QRTIC 26
```

```
      F=0.
      GOTO 50
   30 F=SIGN(SQRT(D),B)
   50 NRE=0
      REAL=-.25*C(1)+.5*L
      DSCR=REAL**2-.5*Y(1)+F
      RAD=SQRT(ABS(DSCR))
      IF(DSCR.LT.0.)GOTO 60
      NRE=2
      R(1)=REAL+RAD
      R(2)=REAL-RAD
      GOTO 65
   60 R(3)=REAL
      R(4)=RAD
   65 REAL=REAL-F
      DSCR=REAL**2-.5*Y(1)-F
      RAD=SQRT(ABS(DSCR))
      IF(DSCR.LT.0.)GOTO 80
      NRE=NRE+2
      R(NRE)=REAL-RAD
      R(NRE-1)=REAL+RAD
      RETURN
   80 R(NRE+1)=REAL
      R(NRE+2)=RAD
      RETURN
      END
C
C
      SUBROUTINE CUBIC(C,R,NRE)
C
C     SOLVES A POLYNOMIAL EQUATION OF THE TYPE
C       X**3 + C(1)*X**2 + C(2)*X + C(3) = 0
C     THE COEFFICIENT OF X**3 IS ASSUMED TO BE 1
C     R CONTAINS THE ROOTS
C     NRE CONTAINS THE NUMBER OF REAL ROOTS
C     IF THERE IS ONE REAL ROOT IT WILL BE IN R(1),
C       WITH THE COMPLEX ROOTS R(2) +- R(3)*I
C
      DIMENSION C(3),R(3)
      C1SQ=C(1)**2
      P=C(2)-C1SQ/3.
      Q=C(3)-C(1)*(C(2)/3.-2.*C1SQ/27.)
      DEL=4.*P**3+27.*Q**2.
      T=C(1)/3.
      IF(DEL.LT.0.)GOTO 10
      SQ=SQRT(DEL/108.)
      HQ=.5*Q
      A=-HQ+SQ
      B=-HQ-SQ
      CRTA=SIGN(ABS(A)**.3333333333333333,A)
      CRTB=SIGN(ABS(B)**.3333333333333333,B)
      Y=CRTA+CRTB
      R(1)=Y-T
      R(2)=-.5*Y-T
      R(3)=.866025404*(CRTA-CRTB)
      NRE=1
      RETURN
   10 PHI3=ATAN2(SQRT(-DEL/27.),-Q)/3.
      CON=2.*SQRT(-P/3.)
      R(1)=CON*COS(PHI3)-T
```

```
      R(2)=-CON*COS(1.04719755-PHI3)-T                                  CUBIC 33
      R(3)=-CON*COS(1.04719755+PHI3)-T                                  CUBIC 34
      NRE=3                                                             CUBIC 35
      RETURN                                                            CUBIC 36
      END                                                               CUBIC 37
C                                                                       CUBIC 38
C                                                                       CUBIC 39
      FUNCTION XDIST(XA,XB)                                             ****  11
C         COMPUTES THE DISTANCE BETWEEN XA AND XB                       XDIST  2
      DIMENSION XA(3),XB(3)                                             XDIST  3
      XSUM=0.                                                           XDIST  4
      DO 10 I=1,3                                                       XDIST  5
      XSUM=XSUM+(XA(I)-XB(I))**2                                        XDIST  6
   10 CONTINUE                                                          XDIST  7
      XDIST=SQRT(XSUM)                                                  XDIST  8
      RETURN                                                            XDIST  9
      END                                                               XDIST 10
C                                                                       XDIST 11
C                                                                       XDIST 12
      SUBROUTINE DCOSP(XA,XB,WA)                                        ****  12
C         COMPUTES DIRECTION COSINES FROM POINT XA TO POINT XB          DCOSP  2
C              AND STORES DIRECTION COSINES IN WA                       DCOSP  3
      DIMENSION XA(3),XB(3),WA(3)                                       DCOSP  4
      DIS=XDIST(XA,XB)                                                  DCOSP  5
      DO 10 I=1,3                                                       DCOSP  6
      WA(I)=(XB(I)-XA(I))/DIS                                           DCOSP  7
   10 CONTINUE                                                          DCOSP  8
      RETURN                                                            DCOSP  9
      END                                                               DCOSP 10
C                                                                       DCOSP 11
C                                                                       DCOSP 12
      SUBROUTINE TROPIC(WP)                                             ****  13
C         GENERATES RANDOM DIRECTION COSINES FROM AN                    TROPIC 2
C              ISOTROPIC DISTRIBUTION                                   TROPIC 3
      DIMENSION WP(3)                                                   TROPIC 4
   10 X1=RAN (-1)                                                       TROPIC 5
      X2=RAN (-1)                                                       TROPIC 6
      X1S=X1**2                                                         TROPIC 7
      X2S=X2**2                                                         TROPIC 8
      T=X1S+X2S                                                         TROPIC 9
      IF(T.GE.1.)GOTO 10                                                TROPIC10
C         CALC SIN AND COS OF A RANDOM ANGLE PHI                        TROPIC11
      CSPHI=(X1S-X2S)/T                                                 TROPIC12
      SNPHI=(2.*X1*X2)/T                                                TROPIC13
      X1=RAN (-1)                                                       TROPIC14
      IF(X1.LE..5)SNPHI=-SNPHI                                          TROPIC15
C         CALC COS AND SIN OF RANDOM ANGLE THT                          TROPIC16
      CSTHT=2.*RAN (-1)-1.                                              TROPIC17
      SNTHT=SQRT(1.-CSTHT**2)                                           TROPIC18
C         CALC DIRECTION COSINES                                        TROPIC19
      WP(1)=SNTHT*SNPHI                                                 TROPIC20
      WP(2)=SNTHT*CSPHI                                                 TROPIC21
      WP(3)=CSTHT                                                       TROPIC22
      RETURN                                                            TROPIC23
      END                                                               TROPIC24
C                                                                       TROPIC25
C                                                                       TROPIC26
C                                                                       TROPIC27
C                                                                       TROPIC28
      SUBROUTINE GENI                                                   ****  14
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```
      DIMENSION MASTER(30000),ITY(11),IAN(8),IAA(8),FX(20),
     1  NO0(3),NO1(3),NO2(3),04(3),TT(3),TT1(3),TT2(3),NBOD(11)
      COMMON ASTER(30000)
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/TEMPOR/XS(6),X(6),IX(8),IT(10),IA(9),IN(9)
      COMMON/CONTRL/ITESTG,IRAYSK,IENTLV,IVOLUM,IWOT,ITAPE8,NO,IYES
      COMMON/SIZE/NDQ
      COMMON/UNCLE/NN,IC(4)
      COMMON/RRPP/LRPPD,LABUT
      EQUIVALENCE(ASTER,MASTER)
C
  901 FORMAT(1H0,24HSTART READING SOLID DATA)
  902 FORMAT(10A6)
  903 FORMAT(1H0,10A6/)
  904 FORMAT(7I10)
  905 FORMAT(4X,34HNO. OF RECTANGULAR PARALLELEPIPEDS,I10/
     1        4X,34HNO. OF TRIPLETS                   ,I10/
     2        4X,34HNO. OF SCALERS                    ,I10/
     3        4X,34HNO. OF SOLIDS                     ,I10/
     4        4X,34HMAX NO. OF REGIONS                ,I10)
  906 FORMAT(1H0,45X,32HRECTANGULAR PARALLELEPIPED INPUT)
  907 FORMAT(1H0,37X,12HTRIPLET DATA)
  908 FORMAT(6E12.6)
  909 FORMAT(I8,17X,3F12.5)
  910 FORMAT(1H0,25X,12HSCALAR  DATA)
  911 FORMAT(1H0,50X,22HDESCRIPTION OF  SOLIDS)
  912 FORMAT(3A1,A3,A4,6F10.5)
  913 FORMAT(1H0,6HITYPE ,A3,27H DOES NOT MATCH WITH AN ITY)
  914 FORMAT(I9,1X,3A1,3X,A3,A4,3X,8I5)
  915 FORMAT(I8,1X,3A1,2X,A3,A4,4X,6F12.5)
  916 FORMAT(25X,6F12.5)
  917 FORMAT(1H0,38HNO MORE ROOM FOR SOLID DATA     LDATA=,I10,
     1  5X,5HLBOT=,I10,5X,4HNDQ=,I10)
  918 FORMAT(1H0,25HFINISH READING SOLID DATA)
  919 FORMAT(1H0,  5HLREGD,7H  LREGL,7H  LENLV,7H   LRIN,7H   LROT,
     1     7H    LIO,7H LEGEOM/I5,6I7)
  920 FORMAT(1H1,36X,23HREGION COMBINATION DATA)
  921 FORMAT(I5,1X,9(A2,I5))
  922 FORMAT(1H0,30HERROR IN DESCRIPTION OF REGION,I5,
     19H IN FIELD,I2,5X,24HBODY NUM.GT.NRPP + NBODY)
  923 FORMAT(10X,9(1H(,A2,I5,1H),1X))
  924 FORMAT(I8,2X,9(1H(,A2,I5,1H),1X))
  925 FORMAT(1H0,30HILLEGAL OPERATOR IN ABOVE CARD,5X,A2,
     1  9H IN FIELD,I2)
  926 FORMAT(1H0,29HERROR IN REGION INPUT    IR=,I5,14H OR N.GT.NRMAX)
  927 FORMAT(1H0,39HNO MORE ROOM FOR REGION DATA     LDATA=,I10,
     1  5X,4HNDQ=,I10)
  928 FORMAT(1H0,26HFINISH READING REGION DATA)
  929 FORMAT(14H ERROR, REGION,I10,18H IS PART OF REGION,I10)
  930 FORMAT(24H FINISH CHECKING REGION ,I5)
  931 FORMAT(1H0,34HNO MORE ROOM FOR ENTER LEAVE TABLE,5X,
     1  6HLDATA=,I10,5X,4HNDQ=I10,5X,4HPASS,I2,5X,3HIR=,I10)
  932 FORMAT(1H0,28HTOTAL ROOM FOR GEOMETRY DATA,5X,7HLEGEOM=,I6)
  933 FORMAT(1H0,5HENTER,18I6/(23X,15I6))
  934 FORMAT(1H ,5HLEAVE,18I6/(23X,15I6))
  935 FORMAT(1H1,50X,18HBEGIN ARRAY OUTPUT/)
  936 FORMAT(3(3I6,1X,E11.4,3H $ ))
  937 FORMAT(/)
```

```
  938 FORMAT(1H0,34HFINISH A PASS OF ENTER LEAVE TABLE,I5)
  939 FORMAT(1H0,14HERROR IN INPUT,5X,A3,23H DOES NOT ALLOW TRIPLET,
     1     22H AND SCALAR TYPE INPUT)
  940 FORMAT(10X,6F10.5)
  941 FORMAT(1H0,37HTERMINATION ON BAD REGION DESCRIPTION)
  942 FORMAT(1H0,32HERROR IN DESCRIPTION OF BODY NUM,I6/
     1     7H VECTOR,3F12.5,24H IS NOT PERPENDICULAR TO /
     2     7H VECTOR,3F12.5/)
  943 FORMAT(1H0,27HERROR IN DESCRIPTION OF TOR,5X,8HR2.GT.R1/)
  944 FORMAT(1H0,27HERROR IN DESCRIPTION OF TRC,5X,7HR1 = R2/)
  945 FORMAT(1H0,5HLBASE,7H  LRPPD,
     1     7H  LABUT,7H  LBODY,7H   LBOD,7H  LDATA,7H   LBOT,7H  LSCAL,
     2     7H  LTRIP,7H    NDQ/I5,9I7)
  946 FORMAT(1H1,17HENTER-LEAVE TABLE)
  947 FORMAT(1H0,11(2X,A3)/11I5)
  948 FORMAT(1H0,27HERROR IN DESCRIPTION OF TEC,5X,
     1     41HHEIGHT VECTOR IS PARALLEL TO BASE ELLIPSE)
C

      INTEGER HHBOX,HHSPH,HHRCC,HHREC,HHTRC,HHELL,HHRAW,HHARB,HHTEC,
     1 HHTOR,HHARS,HHOR,HHBR,HHR,HHRA,HHAR,HHBA,HHA,HHB
C
      DATA HHBOX,HHSPH,HHRCC,HHREC,HHTRC,HHELL,HHRAW,HHARB,
     1HHTEC,HHTOR,HHARS/3HBOX,3HSPH,3HRCC,3HREC,3HTRC,
     23HELL,3HRAW,3HARB,3HTEC,3HTOR,3HARS/
      DATA HHOR,HHBR,HHR,HHRA,HHAR,HHBA,HHA,HHB
     1/2HOR,2HBR,1HR,2HRA,2HAR,2H A,2HA ,2H  /
      ITY(1)=HHBOX
      ITY(2)=HHSPH
      ITY(3)=HHRCC
      ITY(4)=HHREC
      ITY(5)=HHTRC
      ITY(6)=HHELL
      ITY(7)=HHRAW
      ITY(8)=HHARB
      ITY(9)=HHTEC
      ITY(10)=HHTOR
      ITY(11)=HHARS
      IAN(1)=1
      IAN(2)=1
      IAN(3)=1
      IAN(4)=2
      IAN(5)=2
      IAN(6)=3
      IAN(7)=3
      IAN(8)=4
      IAA(1)=HHOR
      IAA(2)=HHBR
      IAA(3)=HHR
      IAA(4)=HHRA
      IAA(5)=HHAR
      IAA(6)=HHBA
      IAA(7)=HHA
      IAA(8)=HHB
      IBL=HHB

C
      WRITE (6,901)
      READ(5,902)(IT(I),I=1,10)
      WRITE  (6,903)(IT(I),I=1,10)
```

```
      READ(5,904)NRPP,NTRIP,NSCAL,NBODY,NRMAX,IPRIN,IRCHEK
      WRITE  (6,905)NRPP,NTRIP,NSCAL,NBODY,NRMAX
C
C     RPP
C
      WRITE (6,906)
      LAR=1
      IF(NRPP.LE.0)GOTO 20
      CALL RPPIN(LAR)
      IF(IERR.GT.0)RETURN
C
C     LBODY STORAGE      RESERVE 3*(NRPP+NBODY) WORDS
C         /      ITYPE       /      LDATA       /
C         / LOC ENTER LIST / LOC LEAVE LIST /
C         / NUM ENTER      / NUM LEAVE      /
C
C     LDATA POINTS TO BODY POINTERS STORED AT LBOD
C
   20 LTRIP=NDQ-3*NTRIP+1
      LSCAL=LTRIP-NSCAL
      LBOT=LSCAL
      L=LAR
      LBODY=L+1
      LDATA=LBODY+3*(NBODY+NRPP)
      LBOD=LDATA
C
C     TRIPLETS
C
      IF(NTRIP.EQ.0)GOTO 30
      WRITE (6,907)
      DO 21 I=1,NTRIP
      I1=LTRIP+3*(I-1)
      I2=I1+2
      READ(5,908)(ASTER(K),K=I1,I2)
      WRITE (6,909)(I,(ASTER(K),K=I1,I2))
   21 CONTINUE
C
C     SCALARS
C
   30 IF(NSCAL.EQ.0)GOTO 50
      I1=LSCAL
      I2=I1+NSCAL-1
      WRITE (6,910)
      DO 31 I=I1,I2
      J=I-I1+1
      READ(5,908)ASTER(I)
      WRITE (6,909)J,ASTER(I)
   31 CONTINUE
C
C     READ AND PROCESS BODIES
C
   50 WRITE (6,911)
C
C     LOOP TO PROCESS SOLIDS
C
      DO 370 N=1,NBODY
      NN=N+NRPP
      LS1=0
      READ(5,912) IC(1),IC(2),IC(3),ITYPE,IC(4),(FX(K),K=1,6)
      DO 51 I=1,11
```

```
      IF(ITYPE.EQ.ITY(I))GOTO 52
   51 CONTINUE
      WRITE (6,913)ITYPE
      STOP
   52 ITYPE=I
      NBOD(I)=NBOD(I)+1
      K=LBODY+3*(NRPP+N-1)
      MASTER(K)=ITYPE*I15+LDATA
      IF(IC(1).NE.IBL)GOTO 200
C
C           BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
      GOTO(101,103,102,101,101,102,101,100,104,101,100),ITYPE
  100 WRITE (6,939)ITY(ITYPE)
      STOP
  101 LE=4
      GOTO 110
  102 LE=3
      GOTO 110
  103 LE=2
      GOTO 110
  104 LE=7
  110 CALL CONVRT(FX,IX,LE)
      WRITE (6,914)NN,IC(1),IC(2),IC(3),ITY(ITYPE),IC(4),(IX(J),J=1,LE)
      LT=LTRIP-3
      J1=IX(1)
      J2=IX(2)
      J3=IX(3)
      J4=IX(4)
      J5=IX(5)
      J6=IX(6)
      J7=IX(7)
C           BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
      GOTO(120,130,140,120,150,160,120,100,170,150,100),ITYPE
C         BOX REC RAW
  120 MASTER(LDATA)=(LT+3*J1)*I30+(LT+3*J2)*I15+LT+3*J3
      MASTER(LDATA+1)=LT+3*J4
      LDATA=LDATA+2
      GOTO 360
C         SPH
  130 MASTER(LDATA)=(LT+3*J1)*I15+LSCAL+J2-1+I30
      LDATA=LDATA+1
      GOTO 360
C         RCC
  140 MASTER(LDATA)=(LT+3*J1)*I30+(LT+3*J2)*I15+LSCAL+J3-1
      LDATA=LDATA+1
      GOTO 360
C         TRC TOR
  150 MASTER(LDATA)=(LT+3*J1)*I30+(LT+3*J2)*I15+LSCAL+J3-1
      MASTER(LDATA+1)=LSCAL+J4-1
      LDATA=LDATA+2
      GOTO 360
C         ELL
  160 MASTER(LDATA)=(LT+3*J1)*I30+(LT+3*J2)*I15+LSCAL+J3-1
      LDATA=LDATA+1
      GOTO 360
C         TEC
  170 MASTER(LDATA)=(LT+3*J1)*I30+(LT+3*J2)*I15+LT+3*J3
      MASTER(LDATA+1)=(LT+3*J4)*I30+(LSCAL+J5-1)*I15+LSCAL+J6-1
      MASTER(LDATA+2)=LSCAL+J7-1
      LDATA=LDATA+3
```

```
      GOTO 360
C
C           BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
  200 GOTO(201,220,202,201,203,202,201,230,204,203,240),ITYPE
  201 LE=12
      GOTO 210
  202 LE= 7
      GOTO 210
  203 LE= 8
      GOTO 210
  204 LE=13
  210 WRITE (6,915)NN,IC(1),IC(2),IC(3),ITY(ITYPE),IC(4),(FX(J),J=1,6)
      READ(5,940)(FX(J),J=7,LE)
      WRITE (6,916)(FX(J),J=7,LE)
C           BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
      GOTO(290,300,300,290,285,270,290,300,260,250,300),ITYPE
C           SPH
  220 WRITE (6,915)NN,IC(1),IC(2),IC(3),ITY(ITYPE),IC(4),(FX(J),J=1,4)
      GOTO 300
C           ARB                   / RI / VI /      6 PER ARB
  230 WRITE (6,915)NN,IC(1),IC(2),IC(3),ITY(ITYPE),IC(4),(FX(J),J=1,6)
      CALL ALBERT(FX,LBOT,NDO,LSI)
      GOTO 360
C           ARS                   /     / LDATA /
  240 CALL ARIN(LBOT,LDATA,MASTER,ASTER,IWH)
      GOTO 360
C           TOR            CONVERT TO UNIT VECTOR
  250 TT(1)=FX(4)
      TT(2)=FX(5)
      TT(3)=FX(6)
      CALL UNIT(TT)
      FX(4)=TT(1)
      FX(5)=TT(2)
      FX(6)=TT(3)
      IF(FX(7).GE.FX(8))GOTO 280
      WRITE (6,943)
      IERR=IERR+1
      GOTO 280
C           TEC
  260 FX(15)=FX(13)
      LE=15
      TT1(1)=FX(7)
      TT1(2)=FX(8)
      TT1(3)=FX(9)
      TT2(1)=FX(10)
      TT2(2)=FX(11)
      TT2(3)=FX(12)
      IF(ABS(DOT(TT1,TT2)).LE.0.01) GOTO 265
      WRITE (6,942)NN,TT1,TT2
      IERR=IERR+1
C           SEMI MAJOR AXIS FX(13)
  265 FX(13)=SQRT(DOT(TT1,TT1))
      CALL UNIT(TT1)
      FX(10)=TT1(1)
      FX(11)=TT1(2)
      FX(12)=TT1(3)
C           SEMI MINOR AXIS FX(14)
      FX(14)=SQRT(DOT(TT2,TT2))
C           NORMAL HEIGHT VECTOR
      CALL CROSS(TT,TT1,TT2)
```

```
      CALL UNIT(TT)
      HDN=FX(4)*TT(1)+FX(5)*TT(2)+FX(6)*TT(3)
      IF(HDN)267,266,268
  266 WRITE(6,948)
      IERR=IERR+1
      GOTO 268
  267 TT(1)=-TT(1)
      TT(2)=-TT(2)
      TT(3)=-TT(3)
  268 FX(7)=TT(1)
      FX(8)=TT(2)
      FX(9)=TT(3)
      GOTO 280
C          ELL              COMPUTE FOCI
  270 IF(IC(4).EQ.IBL)GOTO 300
      ASQ=FX(4)*FX(4)+FX(5)*FX(5)+FX(6)*FX(6)
      C=SQRT(ASQ-FX(7)*FX(7))
      A=SQRT(ASQ)
      FX(7)=A+A
C          X,Y,Z COMPONENTS OF FOCI
      CX=C*FX(4)/A
      CY=C*FX(5)/A
      CZ=C*FX(6)/A
C          VERTEX + AND - X,Y,Z COMPONENTS GIVE THE 2 FOCI
      FX(4)=FX(1)+CX
      FX(5)=FX(2)+CY
      FX(6)=FX(3)+CZ
      FX(1)=FX(1)-CX
      FX(2)=FX(2)-CY
      FX(3)=FX(3)-CZ
C          PRINT NEW INPUT
  280 WRITE (6,915)NN,IC(1),IC(2),IC(3),ITY(ITYPE),IC(4),(FX(J),J=1,6)
      WRITE (6,916)(FX(J),J=7,LE)
      GOTO 300
C          TRC              CHECK R1.NE.R2
  285 IF(FX(7).NE.FX(8))GOTO 300
      WRITE (6,944)
      IERR=IERR+1
      GOTO 300
C          BOX RAW REC             CHECK IF VECTORS ARE PERPINDICULAR
  290 IF(ABS(FX(4)*FX(7)+FX(5)*FX(8)+FX(6)*FX(9)).LE.0.01)GOTO 291
      WRITE (6,942)NN,(FX(J),J=4,9)
      IERR=IERR+1
  291 IF(ABS(FX(4)*FX(10)+FX(5)*FX(11)+FX(6)*FX(12)).LE.0.01)GOTO 292
      WRITE (6,942)NN,FX(4),FX(5),FX(6),FX(10),FX(11),FX(12)
      IERR=IERR+1
  292 IF(ABS(FX(7)*FX(10)+FX(8)*FX(11)+FX(9)*FX(12)).LE.0.01)GOTO 300
      WRITE (6,942)NN,(FX(J),J=7,12)
      IERR=IERR+1
C
C           BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
  300 GOTO(310,320,330,310,340,330,310,230,350,340,240),ITYPE
C          BOX REC RAW          / V1 / V2 /
C                               / V2 / V3 /
  310 CALL SEE3(IWH,ASTER,MASTER,FX(1),FX(2),FX(3),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(4),FX(5),FX(6),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=MASTER(LDATA)+IWH
      CALL SEE3(IWH,ASTER,MASTER,FX(7),FX(8),FX(9),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+1)=IWH*I15
```

```
      CALL SEE3(IWH,ASTER,MASTER,FX(10),FX(11),FX(12),
     1  LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+1)=MASTER(LDATA+1)+IWH
      LDATA=LDATA+2
      GO TO 360
C         SPH                  / V1 / R1 /
  320 CALL SEE3(IWH,ASTER,MASTER,FX(1),FX(2),FX(3),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=IWH*I15
      LS1=1
      CALL SEE3(IWH,ASTER,MASTER,FX(4),FX(4),FX(4),LBOT,LDATA,NDQ,LS1)
      LS1=0
      MASTER(LDATA)=MASTER(LDATA)+IWH
      LDATA=LDATA+1
      GOTO 360
C         RCC ELL              / V1 / V2 /
C                              /    / R1 /
  330 CALL SEE3(IWH,ASTER,MASTER,FX(1),FX(2),FX(3),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(4),FX(5),FX(6),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=MASTER(LDATA)+IWH
      LS1=1
      CALL SEE3(IWH,ASTER,MASTER,FX(7),FX(7),FX(7),LBOT,LDATA,NDQ,LS1)
      LS1=0
      MASTER(LDATA+1)=IWH
      LDATA=LDATA+2
      GO TO 360
C         TRC TOR              / V1 / V2 /
C                              / R1 / R2 /
  340 CALL SEE3(IWH,ASTER,MASTER,FX(1),FX(2),FX(3),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(4),FX(5),FX(6),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=MASTER(LDATA)+IWH
      LS1=1
      CALL SEE3(IWH,ASTER,MASTER,FX(7),FX(7),FX(7),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+1)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(8),FX(8),FX(8),LBOT,LDATA,NDQ,LS1)
      LS1=0
      MASTER(LDATA+1)=MASTER(LDATA+1)+IWH
      LDATA=LDATA+2
      GO TO 360
C         TEC                  / V1 / V2 /
C                              / V3 / V4 /
C                              / R1 / R2 /
C                              /    / R3 /
  350 CALL SEE3(IWH,ASTER,MASTER,FX(1),FX(2),FX(3),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(4),FX(5),FX(6),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA)=MASTER(LDATA)+IWH
      CALL SEE3(IWH,ASTER,MASTER,FX(7),FX(8),FX(9),LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+1)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(10),FX(11),FX(12),
     1  LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+1)=MASTER(LDATA+1)+IWH
      LS1=1
      CALL SEE3(IWH,ASTER,MASTER,FX(13),FX(13),FX(13),
     1  LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+2)=IWH*I15
      CALL SEE3(IWH,ASTER,MASTER,FX(14),FX(14),FX(14),
     1  LBOT,LDATA,NDQ,LS1)
      MASTER(LDATA+2)=MASTER(LDATA+2)+IWH
```

```
      CALL SEE3(IWH,ASTER,MASTER,FX(15),FX(15),FX(15),
     1  LBOT,LDATA,NDQ,LS1)
      LS1=0
      MASTER(LDATA+3)=IWH
      LDATA=LDATA+4
C          CHECK IF ANY MORE ROOM FOR SOLID DATA
  360 IF(LDATA.LT.NDQ)GOTO 370
      WRITE (6,917)LDATA,LBOT,NDQ
      STOP
  370 CONTINUE
      WRITE (6,918)
      WRITE(6,947)ITY,NBOD
      WRITE (6,945)LBASE,LRPPD,LABUT,LBODY,LBOD,LDATA,LBOT,LSCAL,LTRIP,N
     ADQ
C
C     TRANSFER ASTER(LBOT - NDQ) TO ASTER(LDATA - LDATA+LSUB)
C
      LD=LDATA-1
      LSUB=LBOT-LD-1
      DO 375 I=LBOT,NDQ
      ASTER(LDATA)=ASTER(I)
      LDATA=LDATA+1
  375 CONTINUE
C          UNPACK POINTERS AND ADJUST FOR TRANSFER
      K=LBODY+3*(NRPP+NBODY)
      DO 390 I=K,LD
      CALL UN2(I,I1,I2)
      IF(I1.NE.0)I1=I1-LSUB
      IF(I2.NE.0)I2=I2-LSUB
      MASTER(I)=I1*I15+I2
  390 CONTINUE
C
C     REGION STORAGE
C          LREGD     / LOC BODY LIST / NUM OF BODIES /
C          LDATA     / OPERATOR      / BODY NUM      /
C
C
      WRITE (6,920)
      N=0
      J=0
      LREGD=LDATA
      LDATA=LDATA+NRMAX
      LREGL=LDATA
C
C     READ REGION
C
  400 READ(5,921)IR,(IA(I),IN(I),I=1,9)
C          CHECK VALIDITY OF REGION DATA
      DO 410 I=1,9
      IF(IABS(IN(I)).LE.NBODY+NRPP)GOTO 410
      WRITE (6,922)IR,I
      J=J+1
  410 CONTINUE
C
C     STORE REGION DATA
C
      IF(IR)440,420,421
  420 WRITE (6,923)(IA(I),IN(I),I=1,9)
      GOTO 430
  421 N=N+1
```

```
      WRITE (6,924)IR,(IA(I),IN(I),I=1,9)
      M=LREGD+N-1
      MASTER(M)=LDATA*115
C         CHECK OPERATOR
  430 DO 435 I=1,9
      DO 431 K=1,8
      IF(IA(I).EQ.IAA(K))GOTO 432
  431 CONTINUE
      WRITE (6,925)IA(I),I
      STOP
  432 IA(I)=IAM(K)
      IF(IN(I))433,400,434
  433 IA(I)=4+IA(I)
      IN(I)=-IN(I)
  434 MASTER(LDATA)=IA(I)*115+IN(I)
      LDATA=LDATA+1
      MASTER(M)=MASTER(M)+1
      IF(LDATA.LT.NDQ)GOTO 435
      WRITE (6,927)LDATA,NDQ
      STOP
  435 CONTINUE
      GOTO 400
C
C     END REGION READ
C
  440 IF(N.GE.NRMAX)GOTO 441
      WRITE (6,926)IR
      STOP
  441 IF(J.LE.0)GOTO 442
      WRITE (6,941)
      STOP
  442 WRITE (6,928)
C
C     IF(IRCHEK.NE.0)TEST REGION DATA
C         (ERROR IF POINT CAN BE IN MORE THAN 1 REGION)
C
      IF(IRCHEK.EQ.NO)GOTO 500
      WRITE (6,937)
      LL=0
      MIS=0
C
      DO 456 I=1,NRMAX
      JJ=I+1
      DO 455 J=JJ,NRMAX
      KRI=LREGD+I-1
      CALL UN2(KRI,LOCI,NUMI)
      KRJ=LREGD+J-1
      CALL UN2(KRJ,LOCJ,NUMJ)
      IF(NUMI.GE.NUMJ)GOTO 450
      IO=NUMI
      II=NUMJ
      GOTO 451
  450 IO=NUMJ
      II=NUMI
      L=LOCI
      LOCI=LOCJ
      LOCJ=L
C
  451 DO 453 KO=1,IO
      KLK=LOCI+KO-1
```

```
      CALL UN2(KLK,IOPO,NBO)
      DO 452 KI=1,II
      KLK=LOCJ+KI-1
      CALL UN2(KLK,IOPI,NBI)
      IF(IOPO.NE.IOPI)GOTO 452
      IF(NBO .NE.NBI )GOTO 452
      MIS=MIS+1
      GOTO 453
  452 CONTINUE
  453 CONTINUE
      IF(MIS.NE.II)GOTO 454
      WRITE (6,929)J,I
      LL=LL+1
  454 MIS=0
  455 CONTINUE
      WRITE (6,930)I
  456 CONTINUE
      IF(LL.GT.0)STOP
      WRITE (6,937)
C
C     IS=+1    ENTERING TABLE STORED BY I15
C       WHICH REGIONS (J) A RAY MIGHT BE IN IF IT
C            ENTERS A GIVEN BODY (I)
C     IS=-1    LEAVING TABLE STORED BY 1
C       WHICH REGIONS (J) A RAY MIGHT GO INTO IF IT
C            LEAVES A GIVEN BODY (I)
C
  500 IS=-1
      NN=NBODY+NRPP
      LENLV=LDATA
      DO 590 MMM=1,2
      DO 580 I=1,NN
      M=LBODY+3*(I-1)
      IF(IS.GE.0)GO TO 510
      MASTER(M+1)=MASTER(M+1)+LDATA
      GO TO 520
  510 MASTER(M+1)=MASTER(M+1)+LDATA*I15
C
  520 DO 570 J=1,NRMAX
      ITEMP=LREGD+J-1
      CALL UN2(ITEMP,LOC,NC)
      CALL UN2(LOC,IOP,DUM)
      DO 560 N=1,NC
      MM=LOC+N-1
      CALL UN2(MM,IOPER,NUM)
      IF(NUM.NE.I)GOTO 560
      IF(IOP.EQ.1.OR.IOP.EQ.5)GOTO 540
      IF(IOPER.GT.4)GOTO 530
      IF(IS-1)560,550,560
  530 IF(IS+1)560,551,560
  540 IF(IS.LT.0)GOTO 551
  550 MASTER(M+2)=MASTER(M+2)+I15
      GO TO 552
  551 MASTER(M+2)=MASTER(M+2)+1
  552 MASTER(LDATA)=J
      LDATA=LDATA+1
      IF(LDATA.LT.NDQ)GOTO 570
      WRITE (6,931)LDATA,NDQ,MMM,I
      STOP
  560 CONTINUE
```

```
  570 CONTINUE                                                          GENI 602
  580 CONTINUE                                                          GENI 603
      WRITE (6,938)MMM                                                  GENI 604
      IS=IS+2                                                           GENI 605
  590 CONTINUE                                                          GENI 606
C          RIN STORAGE      ROUT STORAGE      G1 TEMP STORAGE           GENI 607
      L1=LDATA-1                                                        GENI 608
      NN=NRPP+NBODY                                                     GENI 609
      LRIN=LDATA+1                                                      GENI 610
      LROT=LRIN+NN                                                      GENI 611
      LIO=LROT+NN                                                       GENI 612
      LEGEOM=LIO+NN                                                     GENI 613
      WRITE (6,932)LEGEOM                                               GENI 614
      WRITE (6,919)LREGD,LREGL,LENLV,LRIN,LROT,LIO,LEGEOM               GENI 615
C                                                                       GENI 616
C     PRINT ENTERING AND LEAVING TABLE                                  GENI 617
C                                                                       GENI 618
      IF(IENTLV.EQ.NO)RETURN                                            GENI 619
      WRITE(6,946)                                                      GENI 620
      NBNR=NBODY+NRPP                                                   GENI 621
C                                                                       GENI 622
      DO 600 N=1,NBNR                                                   GENI 623
      LOC=LBODY+3*(N-1)                                                 GENI 624
      LOC=LOC+1                                                         GENI 625
      CALL UN2(LOC,LENT,LEAV)                                           GENI 626
      LOC=LOC+1                                                         GENI 627
      CALL UN2(LOC,NENT,NEAV)                                           GENI 628
      J1=LENT                                                           GENI 629
      J2=LENT+NENT-1                                                    GENI 630
      WRITE (6,933)N,J1,J2,(MASTER(K),K=J1,J2)                          GENI 631
      J1=LEAV                                                           GENI 632
      J2=LEAV+NEAV-1                                                    GENI 633
      WRITE (6,934)N,J1,J2,(MASTER(K),K=J1,J2)                          GENI 634
  600 CONTINUE                                                          GENI 635
C                                                                       GENI 636
C     MASTER-ASTER ARRAY OUTPUT                                         GENI 637
C                                                                       GENI 638
      IF(IPRIN.EQ.0)RETURN                                              GENI 639
      WRITE (6,935)                                                     GENI 640
C                                                                       GENI 641
      DO 620 K=LBASE,L1,3                                               GENI 642
      IK=K                                                              GENI 643
      IK2=K+2                                                           GENI 644
      M=0                                                               GENI 645
      DO 610 I=IK,IK2                                                   GENI 646
      M=M+1                                                             GENI 647
      CALL UN2(I,I1,I2)                                                 GENI 648
      NO1(M)=I1                                                         GENI 649
      NO2(M)=I2                                                         GENI 650
      O4(M)=ASTER(I)                                                    GENI 651
      NOO(M)=I                                                          GENI 652
  610 CONTINUE                                                          GENI 653
      WRITE (6,936)(NOO(L),NO1(L),NO2(L),O4(L),L=1,3)                   GENI 654
  620 CONTINUE                                                          GENI 655
      RETURN                                                            GENI 656
      END                                                               GENI 657
C                                                                       GENI 658
C                                                                       GENI 659
      SUBROUTINE RPPIN(LAR)                                             ****  15
      DIMENSION MASTER(30000),X(6)                                      RPPIN  2
```

```
      COMMON ASTER(30000)
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1    LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/RRPP/LRPPD,LABUT
      EQUIVALENCE(MASTER,ASTER)
C
  910 FORMAT(6F12.6)
  920 FORMAT(I8,17X,6F12.5)
  930 FORMAT(1H0,27HERROR IN DESCRIPTION OF RPP,I5,5X,10HMIN.GE.MAX)
  940 FORMAT(1H0,27HERROR IN DESCRIPTION OF RPP,7X,I10,10X,I10)
  950 FORMAT(10X,7HSURFACE,I5,8X,2E20.6)
C
C     N IS RPP NUMBER      J IS SURFACE NUMBER
C
C     MASTER-ASTER STORAGE FOR RPP
C
C     LBASE - RPP POINTERS            RESERVE  12 WORDS/RPP
C         /  I  /  J  /
C         /     /  K  /
C              I  (POINTER TO LIST OF ABUTING RPP'S)
C              J  (NUM OF RPP'S THAT ABUT THIS SURFACE)
C              K  (POINTER TO MIN OR MAX CORRESPONDING
C                 TO THIS SURFACE)
C
C     LRPPD - RPP DATA STARTING AT LBASE + 12 * NRPP
C         MIN OR MAX      K POINTS HERE
C
C     LABUT TO LBODY-1
C         LIST OF ABUTING RPP'S PACKED 1 OR 2/WORD
C         I POINTS HERE     /  1  /  2  /
C         J CONTAINS NUMBER IN LIST
C
      IERR=0
      N=1
      I=LBASE+12*NRPP
      LRPPD=I
   10 READ(5,910)(X(J),J=1,6)
      WRITE (6,920)N,(X(J),J=1,6)
      DO 20 J=1,6,2
      IF(X(J).LT.X(J+1))GOTO 20
      WRITE (6,930)N
      STOP
   20 CONTINUE
C
C     STORE MIN AND MAX BEGINNING AT LBASE + 12 * NRPP
C
      DO 33 J=1,6
      II=LBASE+12*NRPP
      L=LBASE+12*(N-1)+2*(J-1)
   30 IF(II.LT.I)GOTO 31
      ASTER(I)=X(J)
      MASTER(L+1)=I
      I=I+1
      GOTO 33
C         CHECK FOR DUPLICATION
   31 IF(X(J).EQ.ASTER(II))GOTO 32
      II=II+1
      GOTO 30
   32 MASTER(L+1)=II
```

```
   33 CONTINUE
      IF(N.GE.NRPP)GOTO 40
      N=N+1
      GOTO 10
C
   40 LABUT=I
      LAST=I-1
      L=LAST
C
C     SEARCH FOR ABUTING RPP'S TO SURFACE
C
      DO 57 I=1,NRPP
      DO 57 N=1,6
      LL=0
      M=1
      K=LBASE+12*(I-1)+2*(N-1)
      MASTER(K)=(L+1)*I15+MASTER(K)
      NC=3*N-1-4*(N/2)
      DO 56 J=1,NRPP
      IF(I.EQ.J)GOTO 56
      IF(S(I,N).NE.S(J,NC))GOTO 56
C
      DO 53 K=1,3
      NN=N+NC
      K41=4*K-1
      IF(NN.EQ.K41)GOTO 53
      K2=2*K
      K21=K2-1
      IF(S(I,K21).GT.S(J,K21))GOTO 50
      IF(S(J,K21).LT.S(I,K2 ))GOTO 53
   50 IF(S(I,K21).GE.S(J,K2 ))GOTO 51
      IF(S(J,K2 ).LE.S(I,K2 ))GOTO 53
   51 IF(S(I,K2 ).GT.S(J,K2 ))GOTO 56
      IF(S(I,K21).LT.S(J,K21))GOTO 56
   53 CONTINUE
      M=-M
      IF(M.LT.0)GOTO 54
      MASTER(L)=MASTER(L)+J
      GOTO 55
   54 L=L+1
      MASTER(L)=J*I15
   55 LL=LL+1
   56 CONTINUE
      K=LBASE+12*(I-1)+2*(N-1)
      MASTER(K)=MASTER(K)+LL
   57 CONTINUE
C
C     TEST VALIDITY OF RPP DATA
C
      IF(NRPP.LE.1)GOTO 63
C
      DO 62 J=1,6
      NRPP1=NRPP-1
      DO 61 I=1,NRPP1
      JJ=LBASE+12*(I-1)+2*(J-1)
      CALL UN2(JJ,IDUM,I2)
      I3=MASTER(JJ+1)
      IF(I2.NE.0)GOTO 61
      II=I+1
      DO 60 K=II,NRPP
```

```
      KK=LBASE+12*(K-1)+2*(J-1)
      CALL UN2(KK,IDUM,I5)
      I6=MASTER(KK+1)
      IF(I5.NE.0)GOTO 60
      IF(I3.EQ.I6)GOTO 60
      IERR=IERR+1
      WRITE (6,940)I,K
      WRITE (6,950)J,ASTER(I3),ASTER(I6)
   60 CONTINUE
      GOTO 62
   61 CONTINUE
   62 CONTINUE
   63 LAR=L
      RETURN
      END
C
C
      SUBROUTINE ALBERT(FX,LBOT,NDQ,LS1)
      DIMENSION MASTER(30000),IA(6,4),AA(8,3),F(4),FX(6)
      COMMON ASTER(30000)
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCCA,I15,I30,LBODY,NASC,KLOOP
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      EQUIVALENCE(ASTER,MASTER)
C
  901 FORMAT(25X,6F12.5)
  902 FORMAT(10X,6(1X,4I1))
  903 FORMAT(10X,6E10.3)
  904 FORMAT(25X,6(4X,4I2))
  905 FORMAT(1H0,15HUNDEFINED PLANE)
  906 FORMAT(I5,10(E11.4))
  907 FORMAT(1H0,26HFOUR POINTS NOT IN A PLANE)
  908 FORMAT(1H0,25HERROR IN SIDE DESCRIPTION)
  909 FORMAT(1H0,16HDEGENERATE PLANE,I5)
C
      K=1
      DO 10 I=1,2
      DO 10 J=1,3
      AA(I,J)=FX(K)
      K=K+1
   10 CONTINUE
      READ(5,903)((AA(I,J),J=1,3),I=3,8)
      READ(5,902)((IA(I,J),J=1,4),I=1,6)
      WRITE  (6,901)((AA(I,J),J=1,3),I=3,8)
      WRITE  (6,904)((IA(I,J),J=1,4),I=1,6)
C
      DO 70 I=1,6
      IX=IA(I,1)
      IY=IA(I,2)
      IZ=IA(I,3)
      X1=AA(IX,1)
      Y1=AA(IX,2)
      Z1=AA(IX,3)
      X2=AA(IY,1)
      Y2=AA(IY,2)
      Z2=AA(IY,3)
      X3=AA(IZ,1)
      Y3=AA(IZ,2)
      Z3=AA(IZ,3)
      D=X1*(Y2*Z3-Z2*Y3)-X2*(Y1*Z3-Z1*Y3)+X3*(Y1*Z2-Z1*Y2)
```

```
      A=(-Y2*Z3+Z2*Y3+Y1*Z3-Z1*Y3-Y1*Z2+Z1*Y2)
      B=(X2*Z3-Z2*X3-X1*Z3+X3*Z1+X1*Z2-Z1*X2)
      C=(Y2*X3-X2*Y3-Y1*X3+X1*Y3+Y1*X2-X1*Y2)
      D12=(X1-X3)**2+(Y1-Y3)**2+(Z1-Z3)**2
      A2B2C2=A*A+B*B+C*C
      IF(A2B2C2.NE.0.)GOTO 21
      WRITE (6,909)I
      D=ABS(D)
      GOTO 61
   21 D1210=D12*1.0E-12
      IF(A2B2C2.GT.D1210)GOTO 22
      WRITE (6,905)
      WRITE (6,906)I,A,B,C,D,D12
      IERR=IERR+1
      GOTO 70
   22 S=SQRT(A2B2C2)
      WX=A/S
      WY=B/S
      WZ=C/S
      IC=IA(I,4)
      X4=AA(IC,1)
      Y4=AA(IC,2)
      Z4=AA(IC,3)
      D2=(-D-(A*X4)-(B*Y4)-(C*Z4))/((A*WX)+(B*WY)+(C*WZ))
      D22=D2*D2
C          THE NEXT CARD BYPASSES THE 4TH POINT TEST
C     IF(D22.LE.0.01)GOTO 30 $ PRINT 907 $ IERR=IERR+1
      IF(D22.LE.1.01)GOTO 30
      WRITE (6,907)
      IERR=IERR+1
      WRITE (6,906)I,A,B,C,D,D12,D2
      GOTO 70
C
   30 DO 31 K=1,4
      F(K)=0.
   31 CONTINUE
      L=1
      DO 32 J=1,8
      IF(J.EQ.IX.OR.J.EQ.IY.OR.J.EQ.IZ.OR.J.EQ.IC)GOTO 32
      F(L)=A*AA(J,1)+B*AA(J,2)+C*AA(J,3)+D
      L=L+1
   32 CONTINUE
      M=0
      N=0
      J=0
C
      DO 44 L=1,4
      IF(ABS(F(L)).LE.1.0E-6)GOTO 42
      IF(F(L))41,42,43
   41 M=M+1
      GOTO 44
   42 N=N+1
      GOTO 44
   43 J=J+1
   44 CONTINUE
C
      IF(N.EQ.0)GOTO 51
      IF(M+N.EQ.4)GOTO 60
      IF(J+N.EQ.4)GOTO 61
      GOTO 52
```

```
   51 IF(M.EQ.4)GOTO 60
      IF(J.EQ.4)GOTC 61                                                 ALBER104
   52 WRITE (6,908)                                                     ALBER105
      WRITE (6,906)I,A,B,C,D,D12,D2,(F(L),L=1,4)                        ALBER106
      IERR=IERR+1                                                       ALBER107
      GOTO 70                                                           ALBER108
C                                                                       ALBER109
   60 A=-A                                                              ALBER110
      B=-B                                                              ALBER111
      C=-C                                                              ALBER112
      D=-D                                                              ALBER113
   61 CALL SEE3(IWH,ASTER,MASTER,A,B,C,LBOT,LDATA,NDQ,LS1)              ALBER114
      MASTER(LDATA)=IWH                                                 ALBER115
      LS1=1                                                             ALBER116
      CALL SEE3(IWH,ASTER,MASTER,D,D,D,LBOT,LDATA,NDQ,LS1)              ALBER117
      LS1=0                                                             ALBER118
      MASTER(LDATA)=MASTER(LDATA)+IWH*I15                               ALBER119
      LDATA=LDATA+1                                                     ALBER120
   70 CONTINUE                                                          ALBER121
      RETURN                                                            ALBER122
      END                                                               ALBER123
C                                                                       ALBER124
C                                                                       ALBER125
      SUBROUTINE ARIN(LBOT,LDATA,MASTER,ASTER,IWH)                      ALBER126
      DIMENSION MASTER(30000),ASTER(30000)                              ****  17
      COMMON/UNCLE/NN,IC(4)                                             ARIN   2
C                                                                       ARIN   3
C          SEE ARS SUBROUTINE FOR STORAGE IN MASTER-ASTER ARRAY         ARIN   4
C                                                                       ARIN   5
  901 FORMAT(10X,2I10)                                                  ARIN   6
  902 FORMAT(10X,6E10.3)                                                ARIN   7
  903 FORMAT(I8,1X,3A1,2X,3HARS,2X,A4,6X,19HNUMBER OF CURVES IS,I6,     ARIN   8
     1     5X,29HNUMBER OF POINTS PER CURVE IS,I6/)                     ARIN   9
  904 FORMAT(25X,6F12.5)                                                ARIN  10
C                                                                       ARIN  11
C       MAX = NUM OF CURVES                                             ARIN  12
C       NAX = NUM OF POINTS/CURVE                                       ARIN  13
C                                                                       ARIN  14
      READ(5,901)MAX,NAX                                                ARIN  15
      WRITE (6,903)NN,(IC(I),I=1,4),MAX,NAX                             ARIN  16
      LBOT=LBOT-4*MAX*NAX-92                                            ARIN  17
      IWH=LBOT                                                          ARIN  18
      MASTER(LDATA)=IWH                                                 ARIN  19
      LDATA=LDATA+1                                                     ARIN  20
C                                                                       ARIN  21
      DO 50 M=1,MAX                                                     ARIN  22
      L1=LBOT+92+4*NAX*(M-1)                                            ARIN  23
      L2=L1+4*NAX-1                                                     ARIN  24
      READ(5,902)(ASTER(L),ASTER(L+1),ASTER(L+2),L=L1,L2,4)             ARIN  25
      WRITE (6,904)(ASTER(L),ASTER(L+1),ASTER(L+2),L=L1,L2,4)           ARIN  26
      WRITE (6,904)                                                     ARIN  27
   50 CONTINUE                                                          ARIN  28
      MASTER(LBOT)=0                                                    ARIN  29
      MASTER(LBOT+1)=MAX                                                ARIN  30
      MASTER(LBOT+2)=NAX                                                ARIN  31
      RETURN                                                            ARIN  32
      END                                                               ARIN  33
C                                                                       ARIN  34
C                                                                       ARIN  35
      SUBROUTINE SEE3(IWH,ASTER,MASTER,FX,FXX,FXXX,LBOT,LDATA,NDQ,LS1)  ARIN  36
                                                                        ****  18
```

```
      DIMENSION ASTER(30000),MASTER(30000)
C
C     STORES TRIPLETS AND SCALARS IN MASTER-ASTER ARRAY
C
      IF(LS1.NE.0)GOTO 50
C         TRIPLETS
      IF(LBOT.GT.NDQ)GOTO 20
      NDQ2=NDQ-2
      DO 10 I=LBOT,NDQ2
      IF(ASTER(I).NE.FX)GOTO 10
      IF(ASTER(I+1).NE.FXX)GOTO 10
      IF(ASTER(I+2).NE.FXXX)GOTO 10
      IWH=I
      RETURN
   10 CONTINUE
   20 ASTER(LBOT-1)=FXXX
      ASTER(LBOT-2)=FXX
      ASTER(LBOT-3)=FX
      LBOT=LBOT-3
      IWH=LBOT
      IF(LBOT.LE.LDATA)WRITE (6,30)LBOT,LDATA
      RETURN
   30 FORMAT(1H0,22HMEMORY OVERLAP IN SEE3,5X,5HLBOT=,I10,
     1  5X,6HLDATA=,I10)
C
C         SCALARS
   50 DO 60 I=LBOT,NDQ
      IF(ASTER(I).NE.FX)GOTO 60
      IWH=I
      RETURN
   60 CONTINUE
      ASTER(LBOT-1)=FX
      LBOT=LBOT-1
      IWH=LBOT
      RETURN
      END
C
C
      FUNCTION S(I,N)
      DIMENSION MASTER(30000)
      COMMON ASTER(30000)
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      EQUIVALENCE(MASTER,ASTER)
C
C     S RETRIEVES COORDINATES OF ANY OF THE 6 SIDES OF AN RPP
C     I IS RPP NUMBER      N IS SURFACE NUMBER
C
      L=LBASE+12*(I-1)+2*(N-1)
      LL=MASTER(L+1)
      S=ASTER(LL)
      RETURN
      END
C
C
      SUBROUTINE CONVRT(FX,IX,LE)
      DIMENSION FX(6),IX(6)
C         LE NUMBER OF REFERENCES TO SCALARS AND TRIPLETS
C         INTEGRAL PART OF FX CONVERTED TO FIXED POINT NUM IN IX(I)
C         FRACTIONAL PART OF FX CONVERTED TO FIXED POINT NUM IN IX(I1)
      NFX=(LE+1)/2
```

```
      DO 10 IFX=1,NFX
      I1=2*IFX
      I=I1-1
      IX(I)=FX(IFX)+.000001
      X=IX(I)
      IX(I1)=(FX(IFX)-X)*100000.+.00001
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE GRID
      DIMENSION WP(3)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/GTRACK/D1,D2,KHIT,LMAX,TR(200),XBS(3),IRSTRT,IENC,
     1  ITR(200),CA,CE,SA,SE
      COMMON/CAL/NIR,SIN,ANGLE,NTYPE,SSPACE,L,XS(3),WS(3),
     1  TRAVEL,SN,V,H,IVIH
      COMMON/WALT/LIRFO,NG1ERR
      COMMON/HOYT/VREF,HREF
      COMMON/CELL/CELSIZ
      COMMON/CONTRL/ITESTG,IRAYSK,IENTLV,IVOLUM,IWOT,ITAPE8,NO,IYES
C
  901 FORMAT(8I10)
  902 FORMAT(6E12.8)
  903 FORMAT(1H0,2HNX,I5,5X,2HNY,I5,5X,7HIRSTART,I5,5X,4HIENC,I5,5X,
     1     6HNSTART,I6,5X,4HNEND,I6,5X,9HCELL SIZE,F7.2//
     2     17H DATUM LINE AT Z=,F10.3,27H WITH RESPECT TO THE ORIGIN/
     3     17H GROUND IS  AT Z=,F10.3,27H WITH RESPECT TO THE ORIGIN/
     4     17H XSHIFT IS  AT X=,F10.3,27H WITH RESPECT TO THE ORIGIN/
     5     17H YSHIFT IS  AT Y=,F10.3,27H WITH RESPECT TO THE ORIGIN/)
  904 FORMAT(1H ,7HAZIMUTH,F12.5,5X,9HELEVATION,F12.5,5X,
     1     13HBACK OFF DIST,F12.5)
  905 FORMAT(2E20.8,4E10.3)
  906 FORMAT(52H0THIS RAY WAS SUPPRESSED BECAUSE IT WAS BELOW GROUND)
  907 FORMAT(1H0,I5,15H  CELLS SKIPPED)
C
      READ (5,901)NX,NY,IRSTRT, IENC,NG1ERR,NSTART,NEND
      READ (5,902)A,E,ENGTH,ZSHIFT,GROUND
      READ (5,902)XSHIFT,YSHIFT,CELSIZ
      IF(IRSTRT .LE.0)IRSTRT=1
      IF(CELSIZ .LE.0.)CELSIZ=4.
      IF(NSTART.LE.0)NSTART=1
      IF(NEND.LE.NSTART)NEND=NX*NY
      IF(NG1ERR.LE.0)NG1ERR=25
C
      WRITE (6,903)NX,NY,IRSTRT, IENC,NSTART,NEND,CELSIZ,
     1     ZSHIFT,GROUND,XSHIFT,YSHIFT
      IF(IWOT.EQ.IYES)WRITE(1,905)A,E,XSHIFT,YSHIFT,ZSHIFT,CELSIZ
      WRITE (6,904)A,E,ENGTH
      RADIAN=.017453292519943
      AR=A*RADIAN
      ER=E*RADIAN
      WRITE (6,904)AR,ER,ENGTH
      SA=SIN(AR)
      CA=COS(AR)
      SE=SIN(ER)
```

```
      CE=COS(ER)
C
C       PROCESS KL CELLS IN GRID
C
      DO 40 KK=NSTART,NEND
      WB(1)=-CE*CA
      WB(2)=-CE*SA
      WB(3)=-SE
      II=((KK-1)/NX)+1
      J=KK-(II-1)*NX
C          COMPUTE COORDINATES OF GRID CELL IN GRID PLANE
      CELL2=.5*CELSIZ
      V=FLOAT((NY/2)-II)*CELSIZ +CELL2
      VREF=V+CELL2
      H=FLOAT((NX/2)- J)*CELSIZ +CELL2
      HREF=H+CELL2
      IV=RAN(-1)*10.
      IH=RAN(-1)*10.
      IVIH=10*IH+IV
C          COMPUTE H,V AT RANDOM POINT IN GRID CELL
      V=V+CELSIZ *FLOAT(IV)/10.+CELSIZ /20.
      H=H+CELSIZ *FLOAT(IH)/10.+CELSIZ /20.
C          X,Y,Z IN COORDINATE SYSTEM OF VEHICLE
      XBS(1)=XSHIFT-V*CA*SE-H*SA
      XBS(2)=YSHIFT-V*SA*SE+H*CA
      XBS(3)=ZSHIFT+V*CE
      CALL TROPIC(WP)
      XBS(1)=XBS(1)+WP(1)*1.0E-4
      XBS(2)=XBS(2)+WP(2)*1.0E-4
      XBS(3)=XBS(3)+WP(3)*1.0E-4
      XB(1)=XBS(1)-ENGTH*WB(1)
      XB(2)=XBS(2)-ENGTH*WB(2)
      XB(3)=XBS(3)-ENGTH*WB(3)
      IF(XB(3).GT.GROUND)GOTO 10
      IF(ITAPE8.EQ.IYES)WRITE (6,906)
      GOTO 40
   10 DO 20 KK1=1,3
      XS(KK1)=XB(KK1)
      WS(KK1)=WB(KK1)
   20 CONTINUE
      CALL TRACK
      IF(IERR.GE.NGIERR)RETURN
      IF(IRAYSK.EQ.NO)GOTO 40
      MSHIFT=RAN(-1)*25.
      WRITE (6,907)MSHIFT
      KK=KK+MSHIFT
   40 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE TRACK
      DIMENSION XP(3),ERROR(2)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/GTRACK/D1,D2,KHIT,LMAX,TR(200),XBS(3),IRSTRT,IENC,
     1  ITR(200),CA,CE,SA,SE
```

```
      COMMON/CAL/NIR,SIN,ANGLE,NTYPE,SSPACE,L,XS(3),WS(3),TRAVEL,       TRACK  9
     1  SN,V,H,IVIH                                                      TRACK 10
      COMMON/CONTRL/ITESTG,IRAYSK,IENTLV,IVOLUM,IWOT,ITAPE8,NO,IYES     TRACK 11
      COMMON/WALT/LIRFO,NG1ERR                                           TRACK 12
      COMMON/HOYT/VREF,HREF                                              TRACK 13
      COMMON/LSU/LSURF                                                   TRACK 14
      COMMON/CELL/CELSIZ                                                 TRACK 15
      COMMON/ERR/IERRO                                                   TRACK 16
C                                                                        TRACK 17
  901 FORMAT(F6.1,1X,F6.1,1X,I2,1X,F7.2,1X,F7.2,4(1X,I1),I3,1X,2I3,    TRACK 18
     1     1X,F8.3,1X,F8.3)                                              TRACK 19
  902 FORMAT(2(I4,F7.2,F7.2,F6.1,I3,F7.2),1X,2I3,1X,I1,I1,I2,4X,A6)    TRACK 20
  903 FORMAT(31H NUMBER OF INTERSECTIONS.GT.200)                         TRACK 21
  904 FORMAT(//)                                                         TRACK 22
  905 FORMAT(1HO,16HO ITEM IN CELL (,I4,1H,,I4,1H),5X,                   TRACK 23
     1     2HH=,F6.1,5X,2HV=,F6.1)                                       TRACK 24
C                                                                        TRACK 25
      ERROR(2)= 6HO ITEM                                                 TRACK 26
      DATA ERROR(1),ERROR(2)/4H    ,4HITEM/                              TRACK 27
      I12=4096                                                           TRACK 28
      NASC=-1                                                            TRACK 29
      IR=IRSTRT                                                          TRACK 30
      L=1                                                                TRACK 31
      KHIT=0                                                             TRACK 32
      JCNT=0                                                             TRACK 33
      MSKRT=0                                                            TRACK 34
      MTARG=1                                                            TRACK 35
      MARMR=0                                                            TRACK 36
      MVOL =0                                                            TRACK 37
C                                                                        TRACK 38
      DO 10 I=1,200                                                      TRACK 39
      ITR(I)=0                                                           TRACK 40
      TR(I)=0.                                                           TRACK 41
   10 CONTINUE                                                           TRACK 42
C                                                                        TRACK 43
C     S1 IS DISTANCE THRU REGION IR                                      TRACK 44
C     IRPRIM IS NEW REGION NUMBER                                        TRACK 45
C     XP IS POINT OF CONTACT                                             TRACK 46
C                                                                        TRACK 47
   20 CALL G1(S1,IRPRIM,XP)                                              TRACK 48
      IF(IRPRIM.LT.0)RETURN                                              TRACK 49
      TR(L)=S1                                                           TRACK 50
      KLSURF=LSURF+7                                                     TRACK 51
      LOC=LIRFO+IR-1                                                     TRACK 52
      CALL UN2(LOC,DUM,IDENT)                                            TRACK 53
      IDENT=IDENT-1                                                      TRACK 54
C          / SURFACE NUM / BODY NUM / NEXT REGION /                      TRACK 55
      ITR(L)=(KLSURF*I12+NASC)*I12+IRPRIM                                TRACK 56
      IF(NASC.LE.NRPP)IRPRIM=0                                           TRACK 57
      IF(IRPRIM.EQ.0)GOTO 100                                            TRACK 58
      IR=IRPRIM                                                          TRACK 59
      KHIT=KHIT+1                                                        TRACK 60
      IF(L.GT.1)GOTO 40                                                  TRACK 61
      SUM=0.                                                             TRACK 62
      DO 30 I=1,3                                                        TRACK 63
      SUM=SUM+WS(I)*XP(I)                                                TRACK 64
   30 CONTINUE                                                           TRACK 65
      D1=-SUM                                                            TRACK 66
      GOTO 60                                                            TRACK 67
C                                                                        TRACK 68
```

```
C      CHECK IDENT CODE     0 NONE
C          10=SKIRT     20=ARMOR     30=TARGET
C          SPACE CODES     1 EXTERIOR VOLUME
C              -1,2-9,11-19,21-29,......,91-99 INTERIOR VOLUME
C
   40 IF(IDENT.EQ.0)GOTO 60
      IF(IDENT-(IDENT/10)*10.EQ.0)GOTO 50
      KHIT=KHIT-1
      IF(IDENT.NE.1)MVOL=1
      GOTO 60
C
   50 IF(IDENT.EQ.20)MARMR=1
      IF(IDENT.EQ.30)MTARG=1
      IF(IDENT.EQ.10)MSKRT=1
   60 L=L+1
      IF(L.LE.200)GOTO 20
      WRITE (6,903)
      STOP
C
C      END OF RAY     PRINT RESULTS
C
  100 IF(L.EQ.1)RETURN
      IF(ITAPE8.EQ.NO.AND.IWOT.EQ.NO)RETURN
      D2=XDIST(XBS,XP)-S1
      D2=-D2
      IF(KHIT.GT.0)GOTO 105
      KHIT=KHIT+1
      MTARG=0
  105 KHIT=KHIT-1
      IH=ABS(H/CELSIZ )+.5
      IF(H.LT.0.)IH=-IH
      IV=ABS(V/CELSIZ )+.5
      IF(V.LT.0.)IV=-IV
C          PRINT CARD NUM 1
      IF(ITAPE8.EQ.NO)GOTO 110
      WRITE (6,904)
      WRITE (6,901)HREF,VREF,IVIH,D1,D2,MSKRT,MTARG,MARMR,MVOL,
     1     KHIT,IH,IV,H,V
  110 IF(IWOT.EQ.IYES)WRITE(1,901)HREF,VREF,IVIH,D1,D2,MSKRT,MTARG,
     1     MARMR,MVOL,KHIT,IH,IV,H,V
C
C       PROCESS COMPONENT CARDS
C
      LMAX=L
      L=0
      TRAVEL=TR(1)
C
C      NIR      REGION IDENTIFICATION(VEHICLE COMPONENT)
C      SIN      LINE-OF-SIGHT DISTANCE
C      ANGLE    OBLIQUITY ANGLE
C      SN       NORMAL DISTANCE THRU REGION
C      NTYPE    TYPE OF SPACE AFTER NIR(NONE=0,END RAY=9)
C      SSPACE   LINE-OF-SIGHT DISTANCE THRU SPACE
C
      DO 200 KIK=1,LMAX,2
      JERRO=1
      L=L+1
      IF(L.GE.LMAX)RETURN
      CALL CALC
      IF(NIR.NE.0)GOTO 113
```

```
      JERRO=2
      IERRO=IERRO+1
  113 IF(SSPACE.NE.0.)JCNT=JCNT+1
      NIR1=NIR
      SIN1=SIN
      ANGLE1=ANGLE
      SN1=SN
      NTYPE1=NTYPE
      SSPACE1=SSPACE
C          SECOND HALF OF CARD
      L=L+1
      IF(L.LT.LMAX)GOTO 115
      NIR=0
      SIN=0.
      ANGLE=0.
      SN=0.
      NTYPE=0
      SSPACE=0.
      GOTO 120
  115 CALL CALC
      IF(NIR.NE.0)GOTO 117
      JERRO=2
      IERRO=IERRO+1
  117 IF(SSPACE.EQ.0.)GOTO 130
  120 JCNT=JCNT+1
  130 I1=0
      I2=0
      N=L-JCNT
C
C     TRACK FLAG    501 IS TRACK EDGE    502 IS TRACK FACE
C     10 IN. NORMAL THICKNESS IS CUTOFF
C
      IF(NIR1.NE.501)GOTO 140
      IF(SN1.LT.10.)NIR1=502
  140 IF(NIR.NE.501)GOTO 150
      IF(SN .LT.10.)NIR=502
C
C     PRINT COMPONENT CARD
C
  150 IF(IWOT.EQ.IYES)WRITE(1,902)NIR1,SIN1,SN1,ANGLE1,NTYPE1,SSPACE1,
     1    NIR,SIN,SN,ANGLE,NTYPE,SSPACE,IH,IV,I1,I2,N
      IF(ITAPE8.EQ.IYES)WRITE(6,902)NIR1,SIN1,SN1,ANGLE1,NTYPE1,SSPACE1,
     1    NIR,SIN,SN,ANGLE,NTYPE,SSPACE,IH,IV,I1,I2,N,ERROR(JERRO)
      IF(ITAPE8.EQ.NO.AND.JERRO.EQ.2)WRITE(6,905)IH,IV,HREF,VREF
C
      IF(L.GE.LMAX)RETURN
      IF(NTYPE .EQ.9)RETURN
  200 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE CALC
      DIMENSION MASTER(30000),XP(3),TEMP(3),TEMP1(3),TEM(3),TEM1(3),
     1  XMID(3),IEMP(4),WN(3),WI(3),WA(3),XI(3),AUN(3),HF(3),
     2  VF(3),Q(3),DELTA(3),ARSTP(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
```

```
     1  LDATA,LKIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/TRACK/D1,D2,KHIT,LMAX,TR(200),XBS(3),IRSTRT,IENC,
     1  IIP(3,2),CA,CE,SA,SE
      COMMON/CALC/NIR,SIN,ANGLE,NTYPE,SSPACE,L,XS(3),WS(3),TRAVEL,
     1  SN,V,H,IVIH
      COMMON/WALT/LIRFO,NOIERR
      EQUIVALENCE(MASTER,ASTER)
      REAL NF(3)
C
  901 FORMAT(1H0,15HTHATS ALL FOLKS//)
  902 FORMAT(1H0,17HBAD ITYPE IN CALC,5X,6HITYPE=,I5,4HNBO=,I5/
     1  16H RETURNS TO TRACK//)
  903 FORMAT(1H0,23HARS DID NOT FIND NORMAL)
  904 FORMAT(//5H NORM/5H NIR=,I10,5X,6HITYPE=,I10,5X,4HNBO=,I10,5X,
     1  6HLSURF=,I10/4H WB=,3E20.10/4H WS=,3E20.10/4H XP=,3E20.8/
     2  4H XB=,3E20.10/4H XI=,3E20.10/6H XNOS=,3E20.10)
  905 FORMAT(35H ERROR IN CALC     A TRC HAS R1 = R2 )
  906 FORMAT(42H ERROR IN CALC     BAD LSURF FOR BOX OR RAW )
C
C          / SURFACE NUM / BODY NUM / NEXT REGION /
C
      CALL OPENK(L,LSURF,NBO,NIR)
      IF(NIR.GT.0)GOTO 10
      WRITE (6,901)
      RETURN
C
C     TRAVEL    LINE-OF-SIGHT DIST TO THIS REGION
C     XS        STARTING POINT   (XS=XB)
C     SIN       LINE-OF-SIGHT DIST THRU THIS REGION
C
   10 SIN=TR(L+1)
      DO 20 I=1,3
      XI(I)=XS(I)+TRAVEL*WS(I)
   20 CONTINUE
      TRAVEL=TRAVEL+SIN
      LSURF=LSURF-7
C
      XNOS=1.
      IF(LSURF.LT.0)XNOS=-1.
      LOC=LBODY+3*(NBO-1)
      CALL UN2(LOC,ITYPE,LDATA)
      LSURF=IABS(LSURF)
      ITYPE=ITYPE+1
      IF(ITYPE.GE.1.AND.ITYPE.LE.12)GOTO 30
      WRITE (6,902)ITYPE,NBO
      RETURN
C
C     COMPUTE NORMAL DIST AND OBLIQUITY ANGLE
C
C          RPP BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
   30 GOTO(50,100,150,200,200,300,350,400,450,500,550,600),ITYPE
C
C     CHECK FOR SPACE CODES    IDENT = -1,1-9,11-19,21-29,....,91-99
C
   40 CALL OPENK(L+1,DUM,DUM,NEXREG)
      ISPOT=LIRFO+NEXREG-1
      CALL UN2(ISPOT,DUM,IDENT)
      ISPOT=LIRFO+NIR-1
      CALL UN2(ISPOT,NIR,DUM)
      IDENT=IDENT-1
```

```
C          CHECK FOR SPACE CODES     IDENT = -1,1-9,11-19,21-29,.....
      IF(IDENT-(IDENT/10)*10.NE.0)GOTO 41
      NTYPE=0
      SSPACE=0.
      RETURN
   41 L=L+1
      IF(L+1.LT.LMAX)GOTO 42
      IDENT=9
      SSPACE=1.0E-4
      NTYPE=IDENT
      RETURN
   42 NTYPE=IDENT
      SSPACE=TR(L+1)
      TRAVEL=TRAVEL+SSPACE
      RETURN
C
C     RPP
C
   50 IF(LSURF-2)52,53,54
   52 XNOS=-XNOS
   53 I=1
      GOTO 60
   54 IF(LSURF-4)55,56,57
   55 XNOS=-XNOS
   56 I=3
      GOTO 60
   57 IF(LSURF.GE.6)GOTO 59
      XNOS=-XNOS
   59 I=5
   60 LKK=LBASF+2*I+1
      LV1=MASTER(LKK)
      LKK=LKK+2
      LV2=MASTER(LKK)
      DO 62 J=1,3
      M=J-1
      IJK=M+LV1
      TEMP(J)=ASTER(IJK)
      IJK=M+LV2
      TEMP1(J)=ASTER(IJK)
   62 CONTINUE
      CALL DCOSP(TEMP,TEMP1,WB)
      DO 63 J=1,3
      WB(J)=XNOS*WB(J)
   63 CONTINUE
      GOTO 1000
C
C     BOX
C
  100 CONTINUE
      KCOM=LSURF-(LSURF/2)*2
      IF(KCOM.EQ.0)XNOS=-XNOS
      IF(LSURF-3)104,103,105
  103 I=1
      GOTO 110
  104 I=2
      GOTO 110
  105 IF(LSURF.LT.5)GOTO 103
      I=3
  110 CALL UN2(LDATA,TEMP(4),TEMP(1))
      LDATA=LDATA+1
```

```
      CALL UN2(LDATA,IEMP(2),IEMP(3))
      DO 115 J=1,3
      LH=IEMP(1)
      LV=IEMP(4)
      M=J-1
      IJK=LH+M
      IJK1=LV+M
      TEMP(J)=ASTER(IJK)+ASTER(IJK1)
      MK=J-1+IEMP(4)
      TEMP1(J)=ASTER(MK)
  115 CONTINUE
      CALL DCOSP(TEMP1,TEMP,WB)
      DO 120 J=1,3
      WB(J)=XNOS*WB(J)
  120 CONTINUE
      GOTO 1000
C
C     SPH
C
  150 CALL UN2(LDATA,LV,DUM)
      DO 160 I=1,3
      M=I-1+LV
      TEM(I)=ASTER(M)
  160 CONTINUE
      CALL DCOSP(XI,TEM,WB)
      DO 170 I=1,3
      WB(I)=XNOS*WB(I)
  170 CONTINUE
      GOTO 1000
C
C     RCC
C
  200 IF(LSURF-2)202,201,210
  201 XNOS=-XNOS
  202 CALL UN2(LDATA,LV1,LV2)
      DO 203 I=1,3
      M=I-1
      IJK1=M+LV1
      IJK2=M+LV2
      TEM(I)=ASTER(IJK1)
      TEM1(I)=ASTER(IJK1)+ASTER(IJK2)
  203 CONTINUE
      CALL DCOSP(TEM,TEM1,WB)
      DO 204 I=1,3
      WB(I)=XNOS*WB(I)
  204 CONTINUE
      GOTO 1000
C
C           DIR COS FOR NORMAL TO SURFACE ONE OR TWO
C           NOW HAVE TO GET FROM A POINT TO THE HEIGHT VECTOR
C
  210 CALL UN2(LDATA,LV,LH)
      LR1=MASTER(LDATA+1)
      DO 211 J=1,3
      M=J-1
      IJK=LV+M
      TEM(J)=ASTER(IJK)
      IJK1=LH+M
      TEM1(J)=ASTER(IJK)+ASTER(IJK1)
  211 CONTINUE
```

```
      CALL DCOSP(TEM,XI,WN)
      CALL DCOSP(TEM,TEM1,WI)
      SUM=0.
      DO 212 J=1,3
      SUM=SUM+WN(J)*WI(J)
  212 CONTINUE
      DO 214 J=1,3
      XP(J)=SUM*XDIST(TEM,XI)
      XP(J)=XP(J)*WI(J)+TEM(J)
  214 CONTINUE
      IF(ITYPE.EQ.5)GOTO 250
      CALL DCOSP(XI,XP,WB)
      DO 220 J=1,3
      WB(I)=XNOS*WB(J)
  220 CONTINUE
      GOTO 1000
C
C     REC
C
C     FOR SURFACE 1 AND 2 NORMAL IS SAME AS RCC
C     FOR SURFACE 3 JUMP OUT WHEN XP(I)=POINT ON HEIGHT VECTOR
C
  250 LDATA=LDATA+1
      CALL UN2(LDATA,LR1,LR2)
      DO 255 J=1,3
      M=J-1
      IJK1=M+LR1
      TEMP(J)=ASTER(IJK1)+XP(J)
      IJK2=M+LR2
      TEMP1(J)=ASTER(IJK2)+XP(J)
  255 CONTINUE
      A1=XDIST(XP,TEMP)
      A2=XDIST(XP,TEMP1)
      IF(A1.GE.A2)GOTO 260
      A1=A2
      A3=A1
      A2=A3
      TEMP(1)=TEMP1(1)
      TEMP(2)=TEMP1(2)
      TEMP(3)=TEMP1(3)
  260 C=SQRT(A1*A1-A2*A2)
      CALL DCOSP(XP,TEMP,WN)
      DO 265 J=1,3
      TEM(J)=XP(J)+C*WN(J)
      TEM1(J)=XP(J)-C*WN(J)
  265 CONTINUE
      CALL DCOSP(TEM,XI,WN)
      DO 270 J=1,3
      TEM(J)=2.*A1*WN(J)+TEM(J)
  270 CONTINUE
      CALL DCOSP(TEM,TEM1,WB)
      DO 275 J=1,3
      WB(J)=XNOS*WB(J)
  275 CONTINUE
      GOTO 1000
C
C     TRC
C
  300 IF(LSURF.LE.2)GO TO 320
      CALL UN2(LDATA,LV,LH)
```

```
      LDATA=LDATA+1
      CALL UN2(LDATA,LR1,LR2)
      DIF=ASTER(LR1)-ASTER(LR2)
      IF(DIF)302,301,303
  301 WRITE (6,905)
      STOP
  302 TEMP(1)=LR1
      LR1=LR2
      LR2=TEMP(1)
      DIF=ABS(DIF)
  303 FACTR=ASTER(LR1)/DIF
      DO 304 J=1,3
      M=J-1
      IJK=M+LV
      IJK1=M+LH
      TEMP1(J)=ASTER(IJK)
      TEMP(J)=ASTER(IJK)+FACTR*ASTER(IJK1)
  304 CONTINUE
      TDIS=XDIST(XI,TEMP)
      QDIS=XDIST(TEMP1,TEMP)
      CALL DCOSP(TEMP,XI,WN)
      CALL DCOSP(TEMP,TEMP1,WA)
      SUM=0.
      DO 310 J=1,3
      SUM=WN(J)*WA(J)+SUM
  310 CONTINUE
      QSUM=TDIS/SUM
      QPLS=QDIS-QSUM
      DO 311 J=1,3
      TEMP(J)=-QPLS*WA(J)+TEMP1(J)
  311 CONTINUE
      CALL DCOSP(XI,TEMP,WB)
      DO 312 J=1,3
      WB(J)=XNOS*WB(J)
  312 CONTINUE
      GOTO 1000
C
  320 IF(LSURF.EQ.2)XNOS=-XNOS
      CALL UN2(LDATA,LV,LH)
      DO 321 J=1,3
      M=J-1
      IJK=M+LV
      TEMP(J)=ASTER(IJK)
      IJK1=M+LH
      TEMP1(J)=ASTER(IJK)+ASTER(IJK1)
  321 CONTINUE
      CALL DCOSP(TEMP,TEMP1,WB)
      DO 322 J=1,3
      WB(J)=XNOS*WB(J)
  322 CONTINUE
      GOTO 1000
C
C     ELL
C
  350 CALL UN2(LDATA,LR1,LR2)
      LS=MASTER(LDATA+1)
      DO 352 J=1,3
      M=J-1
      IJK1=M+LR1
      IJK2=M+LR2
```

```
      TEM(J)=ASTER(IJK1)
      TEM1(J)=ASTER(IJK2)
  352 CONTINUE
      A=ASTER(LS)
      CALL DCOSP(TEM,XI,WN)
      DO 353 J=1,3
      TEM(J)=A*WN(J)+TEM(J)
  353 CONTINUE
      CALL DCOSP(TEM,TEM1,WB)
      DO 354 J=1,3
      WB(J)=XNOS*WB(J)
  354 CONTINUE
      GOTO 1000
C
C     RAW
C
C     THIS WILL SHAPE THE BOX FOR LSURF=1,3,5,6
C     JUMPS TO 100 TO INDICATE BOX PORTION
C
  400 IF(LSURF.EQ.2)GOTO 401
      IF(LSURF.NE.4)GOTO 100
      WRITE (6,906)
      STOP
  401 CALL UN2(LDATA,LV,LV1)
      LDATA=LDATA+1
      CALL UN2(LDATA,LV2,LV3)
      DO 410 J=1,3
      M=J-1
      IJK1=M+LV1
      IJK2=M+LV2
      TEMP(J)=ASTER(IJK1)
      XMID(J)=ASTER(IJK1)-ASTER(IJK2)
      IJK3=M+LV3
      TEM(J)=ASTER(IJK3)
  410 CONTINUE
      I=1
      J=2
      K=3
      LK=0
      DO 411 KK=1,3
      TEM1(I)=XMID(J)*TEM(K)-XMID(K)*TEM(J)
      LK=I
      I=J
      J=K
      K=LK
  411 CONTINUE
      SUM=0.
      DO 412 J=1,3
      SUM=TEM1(J)*TEMP(J)+SUM
  412 CONTINUE
      SUM=-SUM/ABS(SUM)
      TLK=TEM1(1)**2+TEM1(2)**2+TEM1(3)**2
      TLK=SQRT(TLK)
      DO 420 J=1,3
      WB(J)=XNOS*SUM*TEM1(J)/TLK
  420 CONTINUE
      GOTO 1000
C
C     ARB
C
```

```
45  [illegible]
    [illegible]
    [illegible]
    [illegible]
    [illegible]
    [illegible]
    [illegible]
451 [illegible]
    [illegible]
    [illegible]
    [illegible]
    [illegible]
    [illegible]XSTER(I,J)/DIV
460 CONTINUE
    [illegible]
C
C   [illegible]
C
500 IF([illegible]) GO TO 520
    CALL [illegible]
    [illegible]
    CALL [illegible]
    [illegible]
    CALL [illegible](STA,LR1,LR2)
    [illegible]
    X1=ASTER(LR1)
    X2=ASTER(LR2)
    R3=(1/ASTER(LR6))
    R4=(1/ASTER(LR6))
    XDN=0.
    HDN=0.
    VDN=0.
    HDA=0.
    HOK=0.
    DDN=0.
    DO 501 I=1,3
    II=I-1
    J1=LV+II
    J2=LH+II
    J3=LN+II
    J4=LA+II
    DELTA(I)=XI(I)-ASTER(J1)
    HF(I)=ASTER(J2)
    AUN(I)=ASTER(J4)
    NF(I)=ASTER(J3)
    VF(I)=ASTER(J1)
    XDN=XI(I)*NF(I)+XDN
    HDN=HF(I)*NF(I)+HDN
    VDN=VF(I)*NF(I)+VDN
    DDN=DELTA(I)*NF(I)+DDN
    HDA=HF(I)*AUN(I)+HDA
501 CONTINUE
    CALL CROSS(G,AUN,NF)
    HOK=DOT(HF,G)
    T1=XDN/HDN
    T2=VDN/HDN
    DO 502 I=1,3
    TEMP(I)=XI(I)-T1*HF(I)-VF(I)+T2*HF(I)
502 CONTINUE
    TAU=(R3/R4)**2
```

```
      T3=DOT(TEMP,AUN)/TAU
      T4=DOT(TEMP,C)
      GAMMA=DDN/HDN
      EM=GAMMA*R4+(1.0-GAMMA)*R2
      T5=HDA/HDN
      T6=HDK/HDN
      DO 510 I=1,3
      WB(I)=XNOS*(T3*(AUN(I)-T5*NF(I))+
     1     T4*(Q(I)-T6*NF(I))-EM*(R4-R2)*NF(I)/HDN)
  510 CONTINUE
      CALL UNIT(WB)
      GOTO 1000
C
  520 IF(LSURF.EQ.2)XNOS=-XNOS
      CALL UN2(LDATA,LV,LH)
      LDATA=LDATA+1
      CALL UN2(LDATA,LN,DUM)
      DO 521 I=1,3
      J=LN+I-1
      WB(I)=XNOS*ASTER(J)
  521 CONTINUE
      GOTO 1000
C
C     TOR
C
  550 CALL UN2(LDATA,LV,LN)
      LDATA=LDATA+1
      CALL UN2(LDATA,LR1,DUM)
      DO 551 I=1,3
      J=I-1
      IJK=LV+J
      TEMP(I)=XI(I)-ASTER(IJK)
      IJK=LN+J
      TEMP1(I)=ASTER(IJK)
  551 CONTINUE
      R1=ASTER(LR1)
      CALL CROSS(TEM,TEMP1,TEMP)
      CALL CROSS(TEM1,TEM,TEMP1)
      CALL UNIT(TEM1)
      DO 552 I=1,3
      J=I-1
      IJK=LV+J
      TEM(I)=ASTER(IJK)
      TEMP1(I)=TEM(I)+R1*TEM1(I)
  552 CONTINUE
      CALL DCOSP(TEMP1,XI,WB)
      DO 553 I=1,3
      WB(I)=XNOS*WB(I)
  553 CONTINUE
      GOTO 1000
C
C     ARS
C
  600 NE=4
      IWH=PASTER(LDATA)
      INOW=IWH+8
      IEND=IWH+8+20*NE
      DO 610 I=1,3
      IJK=IWH+I+4
      ARSTP(I)=ASTER(IJK)
```

```
  610 CONTINUE
      DTRAV=XDIST(ARSTP,XI)
  620 IF(ABS(DTRAV-ASTER(INOW)).GT.1.0E-07)GOTO 640
      DO 630 I=1,3
      IJK=INOW+I
      WB(I)=ASTER(IJK)
  630 CONTINUE
      CALL UNIT(WB)
      GOTO 1000
C
  640 INOW=INOW+NE
      IF(IEND.GT.INOW)GOTO 620
      WRITE (6,903)
      STOP
C
C     COMPUTE OBLICUITY ANGLE
C     COMPUT NORMAL DIST  (SN)
C
 1000 DO 1001 J=1,3
      XB(J)=XI(J)+WS(J)*1.0E-3
 1001 CONTINUE
      ANGLE=0.
      DO 1002 J=1,3
      ANGLE=ANGLE+WB(J)*WS(J)
 1002 CONTINUE
      IF(ABS(ANGLE).LE.1.)GOTO 1010
      ANGLE=0.
      SN=0.
      WRITE (6,904)NIR,ITYPE,NBO,LSURF,WB,WS,XP,XB,XI,XNOS
      IR=NIR
      GOTO 40
C
 1010 ANGLE=ATAN2(SQRT(1.-ANGLE*ANGLE),ANGLE)*180./3.141592654
      IF(ANGLE.LE.90.)GOTO 1020
      DO 1011 J=1,3
      WB(J)=-WB(J)
 1011 CONTINUE
      GOTO 1000
C
 1020 NASC=-2
      IR=NIR
      CALL G1(S1,IRPRIM,XP)
      SN=S1
      GOTO 40
      END
C
C
C
C
C
      SUBROUTINE TESTG
C
C     TESTG OPTIONS
C
C          NRAYS 0 0    TRACE A RAY BETWEEN TWO GIVEN POINTS
C                            XBS TO XBF
C
      DIMENSION XP(3),XBF(3)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASF,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
```

```
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/WALT/LIRFO,NG1ERR
C
  901 FORMAT(2I10)
  902 FORMAT(1H0,22HNUMBER OF SPECIAL RAYS,I5)
  903 FORMAT(3E15.7,3I15)
  904 FORMAT(1H0,5HSTART,5X,4H XB=,3E15.7,8H IRSTRT=,I5/
     1    4H END,7X,4HXBF=,3E15.7,8H   IRFIN=,I5)
  905 FORMAT(1H0,3HWB=,3E15.7,5X,6HRANGE=,E15.7)
  906 FORMAT(1H0,8X,2HIR,4X,6HIRPRIM,12X,2HS1,13X,2HXP,13X,2HYP,
     1     13X,2HZP,12X,4HDIST)
  907 FORMAT(2I10,5X,5E15.7)
  908 FORMAT(1H0,21HTROUBLE IN REGION IR=,I10)
C
      READ (5,901)NRAYS,NG1ERR
      WRITE (6,902)NRAYS
      IF(NG1ERR.LE.0)NG1ERR=25
C
      DO 50 IRAY=1,NRAYS
      READ (5,903)XB,IRSTRT
      READ (5,903)XBF,IRFIN
      WRITE (6,904)XB,IRSTRT,XBF,IRFIN
      RANGE=XDIST(XB,XBF)
      CALL DCOSP(XB,XBF,WB)
      WRITE (6,905)WB,RANGE
      IR=IRSTRT
      NASC=-1
      WRITE (6,906)
C
   10 CALL G1(S1,IRPRIM,XP)
      IF(IERR.GE.NG1ERR)GOTO 60
      WRITE (6,907)IR,IRPRIM,S1,XP,DIST
      IF(DIST.GE.RANGE)GOTO 30
      IF(IRPRIM.LE.0)GOTO 20
      IR=IRPRIM
      GOTO 10
C
   20 WRITE (6,908)IR
      GOTO 50
   30 IF(IR.NE.IRFIN)GOTO 20
   50 CONTINUE
   60 IERR=0
      RETURN
      END.
C
C
C
C
      SUBROUTINE VOLUM
      DIMENSION VASTER(1000),WAB(3),WTB(3),WOB(3),DSP(3),
     1  XV(3),XT(3),XA(3),XO(3),XP(3),XTEMP(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/WALT/LIRFO,NG1ERR
C
  901 FORMAT(3E20.8)
```

```
  902 FORMAT(2E20.8)
  903 FORMAT(1H0,10X,6HVERTEX,14X,6HTOP.PT,14X,6HBOT.PT,14X,7HSIDE.PT)
  904 FORMAT(4E20.8)
  905 FORMAT(1H0, 8X,12HDELTA ON TOP,E20.8,10X,10HSIDE DELTA,E20.8)
  906 FORMAT(2I10)
  908 FORMAT(1H0, 2X,18HSTARTING REGION IS,I5)
  909 FORMAT(1H0,16HVASTER OVERWRITE,5X,6HNRMAX=,I5)
  910 FORMAT(I10,E20.8)
  911 FORMAT(1H0,8HBAD CARD/I10,E20.8,14H NOT PROCESSED)
  912 FORMAT(I10,E20.8,5X,E20.8,5X,E9.2)
  913 FORMAT(1H0,5HSUMV=,5X,E20.8)
C
      READ (5,906)IR,NG1ERR
      IF(NG1ERR.LE.0)NG1ERR=25
      READ (5,901)(XV(I),I=1,3)
      READ (5,901)(XT(I),I=1,3)
      READ (5,901)(XO(I),I=1,3)
      READ (5,901)(XA(I),I=1,3)
      READ (5,902)DOD,DT
      WRITE (6,903)
      WRITE (6,904)(XV(J),XT(J),XO(J),XA(J),J=1,3)
      WRITE (6,905)DOD,DT
      WRITE (6,908)IR
      IF(NRMAX.GT.2000)WRITE (6,909)NRMAX
      CALL DCOSP(XV,XT,WTB)
      CALL DCOSP(XV,XO,WOB)
      CALL DCOSP(XV,XA,WAB)
      XVDIS=XDIST(XV,XA)
      TESTDN=0.
      TESTOV=0.
      XTEMP(1)=0.
      DO 10 I=1,NRMAX
      VASTER(I)=0.
   10 CONTINUE
      JIR=IR
      IRJ=IR
      N2=XDIST(XV,XO)/DOD+1.
      N1=XDIST(XV,XT)/DT+1.
C
      DO 300 J=1,N2
      DO 100 I=1,3
      DSP(I)=WTB(I)*DT
      XB(I)=XV(I)
      WB(I)=WAB(I)
  100 CONTINUE
      S1=0.
      IR=JIR
      DO 200 I=1,N1
      NASC=-1
  110 CALL G1(S1,IRPRIM,XP)
      IF(IERR.GE.NG1ERR)GOTO 400
      VASTER(IR)=VASTER(IR)+S1
      IF(DIST.GE.XVDIS)GOTO 115
      IF(IRPRIM.LE.0)GOTO 120
      IR=IRPRIM
      GOTO 110
  115 VASTER(IR)=VASTER(IR)-(DIST-XVDIS)
  120 XTEMP(1)=WB(1)
      XTEMP(2)=WB(2)
      XTEMP(3)=WB(3)
```

```
      IR=JIR
      TESTDN=TESTDN-DT
      IF(TESTDN.GT.0.)GOTO 180
      WB(1)=WTB(1)
      WB(2)=WTB(2)
      WB(3)=WTB(3)
      NASC=-1
      CALL G1(S1,IRPRIM,XP)
      IF(IERR.GE.NG1ERR)GOTO 400
      IF(S1-DT)130,160,170
  130 IR=IRPRIM
      JIR=IR
      CALL G1(S1,IRPRIM,XP)
      IF(IERR.GE.NG1ERR)GOTO 400
      IF(DIST-DT)140,160,170
  140 IF(IRPRIM)150,210,130
  150 STOP
  160 IR=IRPRIM
      JIR=IR
  170 TESTDN=S1
  180 DO 190 JI=1,3
      WB(JI)=XTEMP(JI)
      XB(JI)=XB(JI)+DSP(JI)
  190 CONTINUE
  200 CONTINUE
C
C     ONE PLANE DONE - MOVE IN FOR NEXT PLANE IN LINE
C
  210 NASC=-1
      DO 220 I=1,3
      WB(I)=WOB(I)
      XB(I)=XV(I)
  220 CONTINUE
      JIR=IRJ
      IR=JIR
      TESTDN=0.
      TESTOV=TESTOV-DOD
      IF(TESTOV)230,230,280
  230 CALL G1(S1,IRPRIM,XP)
      IF(IERR.GE.NG1ERR)GOTO 400
      IF(S1-DOD)240,260,270
  240 IR=IRPRIM
      IRJ=IR
      CALL G1(S1,IRPRIM,XP)
      IF(IERR.GE.NG1ERR)GOTO 400
      IF(DIST-DOD)250,260,270
  250 IF(IRPRIM)150,400,230
  260 IR=IRPRIM
      IRJ=IR
  270 TESTOV=S1
  280 DO 290 I=1,3
      XA(I)=XA(I)+WOB(I)*DOD
      XV(I)=XV(I)+WOB(I)*DOD
      XT(I)=XT(I)+WOB(I)*DOD
  290 CONTINUE
      JIR=IR
  300 CONTINUE
C
C     VOLUMES COMPUTED
C
```

```
  400 READ (5,910)IR1,VR
      IF(IERR.GE.NG1ERR)GOTO 500
      IF(IR1.LE.0)IR1=NRMAX+1
      SUMV=0.
C
      DO 450 I=1,NRMAX
      VASTER(I)=VASTER(I)*DOD*DT
      IF(I-IR1)410,430,420
  410 WRITE (6,910)I,VASTER(I)
      GOTO 440
  420 WRITE (6,911)IR1,VR
      READ (5,910)IR1,VR
      GOTO 410
C          VOLUME REPLACEMENT
  430 XPERC=100.*(VASTER(I)/VR-1.)
      WRITE (6,912)I,VASTER(I),VR,XPERC
      VASTER(I)=VR
      READ (5,910)IR1,VR
  440 SUMV=SUMV+VASTER(I)
  450 CONTINUE
      WRITE (6,913)SUMV
  500 IERR=0
      RETURN
      END
C
C
C
C
      SUBROUTINE AREA
      DIMENSION XP(3),WP(3),XBS(3),CONVRT(4,4),TYPEUN(4)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
       COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/CAL/NIR,SIN,ANGLE,NTYPE,SSPACE,L,XS(3),WS(3),
     1  TRAVEL,SN,V,H,IVIH
      COMMON/WALT/LIRFO,NG1ERR
      COMMON/CELL/CELSIZ
      COMMON/ENGEOM/LEGEOM
C
  901 FORMAT(/I10,6X,2A2)
  902 FORMAT(6E12.8)
  908 FORMAT(1H0,22HMEMORY OVERLAP IN AREA,5X,7HLEGEOM=,I6,
     1     5X,6HLAREA=,I6,5X,6HLIRFO=,I6)
  909 FORMAT(1H0,13HERROR IN AREA,5X,9HICODE = 0)
  910 FORMAT(1H0,8HAZIMUTH=,F10.3,5X,10HELEVATION=,F10.3)
  911 FORMAT(1H0,12HCELL SIZE IS,F4.1,1X,1HX,F4.1,1X,A2,1H.,10X,
     1      12HAREAS IN SQ.,1X,A2,1H.)
  912 FORMAT(1H0,5HICODE,19X,4HAREA/)
  913 FORMAT(I5,15X,F12.5)
  914 FORMAT(1H0,15HPRESENTED AREA=,F12.5)
  915 FORMAT(1H0,18HNUMBER OF CELLS IS,I5,10X,
     1      22HNUMBER OF CELLS HIT IS,I5)
C
C          IN=1     FT=2     CM=3     M=4
C              1 SQ. M. = 39.37 * 39.37 SQ. IN.
C
      DATA HHIN,HHFT,HHCM,HHMB,HHBB/2HIN,2HFT,2HCM,2HM ,2H  /
      TYPEUN(1)=HHIN
```

```
      TYPEUN(2)=HHFT
      TYPEUN(3)=HHCM
      TYPEUN(4)=HHMB
      CONVRT(1,1)=1.
      CONVRT(1,2)=.0069444444444444444
      CONVRT(1,3)=6.451625806
      CONVRT(1,4)=.0006451625806
      CONVRT(2,1)=144.
      CONVRT(2,2)=1.
      CONVRT(2,3)=929.0341161
      CONVRT(2,4)=.09290341161
      CONVRT(3,1)=.15499969
      CONVRT(3,2)=.001076386736
      CONVRT(3,3)=1.
      CONVRT(3,4)=.0001
      CONVRT(4,1)=1549.9969
      CONVRT(4,2)=10.7636736
      CONVRT(4,3)=10000.
      CONVRT(4,4)=1.
      BLANK=HHBB
C
      LAREA=LIRFO-1000
      IF(LAREA.GE.LEGEOM)GOTO 10
      WRITE (6,908)LEGEOM,LAREA,LIRFO
      STOP
   10 LAREA1=LIRFO-1
      DO 20 L=LAREA,LAREA1
      ASTER(L)=0.
   20 CONTINUE
C
      READ (5,901)NX,NY,IRSTRT ,IENC,NG1ERR,NSTART,NEND,CELLUN,AREAUN
      READ (5,902)A,E,ENGTH,ZSHIFT,GROUND
      READ (5,902)XSHIFT,YSHIFT,CELSIZ
      IF(IRSTRT .LE.0)IRSTRT=1
      IF(CELSIZ .LE.0.)CELSIZ=4.
      IF(NSTART.LE.0)NSTART=1
      IF(NG1ERR.LE.0)NG1ERR=25
      IF(AREAUN.EQ.BLANK)AREAUN=HHIN
      IF(CELLUN.EQ.BLANK)CELLUN=HHIN
      DO 30 I=1,4
      IF(CELLUN.EQ.TYPEUN(I))GOTO 40
   30 CONTINUE
   40 DO 50 J=1,4
      IF(AREAUN.EQ.TYPEUN(J))GOTO 60
   50 CONTINUE
   60 AREA=CELSIZ *CELSIZ *CONVRT(I,J)
C
      RADIAN=.017453292519943
      AR=A*RADIAN
      ER=E*RADIAN
      SA=SIN(AR)
      CA=COS(AR)
      SE=SIN(ER)
      CE=COS(ER)
      KL=NX*NY
      NHIT=0
C
C       PROCESS KL CELL'S IN GRID
C
      DO 200 KK=NSTART,KL
```

```
      WB(1)=-CF*CA
      WB(2)=-CF*SA
      WB(3)=-SF
      II=((KK-1)/NX)+1
      J=KK-(II-1)*NX
C         COMPUTE COORDINATES OF GRID CELL IN GRID PLANE
      CELL2=.5*CELSIZ
      V=FLOAT((NY/2)-II)*CELSIZ +CELL2
      VREF=V+CELL2
      H=FLOAT((NX/2)- J)*CELSIZ +CELL2
      HREF=H+CELL2
      IV=RAN(-1)*10.
      IH=RAN(-1)*10.
      IVIH=10*IH+IV
C         COMPUTE H,V AT RANDOM POINT IN GRID CELL
      V=V+CELSIZ *FLOAT(IV)/10.+CELSIZ /20.
      H=H+CELSIZ *FLOAT(IH)/10.+CELSIZ /20.
C         X,Y,Z IN COORDINATE SYSTEM OF VEHICLE
      XBS(1)=XSHIFT-V*CA*SE-H*SA
      XBS(2)=YSHIFT-V*SA*SE+H*CA
      XBS(3)=ZSHIFT+V*CE
      CALL IRNPIC(WP)
      XBS(1)=XBS(1)+WP(1)*1.0E-4
      XBS(2)=XBS(2)+WP(2)*1.0E-4
      XBS(3)=XBS(3)+WP(3)*1.0E-4
      XB(1)=XBS(1)-ENGTH*WB(1)
      XB(2)=XBS(2)-ENGTH*WB(2)
      XB(3)=XBS(3)-ENGTH*WB(3)
      IF(XB(3).LE.GROUND)GOTO 200
C
C     TRACE RAY TO FIRST COMPONENT HIT
C
      IR=IRSTRT
      NASC=-1
  110 CALL GI(SI,IRPRIM,XP)
      IF(IERR.GE.NGIERR)RETURN
      IF(IRPRIM.LT.0)GOTO 200
      IF(NASC.LE.NRPP)IRPRIM=0
      IF(IRPRIM.EQ.0)GOTO 200
      LOC=LIREG+IRPRIM-1
      CALL UN2(LOC,ICODE,IDENT)
      IDENT=IDENT-1
      IF(IDENT-(IDENT/10)*10.EQ.0)GOTO 120
      IR=IRPRIM
      GOTO 110
  120 IF(ICODE.NE.0)GOTO 130
      WRITE (6,909)
      GOTO 200
  130 LOC=LAREA+ICODE-1
      ASTER(LOC)=ASTER(LOC)+AREA
      NHIT=NHIT+1
  200 CONTINUE
C
C     PRINT RESULTS
C
      WRITE (6,910)A,E
      WRITE (6,911)CELSIZ, CELSIZ, CELLUN,AREAUN
      WRITE (6,912)
      SUMA=0.
      DO 250 I=1,999
```

```
      LOC=LAREA+I-1
      IF(ASTER(LOC).EQ.0.)GOTO 250
      WRITE (6,913)L,ASTER(LOC)
      SUMA=SUMA+ASTER(LOC)
  250 CONTINUE
      WRITE (6,914)SUMA
      WRITE (6,915)KL,NHIT
      RETURN
      END
C
C
C
C
      SUBROUTINE G1(S1,IRPRIM,XP)
C
C     MAIN RAY TRACKING ROUTINE
C
C     GIVEN A RAY IN REGION IR AT POINT XB WITH DIRECTION
C         COSINES WB; FIND THE DISTANCE (S1) TO THE NEXT REGION
C         AND THE NUMBER OF THAT REGION (IRPRIM)
C
C     NASC=-2            $$  CALL FROM CALC TO FIND NORMAL DIST
C     NASC=-1            $$  START NEW RAY
C     IVOLUM=1           $$  CALL FROM VOLUM
C     ITESTG=1           $$  CALL FROM TESTG
C     DIST               $$  TOTAL DIST TRAVELED BY RAY SO FAR
C
      DIMENSION MASTER(30000),XP(3),XBD(3),LSURT(50),NASCT(50)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/CAL/NIR,SIN,ANGLE,NTYPE,SSPACE,L,XS(3),WS(3),TRAVEL,
     1  SN,V,H,IVIII
      COMMON/WALT/LIRFO,NG1ERR
      COMMON/LSU/LSURF
      COMMON/CONTRL/ITESTG,IRAYSK,IENTLV,IVOLUM,IWOT,ITAPE8,NO,IYES
      COMMON/DAVIS/IGRID,LOOP,INORM
      COMMON/CELL/CELSIZ
      EQUIVALENCE (ASTER,MASTER)
C
  901 FORMAT(1H0,32HERROR IN G1 AT 140      BAD ITYPE,5X,4HITY=,I5)
  902 FORMAT(1H0,33HERROR IN G1 AT 510      SM 0= PINF,5X,3HIR=,I5)
  903 FORMAT(4H XB=,3E20.8/4H WB=,3E20.8/10X,5HKLOOP,12X,3HNBO,
     1  12X,3HLRI,12X,3HLRO,11X,4HNHIT,11X,4HLOOP/6I15)
  904 FORMAT(1H1,15(2H* ),3X, 9HERROR NO.,I5,3X,15(2H *)//)
  905 FORMAT(34X,4HCELL,2I4)
  906 FORMAT(19H ERROR IN G1 AT 640//4H J1=,I10,4H J2=,I10,7H LSURF=,
     1  I10,6H NASC=,I10,4H IR=,I10/4H SM=,E21.10,4H S1=,E17.10/
     2  4H WB=,3E21.10/4H XB=,3E21.10)
  907 FORMAT(50H THE (SOLID POSITION/DEPTH/POINT NOW AT) IS ONE OF,
     1  6H THESE/6H XBD =,3E21.10/6H DIST=,E21.10//)
  908 FORMAT(9X,3HRIN,12X,4HROUT,7X,8HENTERING,2X,7HLEAVING,3X,
     1  8HBODY NO.,5X,3HRAY,/35X,8HSIDE NO.,2X,8HSIDE NO.//)
  910 FORMAT(//16H TILT  RIN=ROUT=,E20.10,30X,2HI=,I5//)
  911 FORMAT(2(2X,E15.8),4X,I2,8X,I2,6X,I5,5X,7HSTARTED/)
  912 FORMAT(2(2X,E15.8),4X,I2,8X,I2,6X,I5,5X,7HHAS HIT/)
  913 FORMAT(2(2X,E15.8),4X,I2,8X,I2,6X,I5,5X,7HLEAVING/)
  914 FORMAT(2(2X,E15.8),4X,I2,8X,I2,6X,I5,5X,7H IN    /)
```

```
  915 FORMAT(2(2X,E15.8),4X,I2,8X,I2,6X,I5,5X,8HENTERING/)
  916 FORMAT(2(2X,E15.8),4X,I2,8X,I2,6X,I5,5X,8HWILL HIT/)
  917 FORMAT(//4(14H END ERROR NO.,I4,3X)/)
  918 FORMAT(1H0,I5,21H ERRORS IN G1, RETURN)
C
      INORM=0
      IF(NASC.EQ.-2)INORM=1
      S1=0.
      IF(NASC.GT.0)GOTO 20
C        NEW RAY
      DIST=0.
      IF(KLOOP.LT.32000)GOTO 15
      KLOOP=0
      LION=LIO+NBODY+NRPP-1
      DO 10 I=LIO,LION
      MASTER(I)=0
   10 CONTINUE
   15 KLOOP=KLOOP+1
C
C     BEGIN TRACING RAY
C
   20 SM=PINF
      NHIT=0
      LOC=LREGD+IR-1
      CALL UN2(LOC,LOC,NC)
      LOC=LOC-1
C
C     NC=NUM OF BODIES IN REGION DESCRIPTION
C     FIND RIN AND ROUT FOR EACH OF THESE BODIES
C         RIN  IS DIST FROM XB TO POINT WHERE RAY ENTERS THE BODY
C         ROUT IS DIST FROM XB TO POINT WHERE RAY LEAVES THE BODY
C              IF ROUT = -PINF RAY DOES NOT HIT BODY
C        G1 SELECTS SMALLEST OF RIN AND ROUT DISTANCES O DIST
C        1)  UNIQUE RIN VALUE - NEXT BODY IN PATH OF RAY
C        2)  2 OR MORE RIN VALUES - 2 OR MORE BODIES HAVE
C            A COMMON SURFACE
C        3)  ROUT FOR CURRENT BODY MEANS RAY WILL LEAVE
C            THIS BODY BEFORE ENCOUNTERING ANOTHER
C
      DO 500 N=1,NC
      LOC=LOC+1
      CALL UN2(LOC,DUM,NBO)
      ITEMP=LIO+NBO-1
      CALL UN3(ITEMP,LRI,LRO,LOOP)
      ITEMP=LBODY+3*(NBO-1)
      CALL UN2(ITEMP,ITYPE,LOCDA)
      IF(LOOP.NE.KLOOP)GOTO 130
C        CONTINUATION OF RAY
      IF(ITYPE.GT.11)GOTO 140
      IJK=LRIN+NBO-1
      RIN=ASTER(IJK)
      IJK=LROT+NBO-1
      ROUT=ASTER(IJK)
      IF(ITYPE.LT.10)GOTO 320
C        TOR AND ARS
C        IF DIST .GE. ROUT COMPUTE RIN / ROUT SET
      IF(ROUT.LT.0.)GOTO 320
      IF(DIST.LT.ROUT)GOTO 320
      IF(NASC.EQ.NBO)NASC=0
C
```

```
  130 LRI=1
      LRO=1
      ITY=ITYPE+1
      IF(ITY.GE.1.AND.ITY.LE.12)GOTO 200
  140 IERR=IERR+1
      WRITE (6,901)ITYPE
      GOTO 800
C
C              RPP BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
  200 GOTO(205,210,215,220,225,230,235,240,245,250,255,260),ITY
  205 CALL RPP(NBO)
      GOTO 300
  210 CALL BOX
      GOTO 300
  215 CALL SPH
      GOTO 300
  220 CALL RCC
      GOTO 300
  225 CALL REC
      GOTO 300
  230 CALL TRC
      GOTO 300
  235 CALL ELL
      GOTO 300
  240 CALL RAW
      GOTO 300
  245 CALL ARB
      GOTO 300
  250 CALL TEC
      GOTO 300
  255 CALL TOR
      GOTO 300
  260 CALL ARS
C
  300 IJK=LRIN+NBO-1
      ASTER(IJK)=RIN
      IJK=LROT+NBO-1
      ASTER(IJK)=ROUT
      IJK=LIO+NBO-1
      MASTER(IJK)=KLOOP+115*(LRO+64*LRI)
C
  320 IF(NASC.NE.NBO)GOTO 330
      IF(LSURF)500,500,340
C
  330 IF(ROUT.LE.0.)GOTO 500
      IF(RIN.GT.0.)GOTO 350
C
  340 IF(ABS(ROUT-SM).GT.SM*1.0E-6)GOTO 341
      ROUT=SM
      IJK=LROT+NBO-1
      ASTER(IJK)=ROUT
      GOTO 345
  341 IF(ROUT-SM)342,345,500
  342 IF(DIST.GE.ROUT)GOTO 500
      NHIT=0
  345 NHIT=NHIT+1
      SM=ROUT
      LSURT(NHIT)=-LRO
      NASCI(NHIT)=NBO
      GOTO 500
```

```
C
  350 IF(ABS(RIN-SM).GT.SM*1.0E-6)GOTO 351
      RIN=SM
      IJK=LRIN+NBO-1
      ASTER(IJK)=RIN
      GOTO 355
  351 IF(RIN-SM)352,355,500
  352 IF(DIST.GE.RIN)GOTO 340
      NHIT=0
  355 NHIT=NHIT+1
      SM=RIN
      LSURT(NHIT)=LRI
      NASCT(NHIT)=NBO
C
  500 CONTINUE
C
C     SM.GE.PINF   ERROR AT 510 IN G1
C
      IF(SM.LT.PINF)GOTO 530
      WRITE (6,902)IR
      WRITE (6,903)XB,WB,KLOOP,NBO,LRI,LRO,NHIT,LOOP
      GOTO 700
C
  530 S1=S1+SM-DIST
      DIST=SM
      XP(1)=XB(1)+SM*WB(1)
      XP(2)=XB(2)+SM*WB(2)
      XP(3)=XB(3)+SM*WB(3)
C
      IF(NASC.EQ.-2)RETURN
C
C     FIND NEXT REGION (IRPRIM)
C
      DO 640 NN=1,NHIT
      NASC =NASCT(NN)
      LSURF=LSURT(NN)
      LTRUE=0
      LOC=LBODY+3*(NASC-1)
      LOC=LOC+1
      CALL UN2(LOC,LENT,LEAV)
      LOC=LOC+1
      CALL UN2(LOC,NENT,NEAV)
      IF(LSURF.LE.0)GOTO 600
      J1=LENT
      J2=LENT+NENT-1
      GOTO 610
  600 J1=LEAV
      J2=LEAV+NEAV-1
C
  610 IRPRIM=MASTER(J2)
      IF(J1.LE.J2)GOTO 620
      IF(NASC.GT.NRPP)GOTO 700
      IF(LSURF)630,700,700
C
  620 DO 625 J=J1,J2
      IRPRIM=MASTER(J)
      CALL WOWI(IRPRIM,LSURF,NASC,LTRUE)
      IF(LTRUE.GT.0)GOTO 650
  625 CONTINUE
C
```

```
C     RPP CHECK
C
      IF(NASC.GT.NRPP)GOTO 640
      IF(LSURF)630,700,640
  630 CALL RPP2(LSURF,XP,IRP)
      IF(IRP.GT.0)GOTO 631
      IRPRIM=0
      RETURN
C
  631 LTRUE=0
      LOC=LBODY+3*(IRP-1)
      LOC=LOC+1
      CALL UN2(LOC,LENT,LEAV)
      LOC=LOC+1
      CALL UN2(LOC,NENT,NEAV)
      J1=LENT
      J2=LENT+NENT-1
      IF(J1.GT.J2)GOTO 700
C
      DO 632 J=J1,J2
      IRPRIM=MASTER(J)
      CALL WOWI(IRPRIM,LSURF,IRP,LTRUE)
      IF(LTRUE.GT.0)GOTO 650
  632 CONTINUE
C
  640 CONTINUE
      GOTO 700
C
C     NEXT REGION (IRPRIM) HAS BEEN DETERMINED
C
  650 IF(IR.EQ.IRPRIM)GOTO 660
      IF(S1.EQ.0.)GOTO 660
      IF(S1.LT.0.)GOTO 700
      IF(ABS(S1).LE.1.0E-6)GOTO 660
      IF(IVOLUM.EQ.IYES)RETURN
      IF(ITESTG.EQ.IYES)RETURN
      LOC=LIRFO+IR-1
      CALL UN2(LOC,ICODE,IDENT)
      LOC=LIRFO+IRPRIM-1
      CALL UN2(LOC,ICODE1,IDENT1)
      IF(IDENT.EQ.1)GOTO 655
      IF(IDENT.EQ.IDENT1)GOTO 660
      RETURN
  655 IF(ICODE.NE.ICODE1)RETURN
  660 IR=IRPRIM
      GOTO 20
C
C     DIAGNOSTIC ERROR PRINT
C
  700 IERR=IERR+1
      WRITE (6,904)IERR
      IF(IVOLUM.EQ.IYES.OR.ITESTG.EQ.IYES)GOTO 705
      IH=ABS(H/CELSIZ )+.5
      IF(H.LT.0.)IH=-IH
      IV=ABS(V/CELSIZ )+.5
      IF(V.LT.0.)IV=-IV
      WRITE (6,905)IH,IV
  705 WRITE (6,906)J1,J2,LSURF,NASC,IR,SM,S1,WB,XB
      XBD(1)=XB(1)-DIST
      XBD(2)=XB(2)-DIST
```

```
      XBD(3)=XB(3)-DIST
      WRITE (6,907)XBD,DIST
      WRITE (6,908)
      NN=NBODY+NRPP
C
      DO 750 I=1,NN
      LOC=LIO+I-1
      CALL UN3(LOC,I1,I2,I3)
      IF(KLOOP.NE.I3)GOTO 750
      IJK=LRIN+I-1
      RIN=ASTER(IJK)
      IJK=LROT+I-1
      ROUT=ASTER(IJK)
      IF(RIN.NE.ROUT)GOTO 710
      WRITE (6,910)RIN,I
      GOTO 750
C
  710 IF(ABS(RIN).NE.PINF)GOTO 720
      IF(ABS(ROUT)-PINF)740,750,740
  720 IF(RIN-DIST)730,744,745
  730 IF(ROUT-DIST)741,742,743
C
  740 WRITE (6,911)RIN,ROUT,I1,I2,I
      GOTO 750
  741 WRITE (6,912)RIN,ROUT,I1,I2,I
      GOTO 750
  742 WRITE (6,913)RIN,ROUT,I1,I2,I
      GOTO 750
  743 WRITE (6,914)RIN,ROUT,I1,I2,I
      GOTO 750
  744 WRITE (6,915)RIN,ROUT,I1,I2,I
      GOTO 750
  745 WRITE (6,916)RIN,ROUT,I1,I2,I
C
  750 CONTINUE
      WRITE (6,917)IERR,IERR,IERR,IERR
      IRPRIM=-1
C
  800 IF(IERR.GE.NG1ERR)WRITE (6,918)NG1ERR
      RETURN
      END
C
C
      SUBROUTINE WOWI(JREG,LSURF,NEX,LTRUE)
C
C     GIVEN A POINT (XB) AND A REGION (JREG), DOES XB
C         LIE WITHIN JREG
C
C     SUFFICIENT CONDITION FOR POINT XB TO BE IN REGION
C         JREG, IS THAT REGION DESCRIPTION OF JREG BE
C         SATISFIED. TWO REGIONS CANNOT BE SATISFIED FOR
C         THE SAME POINT
C
C     + OPERATOR VALID IF ROUT.GT.O AND RIN.LE.DIST.LT.ROUT
C     - OPERATOR VALID IF ROUT.LE.O OR DIST.LT.RIN OR DIST.GE.ROUT
C     OR OPERATOR VALID IF ALL (+) AND (-) IN (OR) STATEMENT VALID
C
C     REGION DESCRIPTION WITH 1 OR MORE (OR) STATEMENTS VALID
C         IF ANY ONE OF (OR) STATEMENTS IS VALID
C     REGION DESCRIPTION WITH NO (OR) STATEMENTS IS VALID ONLY
```

```
C          IF EVERY (+) AND (-) OPERATOR IS VALID
C
      DIMENSION MASTER(30000)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE(ASTER,MASTER)
C
  901 FORMAT(1H0,32HERROR IN G1 AT 140      BAD ITYPE,5X,4HITY=,I5)
C
      LOC=LREGD+JREG-1
      CALL UN2(LOC,LOCD,NC)
      CALL UN2(LOCD,IOP,NBO)
      N=1
      IOPER=IOP
C
C     EXAMINE NC CHOICES N=1,NC
C
   10 ITEMP=LIO+NBO-1
      CALL UN3(ITEMP,LRI,LRO,LOOP)
      ITEMP=LBODY+3*(NBO-1)
      CALL UN2(ITEMP,ITYPE,LOCDA)
      IF(LOOP.NE.KLOOP)GOTO 30
C          CONTINUATION OF RAY
      IF(ITYPE.GT.11)GOTO 40
      IJK=LRIN+NBO-1
      RIN=ASTER(IJK)
      IJK=LROI+NBO-1
      ROUT=ASTER(IJK)
      IF(ITYPE.LT.10)GOTO 310
C          TOR AND ARS
C          IF DIST 0 ROUT COMPUT RIN/ROUT SET
      IF(ROUT.LT.0.)GOTO 400
      IF(DIST.LE.ROUT)GOTO 310
C
   30 LRI=1
      LRO=1
      ITY=ITYPE+1
      IF(ITY.GE.1.AND.ITY.LE.12)GOTO 100
   40 IERR=IERR+1
      WRITE (6,901)ITYPE
      RETURN
C          RPP BOX SPH RCC REC TRC ELL RAW ARB TEC TOR ARS
  100 GOTO(110,120,130,140,150,160,170,180,190,200,210,220),ITY
  110 CALL RPP(NBO)
      GOTO 300
  120 CALL BOX
      GOTO 300
  130 CALL SPH
      GOTO 300
  140 CALL RCC
      GOTO 300
  150 CALL REC
      GOTO 300
  160 CALL TRC
      GOTO 300
  170 CALL ELL
      GOTO 300
```

```
  180 CALL RAW
      GOTO 300
  190 CALL ARB
      GOTO 300
  200 CALL TEC
      GOTO 300
  210 CALL TOR
      GOTO 300
  220 CALL ARS
C
  300 IJK=LIO+NBO-1
      MASTER(IJK)=KLOOP+I15*(LRO+64*LRI)
C
  310 IF(ROUT.LE.0.)GOTO 330
      IF(ABS(RIN-DIST).GT.DIST*1.0E-6)GOTO 320
      RIN=DIST
      GOTO 330
C
  320 IF(ABS(ROUT-DIST).LE.DIST*1.0E-6)ROUT=DIST
C
  330 IJK=LRIN+NBO-1
      ASTER(IJK)=RIN
      IJK=LROT+NBO-1
      ASTER(IJK)=ROUT
C
C     TEST CONDITIONS FOR XB IN JREG (LTRUE SET=1)
C
  400 IF(IOPER.GT.4)GOTO 500
C         (+) OPERATOR TEST FOR INSIDE RIN.LE.DIST.LT.ROUT
      IF(RIN.GT.DIST)GOTO 700
      IF(DIST-ROUT)600,700,700
C         (-) OPERATOR TEST FOR OUTSIDE  DIST.LT.RIN    DIST.GE.ROUT
  500 IF(ROUT.LE.0.)GOTO 600
      IF(DIST.LT.RIN)GOTO 600
      IF(DIST.EQ.RIN)GOTO 700
      IF(DIST.LT.ROUT)GOTO 700
C         CHECK NEXT BODY IN DESCRIPTION
  600 IF(N.GE.NC)GOTO 800
      N=N+1
      LOCD=LOCD+1
      CALL UN2(LOCD,IOPER,NBO)
      IF(IOPER.EQ.1.OR.IOPER.EQ.5)GOTO 800
      GOTO 10
C         OR OPERATOR
  700 IF(IOP.NE.1.AND.IOP.NE.5) RETURN
      IF(N.GE.NC)RETURN
      N=N+1
      DO 710 NN=N,NC
      LOCD=LOCD+1
      CALL UN2(LOCD,IOPER,NBO)
      IF(IOPER.NE.1.AND.IOPER.NE.5)GOTO 710
      N=NN
      GOTO 10
  710 CONTINUE
      RETURN
C
  800 LTRUE=LTRUE+1
      RETURN
      END
C
```

```
C
      SUBROUTINE ARB
      DIMENSION AA(6,4),XP(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
C
      LOC=LOCDA-1
      DO 10 I=1,6
      LOC=LOC+1
      CALL UN2(LOC,LD,LC)
      AA(I,1)=ASTER(LC)
      AA(I,2)=ASTER(LC+1)
      AA(I,3)=ASTER(LC+2)
      AA(I,4)=ASTER(LD)
   10 CONTINUE
      RIN=-PINF
      ROUT=PINF
      LRO=0
      LRI=0
      S1=0.
      S2=0.
      L1=0
      L2=0
      DO 70 I=1,6
      D=AA(I,4)
      SNUM=-D-AA(I,1)*XB(1)-AA(I,2)*XB(2)-AA(I,3)*XB(3)
      SDEN=AA(I,1)*WB(1)+AA(I,2)*WB(2)+ AA(I,3)*WB(3)
      IF(SDEN)20,70,30
   20 IF(SNUM)40,70,70
   30 IF(SNUM)70,70,40
   40 S=SNUM/SDEN
      DO 50 K=1,3
      XP(K)=XB(K)+S*WB(K)
   50 CONTINUE
      DO 60 J=1,6
      IF(I.EQ.J)GOTO 60
      T=AA(J,1)*XP(1)+AA(J,2)*XP(2)+AA(J,3)*XP(3)+AA(J,4)
      IF(ABS(T).LE.1.0E-6)T=0.
      IF(T.LT.0.)GOTO 70
   60 CONTINUE
      IF(L1.GT.0)GOTO 65
      L1=I
      S1=S
      GOTO 70
   65 IF(ABS(S1-S).GT.1.0E-6)GOTO 100
   70 CONTINUE
C
      IF(L1)200,200,150
  100 S2=S
      L2=I
      IF(ABS(S1-S2).LE.S1*1.0E-5)GOTO 200
      IF(S1-S2)110,200,120
  110 RIN=S1
      ROUT=S2
      LRI=L1
      LRO=L2
      RETURN
```

```
  120 RIN=S2
      LRI=L2
  130 ROUT=S1
      LRO=L1
      RETURN
  150 DO 160 J=1,6
      IF(L1.EQ.J)GOTO 160
      T1=AA(J,1)*XB(1)+AA(J,2)*XB(2)+AA(J,3)*XB(3)+AA(J,4)
      IF(ABS(T1).LE.1.0E-6)T1=0.
      IF(T1.LT.0.)GOTO 200
  160 CONTINUE
      GOTO 130
C
  200 RIN=PINF
      ROUT=-PINF
      LRI=0
      LRO=0
      RETURN
      END
C
C
      SUBROUTINE ARS
      DIMENSION MASTER(30000),COL1(3),COL2(3),COL3(3),COL4(3),
     1  U(3),V(3),W(3),SAVE(84)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROI,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      COMMON/DAVIS/IGRID,LOOP,INORM
      EQUIVALENCE(COL11,COL1(1)),(COL12,COL1(2)),(COL13,COL1(3))
      EQUIVALENCE(COL21,COL2(1)),(COL22,COL2(2)),(COL23,COL2(3))
      EQUIVALENCE(COL31,COL3(1)),(COL32,COL3(2)),(COL33,COL3(3))
      EQUIVALENCE(COL41,COL4(1)),(COL42,COL4(2)),(COL43,COL4(3))
      EQUIVALENCE(ASTER,MASTER)
C
  901 FORMAT(1H0,21HTROUBLE IN ARS AT 150)
  902 FORMAT(1H0,48HPOSSIBLE ERROR IN ARBITRARY SURFACE, CHECK INPUT,I5)
C
C                 ASTER/MASTER
C     LOCDA+0          T                     TEMPORARY STORAGE
C          +1          M                     NO. CURVES
C          +2          N                     NO. POINTS/CURVE
C          +3        IGDTL                   GRID TOLERANCE
C          +4        BIAS                    NO. OF NEGATIVE OR ZERO HITS
C          +5        XB(X)
C          +6        XB(Y)
C          +7        XB(Z)
C          +8        (84 WORDS)              RESERVED FOR HITS
C          .           .
C          .           .
C          .           .
C          +91         .
C          +92         X   )      )
C          .           Y   )N=1   )          M SETS OF N POINTS
C          .           Z   )      )M=1
C          .           K   )      )
C          .           .   )      )
C          .           .   )N=2   )
C          .           .   )      )
```

```
C              .          . )        )
C
C       M = THE NUMBER OF CURVES INPUT
C       N = THE NUMBER POINTS/CURVE
C       IGDTL = THE NUMBER OF GRID SQUARES TO ALOW AROUND EACH POINT
C       IBIAS = THE INDEX INTO MASTER TO THE NUMBER OF DISCARDED HITS
C
C       LOCHTS IS THE LOCATION OF THE AREA IN MASTER-ASTER
C           RESERVED FOR STORING HITS
C
C       LOCARY IS THE LOCATION IN MASTER-ASTER OF THE DATA POINTS
C           THEMSELVES IN FORMAT( X , Y , Z , GRID SQUARE)
C
C
      NE=4
      IWH=MASTER(LOCDA)
      IBIAS=IWH+4
      LOCHTS=IBIAS+4
      IF(INORM.EQ.0)GOTO 20
      DO 10 I=1,84
      IJK=LOCHTS+I-1
      SAVE(I)=ASTER(IJK)
   10 CONTINUE
      GOTO 30
   20 ASTER(IWH+5)=XB(1)
      ASTER(IWH+6)=XB(2)
      ASTER(IWH+7)=XB(3)
   30 IF(KLOOP.EQ.LOOP)GOTO 400
C
      LRI=1
      LRO=1
      M=MASTER(IWH+1)
      N=MASTER(IWH+2)
      IGDTL=MASTER(IWH+3)
      LOCARY=LOCHTS+21*NE
      NHITS=0
      ASTER(LOCHTS)=PINF
      MASTER(IBIAS)=0
      KAPPA=M-1
C
C
C       IN THE EVEN CASE, THE TRIANGLES ARE -
C
C       (1)  (I,J)  (I+1,J)  (I,J+1)
C       (2)                  (I,J-1)
C       (3)         (I-1,J)  (I,J+1)
C       (4)                  (I,J-1)
C
C
C       IN THE ODD CASE, THE TRIANGLES ARE -
C
C       (1)  (I,J)  (I+1,J)  (I+1,J+1)
C       (2)                  (I+1,J-1)
C       (3)         (I-1,J)  (I+1,J+1)
C       (4)                  (I+1,J-1)
C
C       NOTE THAT THE ONLY DIFFERENCE IS THE ROW DESIGNATION OF W
C
C       BECAUSE OF THE INCREMENTATION OF I AND J, WE NEED
C           CONSIDER ONLY CASES (1) AND (2)
```

```
C
      DO 200 I=1,KAPPA
      DO 200 J=1,N
      ITRY=0
      K=(I+J)/2
      IODD=I+J-2*K
C
      IW1=4*((I-1+IODD)*N+J)+LOCARY
      IF(N.LE.J)GOTO 190
  100 IV1=4*(I*N+(J-1))+LOCARY
      IU1=4*((I-1)*N+(J-1))+LOCARY
      IF(INORM.EQ.0)GOTO 110
      IF(IABS(IGRID-MASTER(IU1+3)).GT.IGDTL)GOTO 200
      IF(IABS(IGRID-MASTER(IV1+3)).GT.IGDTL)GOTO 200
      IF(IABS(IGRID-MASTER(IW1+3)).GT.IGDTL)GOTO 180
  110 DO 115 K=1,3
      IJK=IU1+K-1
      U(K)=ASTER(IJK)
      IJK=IV1+K-1
      V(K)=ASTER(IJK)
      IJK=IW1+K-1
      W(K)=ASTER(IJK)
  115 CONTINUE
C
C     AT THIS TIME WE HAVE U,V,W   SIDES OF TRIANGLE
C
      DO 120 K=1,3
      COL1(K)=U(K)-W(K)
      COL2(K)=V(K)-W(K)
      COL3(K)=-WB(K)
      COL4(K)=XB(K)-W(K)
  120 CONTINUE
      D      = COL11*(COL22*COL33-COL23*COL32)
     1        -COL12*(COL21*COL33-COL23*COL31)
     2        +COL13*(COL21*COL32-COL22*COL31)
      IF(ABS(D).LE.1.0E-6)GOTO 180
C
      DALPHA= COL41*(COL22*COL33-COL23*COL32)
     1        -COL42*(COL21*COL33-COL23*COL31)
     2        +COL43*(COL21*COL32-COL22*COL31)
      ALPHA=DALPHA/D
      IF(ALPHA*(1.-ALPHA).LT.0.)GOTO 180
C
      DBETA = COL11*(COL42*COL33-COL43*COL32)
     1        -COL12*(COL41*COL33-COL43*COL31)
     2        +COL13*(COL41*COL32-COL42*COL31)
      BETA=DBETA/D
      IF(BETA*(1.-BETA).LT.0.)GOTO 180
      TP=ALPHA+BETA
      IF(TP*(1.-TP).LT.0.)GOTO 180
C
      DS     = COL11*(COL22*COL43-COL23*COL42)
     1        -COL12*(COL21*COL43-COL23*COL41)
     2        +COL13*(COL21*COL42-COL22*COL41)
      S=DS/D
C
      IF(NHITS.GT.20)GOTO 400
      LIMIT=NHITS+1
      LIMIT1=LOCHTS+20*NE-1
      TRY=1-ITRY-ITRY
```

```
      CALL CROSS(COL3,COL1,COL2)
      DO 140 L=1,3
      COL3(L)=TRY*COL3(L)
  140 CONTINUE
      DO 150 L=1,LIMIT
      INDEX=LOCHTS+(L-1)*NE
      IF(S.LE.ASTER(INDEX))GOTO 160
  150 CONTINUE
      WRITE (6,901)
      GOTO 180
C
C
  160 DO 165 L=INDEX,LIMIT1
      IJK=LIMIT1+INDEX-L
      IJK1=IJK+NE
      ASTER(IJK1)=ASTER(IJK)
  165 CONTINUE
      ASTER(INDEX)=S
      DO 170 L=1,3
      IJK=INDEX+L
      ASTER(IJK)=COL3(L)
  170 CONTINUE
      NHITS=NHITS+1
  180 IF(ITRY.GT.0)GOTO 200
  190 IW1=IW1-8
      ITRY=1
      IF(J.GT.1)GOTO 100
  200 CONTINUE
C
C     THIS SECTION CHECKS FOR PROPER ENTER-LEAVE SEQUENCE IN HITS TABLE
C
      IF(NHITS-1)800,210,220
  210 ASTER(LOCHTS)=PINF
      IJK=LOCHTS+NE
      ASTER(IJK)=PINF
      GOTO 800
  220 ILEAVE=1
      SLAST=-PINF
C
C     ILEAVE = -1 IMPLIES AN ENTRY
C     ILEAVE = +1 IMPLIES AN EXIT
C     ENTRIES AND EXITS SHOULD ALTERNATE IN TABLE
C
      DO 300 L=1,NHITS
      INDEX=LOCHTS+(L-1)*NE
      DO 230 L1=1,3
      IJK=INDEX+L1
      COL4(L1)=ASTER(IJK)
  230 CONTINUE
      TEMP=DOT(WB,COL4)
      INEXT=SIGN(1.0,TEMP)
      IF(ABS(SLAST-ASTER(INDEX)).GT.1.0E-7)GOTO 235
      IF(ILEAVE*INEXT.GE.0)GOTO 260
      LTRY=L
      INDEX=INDEX-NE
      GOTO 270
  235 IJK=INDEX+NE
      IF(ABS(ASTER(INDEX)-ASTER(IJK)).GT.1.0E-7)GOTO 240
      IF(ILEAVE*INEXT)290,250,250
  240 IF(ILEAVE*INEXT)290,280,280
```

```
C
C     BAD START OF A NEW S SET - TRY TO FIND AN ALTERNATING MEMBER
C
  250 LTRY=L
  251 LTRY=LTRY+1
      IF(LTRY.GT.NHITS)GOTO 280
      INDEX1=LOCHTS+(LTRY-1)*NE
      IF(ABS(ASTER(INDEX)-ASTER(INDEX1)).GT.1.0E-7)GOTO 280
      DO 252 L1=1,3
      IJK=INDEX1+L1
      COL4(L1)=ASTER(IJK)
  252 CONTINUE
      TEMP=DOT(WB,COL4)
      INEXT=SIGN(1.0,TEMP)
      IF(ILEAVE*INEXT.GE.0)GOTO 251
      LTRY=L+1
      GOTO 270
C
C     AT THIS POINT WE HAVE DETECTED TWO CONSECUTIVE ENTRIES OR EXITS
C         TRY TO RESOLVE BY DELETING ITEMS WITH EQUAL S ENTRIES
C
  260 LTRY=L
  261 LTRY=LTRY+1
      IF(LTRY.LE.NHITS)GOTO 262
      LTRY=L+1
      GOTO 270
  262 INDEX1=LOCHTS+(LTRY-1)*NE
      IF(ABS(ASTER(INDEX)-ASTER(INDEX1)).LE.1.0E-7)GOTO 263
      LTRY=L+1
      GOTO 270
  263 DO 264 L1=1,3
      IJK=INDEX1+L1
      COL4(L1)=ASTER(IJK)
  264 CONTINUE
      TEMP=DOT(WB,COL4)
      INEXT=SIGN(1.0,TEMP)
      IF(ILEAVE*INEXT.GE.0)GOTO 261
      LTRY=L
      INDEX=INDEX-NE
      GOTO 270
C
C      PROCEED TO FORGET FROM INDEX THRU NEXT ENTRY WITH DIFFERENT S
C         COMMENCING TO CHECK WITH THE L TH ENTRY
C
  273 INDEX1=LOCHTS+(LTRY-1)*NE
      IF(ABS(ASTER(INDEX1)-ASTER(INDEX)).GT.0.)GOTO 271
      LTRY=LTRY+1
  270 NHITS=NHITS-1
      IF(NHITS-1)800,210,273
  271 DO 272 LTRY=INDEX,LIMIT1
      IJK=LTRY+INDEX1-INDEX
      ASTER(LTRY)=ASTER(IJK)
  272 CONTINUE
      GOTO 220
C
  280 WRITE (6,902)INDEX
  290 SLAST=ASTER(INDEX)
      ILEAVE=INEXT
  300 CONTINUE
C
```

```
C     NOW CHOOSE THE HIT (THIS SECTION ALSO ENTERED FOR REENTRY)
C
  400 DO 420 I=1,20
      I1ST=LOCHTS+(I-1)*NE
      I2ND=LOCHTS+I*NE
      IF(ASTER(I2ND).GE.PINF)GOTO 800
      IF(ASTER(I1ST).GE.PINF)GOTO 800
      IF(ABS(ASTER(I1ST)-ASTER(I2ND)).LE.1.0E-7)GOTO 420
      IF(DIST.LT.ASTER(I1ST))GOTO 410
      IF(DIST.GT.ASTER(I2ND))GOTO 420
  410 K=(MASTER(IBIAS)+I)/2
      IF(2*K-I-MASTER(IBIAS))500,510,510
  420 CONTINUE
C
  500 RIN=ASTER(I1ST)
      ROUT=ASTER(I2ND)
      GOTO 810
  510 RIN=ASTER(I2ND)
      IJK=I2ND+NE
      ROUT=ASTER(IJK)
      GOTO 810
  800 RIN=-PINF
      ROUT=0.
  810 IF(NASC.GT.-2)RETURN
      DO 820 I=1,84
      IJK=LOCHTS+I-1
      ASTER(IJK)=SAVE(I)
  820 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE BOX
      DIMENSION MASTER(30000)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE (MASTER,ASTER)
C
      CALL UN2(LOCDA,IV,IH1)
      LOC=LOCDA+1
      CALL UN2(LOC,IH2,IH3)
      RIN=-PINF
      ROUT=PINF
      DO 105 I=1,3
      IF(I-2)11,12,13
   11 II=2
      GOTO 14
   12 II=1
      GOTO 14
   13 II=3
   14 A=0.
      VP=0.
      W=0.
      DO 15 J=1,3
      JV=IV+J
      JA=IH1+J
      VP=VP+(ASTER(JV-1)-XB(J))*ASTER(JA-1)
```

```
      W=W+WB(J)*ASTER(JA-1)
      A=A+ASTER(JA-1)**2
   15 CONTINUE
      IF(W)30,20,40
   20 IF(-VP.LT.0.)GOTO 200
      IF(-VP-A)100,100,200
   30 CP=VP/W
      LO=2*II-1
      IF(CP.LE.0.)GOTO 200
      CM=(VP+A)/W
      LI=LO+1
      GOTO 60
   40 CP=(VP+A)/W
      LO=2*II
      IF(CP.LE.0.)GOTO 200
      CM=VP/W
      LI=LO-1
   60 IF(ROUT.LE.CP)GOTO 80
      ROUT=CP
      LRO=LO
   80 IF(RIN.GE.CM)GOTO 100
      RIN=CM
      LRI=LI
  100 IH1=IH2
      IH2=IH3
  105 CONTINUE
      IF(ABS(RIN-ROUT).LE.ROUT*1.0E-6)GOTO 200
      IF(RIN.LT.ROUT)RETURN
  200 RIN=PINF
      ROUT=-PINF
      RETURN
      END
C
C
      SUBROUTINE ELL
      DIMENSION FOCIA(3),FOCIB(3),MASTER(30000)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE (ASTER,MASTER)
C
      CALL UN2(LOCDA,IV1,IV2)
      IRR=MASTER(LOCDA+1)
      FOCIA(1)=ASTER(IV1)
      FOCIA(2)=ASTER(IV1+1)
      FOCIA(3)=ASTER(IV1+2)
      FOCIB(1)=ASTER(IV2)
      FOCIB(2)=ASTER(IV2+1)
      FOCIB(3)=ASTER(IV2+2)
      C=ASTER(IRR)
      RIN=PINF
      ROUT=-PINF
      D1X=XB(1)-FOCIA(1)
      D1Y=XB(2)-FOCIA(2)
      D1Z=XB(3)-FOCIA(3)
      D2X=XB(1)-FOCIB(1)
      D2Y=XB(2)-FOCIB(2)
      D2Z=XB(3)-FOCIB(3)
```

```
      A1=2.*(D1X*WB(1)+D1Y*WB(2)+D1Z*WB(3))
      A2=2.*(D2X*WB(1)+D2Y*WB(2)+D2Z*WB(3))
      B1=D1X*D1X+D1Y*D1Y+D1Z*D1Z
      B2=D2X*D2X+D2Y*D2Y+D2Z*D2Z
      AA=(A2-A1)/(2.*C)
      BB=(C*C+B2-B1)/(2.*C)
      ALAMD=AA*AA-1.
      ALAM1=(AA*BB-.5*A2)/ALAMD
      U=(BB*BB-B2)/ALAMD
      DISCRM=ALAM1*ALAM1-U
      IF(DISCRM.LE.0.)RETURN
      SQRTDI=SQRT(DISCRM)
      RIN=-ALAM1-SQRTDI
      ROUT=-ALAM1+SQRTDI
      RETURN
      END
C
C
      SUBROUTINE RAW
      DIMENSION H1(3),H2(3),H3(3),V(3),ASQ(3),PV(4),G(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
C
      CALL UN2(LOCDA,IV,IH1)
      LOC=LOCDA+1
      CALL UN2(LOC,IH2,IH3)
      H1(1)=ASTER(IH1)
      H1(2)=ASTER(IH1+1)
      H1(3)=ASTER(IH1+2)
      H2(1)=ASTER(IH2)
      H2(2)=ASTER(IH2+1)
      H2(3)=ASTER(IH2+2)
      H3(1)=ASTER(IH3)
      H3(2)=ASTER(IH3+1)
      H3(3)=ASTER(IH3+2)
      V(1)=ASTER(IV)
      V(2)=ASTER(IV+1)
      V(3)=ASTER(IV+2)
      RIN=-PINF
      ROUT=PINF
      CM=-PINF
      CP=PINF
      L=0
      L1=0
      K=0
      LRI=0
      LRO=0
      ASQ(1)=H1(1)*H1(1)+H1(2)*H1(2)+H1(3)*H1(3)
      ASQ(2)=H2(1)*H2(1)+H2(2)*H2(2)+H2(3)*H2(3)
      ASQ(3)=H3(1)*H3(1)+H3(2)*H3(2)+H3(3)*H3(3)
      XB1V1=XB(1)-V(1)
      XB2V2=XB(2)-V(2)
      XB3V3=XB(3)-V(3)
      PV(1)=XB1V1*H1(1)+XB2V2*H1(2)+XB3V3*H1(3)
      PV(2)=XB1V1*H2(1)+XB2V2*H2(2)+XB3V3*H2(3)
      PV(3)=XB1V1*H3(1)+XB2V2*H3(2)+XB3V3*H3(3)
      G(1)=WB(1)*H1(1)+WB(2)*H1(2)+WB(3)*H1(3)
```

```
      G(2)=WB(1)*H2(1)+WB(2)*H2(2)+WB(3)*H2(3)
      G(3)=WB(1)*H3(1)+WB(2)*H3(2)+WB(3)*H3(3)
C
      DO 140 I=1,2
      IF(G(I))10,110,60
C
   10 IF(-PV(I))20,400,400
   20 TEMP=-PV(I)/G(I)
      IF(TEMP-CP)30,130,130
   30 CP=TEMP
      L=I
      GOTO(40,50),I
   40 LRO=3
      GOTO 130
   50 LRO=1
      GOTO 130
C
   60 IF(-PV(I).LE.0.)GOTO 130
      TEMP=-PV(I)/G(I)
      IF(TEMP.LE.CM)GOTO 130
      CM=TEMP
      K=I
      GOTO(90,100),I
   90 LRI=3
      GOTO 130
  100 LRI=1
      GOTO 130
C
  110 IF(PV(I).LE.0.)GOTO 810
      IF(PV(I).GE.ASQ(I))GOTO 810
  130 LI=LI+I
  140 CONTINUE
C
      IF(G(3))150,210,230
  150 TEMP=ASQ(3)-PV(3)
      IF(TEMP.GE.0.)GOTO 180
      TEMP=TEMP/G(3)
      IF(TEMP.LE.CM)GOTO 190
      CM=TEMP
      K=3
      LRI=6
  180 IF(-PV(3))190,400,400
  190 TEMP=-PV(3)/G(3)
      IF(TEMP.GE.CP)GOTO 290
      CP=TEMP
      L=3
      LRO=5
      GOTO 290
C
  210 IF(PV(3).LE.0.)GOTO 400
      IF(PV(3)-ASQ(3))290,290,400
C
  230 IF(-PV(3).LE.0.)GOTO 260
      TEMP=-PV(3)/G(3)
      IF(TEMP.LE.CM)GOTO 260
      CM=TEMP
      K=3
      LRI=5
  260 TEMP=ASQ(3)-PV(3)
      IF(TEMP.LE.0.)GOTO 400
```

```
      TEMP=TEMP/G(3)
      IF(TEMP.GE.CP)GOTO 290
      CP=TEMP
      L=3
      LRO=6
  290 AG=ASQ(2)*G(1)+ASQ(1)*G(2)
      PV(4)=PV(1)*ASQ(2)+PV(2)*ASQ(1)
      TOP=ASQ(1)*ASQ(2)-PV(4)
      IF(AG)310,350,330
  310 TEMP=TOP/AG
      IF(TEMP.LE.CM)GOTO 380
      CM=TEMP
      K=4
      LRI=2
      GOTO 380
C
  330 IF(TOP.LT.0.)GOTO 400
      TEMP=TOP/AG
      IF(TEMP-CP)370,380,380
C
  350 IF(PV(4).LE.0.)GOTO 400
      IF(-TOP)380,400,400
  370 CP=TEMP
      L=4
      LRO=2
  380 IF(L+K.LE.0)GOTO 400
      ROUT=CP
      RIN=CM
C
  400 IF(ROUT.GE.PINF)GOTO 810
      IF(ROUT.LE.0.)GOTO 810
      IF(RIN.GE.ROUT)GOTO 810
      IF(ABS(RIN-ROUT).GT.ROUT*1.0E-5)GOTO 820
C
  810 ROUT=-PINF
      RIN=PINF
      LRO=0
      LRI=0
  820 RETURN
      END
C
C
      SUBROUTINE RCC
      DIMENSION V(3),H(3),MASTER(30000)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE (ASTER,MASTER)
C
      CALL UN2(LOCDA,IV,IH)
      IRR=MASTER(LOCDA+1)
      H(1)=ASTER(IH)
      H(2)=ASTER(IH+1)
      H(3)=ASTER(IH+2)
      V(1)=ASTER(IV)
      V(2)=ASTER(IV+1)
      V(3)=ASTER(IV+2)
      R=ASTER(IRR)
```

```
      RIN=-PINF
      ROUT=PINF
      RSQ=R*R
      LRO=0
      LRI=0
      TOP=0.
      POT=0.
      HH=H(1)*H(1)+H(2)*H(2)+H(3)*H(3)
      VPH=H(1)*(V(1)-XB(1))+H(2)*(V(2)-XB(2))+H(3)*(V(3)-XB(3))
      WH=WB(1)*H(1)+WB(2)*H(2)+WB(3)*H(3)
      DEN=HH-WH*WH
      DO 10 I=1,3
      TOP=TOP+WB(I)*(XB(I)-V(I))
      POT=POT+(XB(I)-V(I))**2
   10 CONTINUE
      AMBD=-HH*TOP-WH*VPH
      UM=(POT-RSQ)*HH-VPH**2
      IF(WH)40,70,50
   40 CP=VPH/WH
      CM=(VPH+HH)/WH
      LCP=1
      LCM=2
      GOTO 60
   50 CP=(VPH+HH)/WH
      CM=VPH/WH
      LCM=1
      LCP=2
   60 IF(CP)300,80,80
   70 CP=PINF
      CM=-CP
      IF(VPH.GT.0.)GOTO 300
      IF(HH+VPH)300,90,90
   80 IF(ABS(DEN).GE.1.0E-6)GOTO 90
      R1=-PINF
      R2=PINF
      GOTO 100
   90 R1=0.
      R2=0.
      AMBDA=AMBD/DEN
      UMU=UM/DEN
      DISC=AMBDA**2-UMU
      IF(DISC.LE.0.)GOTO 300
      SD=SQRT(DISC)
      R1=AMBDA-SD
      R2=AMBDA+SD
  100 IF(CM.GT.R1)GOTO 110
      RIN=R1
      LRI=3
      GOTO 120
  110 RIN=CM
      LRI=LCM
  120 IF(CP.LE.R2)GOTO 130
      ROUT=R2
      LRO=3
      GOTO 200
  130 ROUT=CP
      LRO=LCP
  200 IF(ABS(ROUT-RIN).LE.ROUT*1.0E-5)GOTO 300
      GOTO(210,210,220),LRO
  210 F1=DEN*ROUT**2-2.*AMBD*ROUT+UM
```

```
      IF(F1)250,250,300
  220 F1=ROUT*WH-VPH
      IF(F1)300,250,230
      GOTO 230
  230 IF(F1.GT.HH) GOTO 300
  250 GOTO(260,260,270),LRI
  260 F1=DEN*RIN**2-2.*AMBD*RIN+UM
      IF(F1)310,310,300
  270 F1=RIN*WH-VPH
      IF(F1)300,310,280
      GOTO 280
  280 IF(F1.LE.HH)GOTO 310
  300 RIN=PINF
      ROUT=-PINF
      LRO=0
      LRI=0
  310 RETURN
      END
C
C
      SUBROUTINE REC
      DIMENSION V(3),H(3),A(3),B(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
C
      CALL UN2(LOCDA,IV,IH)
      LOC=LOCDA+1
      CALL UN2(LOC,IA,IB)
      V(1)=ASTER(IV)
      V(2)=ASTER(IV+1)
      V(3)=ASTER(IV+2)
      H(1)=ASTER(IH)
      H(2)=ASTER(IH+1)
      H(3)=ASTER(IH+2)
      A(1)=ASTER(IA)
      A(2)=ASTER(IA+1)
      A(3)=ASTER(IA+2)
      B(1)=ASTER(IB)
      B(2)=ASTER(IB+1)
      B(3)=ASTER(IB+2)
      RIN=-PINF
      ROUT=PINF
      LRO=0
      LRI=0
      AA=A(1)*A(1)+A(2)*A(2)+A(3)*A(3)
      BB=B(1)*B(1)+B(2)*B(2)+B(3)*B(3)
      V1XB1=V(1)-XB(1)
      V2XB2=V(2)-XB(2)
      V3XB3=V(3)-XB(3)
      VPA=V1XB1*A(1)+V2XB2*A(2)+V3XB3*A(3)
      VPB=V1XB1*B(1)+V2XB2*B(2)+V3XB3*B(3)
      WBA=WB(1)*A(1)+WB(2)*A(2)+WB(3)*A(3)
      WBB=WB(1)*B(1)+WB(2)*B(2)+WB(3)*B(3)
      WBAWBA=WBA*WBA
      WBBWBB=WBB*WBB
      AAAA=AA*AA
      BBBB=BB*BB
```

```
      AMBD=WBA*VPA*BBBB+WBB*VPB*AAAA
      UM=BBBB*VPA*VPA+AAAA*VPB*VPB-AAAA*BBBB
      DEN=WBAWBA*BBBB+WBBWBB*AAAA
      IF(ABS(DEN).LE.1.0E-6)GOTO 10
      AMBDA=AMBD/DEN
      UMU=UM/DEN
      DISC=AMBDA**2-UMU
      IF(DISC.LE.0.)GOTO 300
      SD=SQRT(DISC)
      R1=AMBDA-SD
      R2=AMBDA+SD
      GOTO 20
   10 R1=-PINF
      R2=PINF
   20 HH=H(1)*H(1)+H(2)*H(2)+H(3)*H(3)
      WH=WB(1)*H(1)+WB(2)*H(2)+WB(3)*H(3)
      VPH=V1XB1*H(1)+V2XB2*H(2)+V3XB3*H(3)
      IF(WH)40,70,50
   40 IF(VPH.GE.0.)GOTO 300
      CP=VPH/WH
      CM=(VPH+HH)/WH
      LCP=1
      LCM=2
      GOTO 100
   50 VPHHH=VPH+HH
      IF(VPHHH.LE.0.)GOTO 300
      CP=VPHHH/WH
      CM=VPH/WH
      LCM=1
      LCP=2
      GOTO 100
   70 CP=PINF
      CM=-CP
  100 IF(CM.GT.R1)GOTO 110
      RIN=R1
      LRI=3
      GOTO 120
  110 RIN=CM
      LRI=LCM
  120 IF(CP.LE.R2)GOTO 130
      ROUT=R2
      LRO=3
      GOTO 200
  130 ROUT=CP
      LRO=LCP
  200 IF(ABS(ROUT-RIN).LE.ROUT*1.0E-5)GOTO 300
      GOTO(210,210,220),LRO
  210 F1=DEN*ROUT**2-2.*AMBD*ROUT+UM
      IF(F1)250,250,300
  220 F1=ROUT*WH-VPH
      IF(F1)300,250,230
      GOTO 230
  230 IF(F1.GT.HH)GOTO 300
  250 GOTO(260,260,270),LRI
  260 F1=DEN*RIN**2-2.*AMBD*RIN+UM
      IF(F1)310,310,300
  270 F1=RIN*WH-VPH
      IF(F1)300,310,280
      GOTO 280
  280 IF(F1.LE.HH)GOTO 310
```

```
  300 RIN=PINF
      ROUT=-PINF
      LRI=0
      LRO=0
  310 RETURN
      END
C
C
      SUBROUTINE RPP(NBO)
      DIMENSION MASTER(30000),PR(6),LR(6),XS(6),LST(6)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE (MASTER,ASTER)
C
  901 FORMAT(1HO,12HERROR IN RPP/4H L =,I10,5X,4HNBO=,I10,5X,3HIR=,
     1  I10/4H XB=,3E20.10/4H WB=,3E20.10/4H PR=,6E20.10/4H LR=,6I10)
C
      LST(1)=1
      LST(2)=1
      LST(3)=2
      LST(4)=2
      LST(5)=3
      LST(6)=3
      L=0
      PR(1)=0.
      PR(2)=0.
      DO 10 I=1,6
      XS(I)=S(NBO,I)
   10 CONTINUE
C
      DO 100 I=1,6
      II=LST(I)
      TEMP=XS(I)-XB(II)
      IF(WB(II)) 20,100,30
   20 IF(TEMP)40,100,100
   30 IF(TEMP.LE.0.)GOTO 100
   40 TRY=TEMP/WB(II)
      DO 60 J=1,3
      IF(J.EQ.II)GOTO 60
      XRY=XB(J)+TRY*WB(J)
      IF((XS(2*J-1)-XRY)*(XRY-XS(2*J)).LT.0.)GOTO 100
   60 CONTINUE
      L=L+1
      PR(L)=TRY
      LR(L)=I
      IF(L.EQ.2)GOTO 130
      IF(L.LT.2)GOTO 100
      WRITE (6,901)L,NBO,IR,XB,WB,PR,LR
      ROUT=-PINF
      RETURN
  100 CONTINUE
      GOTO 160
C
  130 IF(ABS(PR(1)-PR(2)).LE.PR(1)*1.0E-6)GOTO 200
      IF(PR(1)-PR(2))140,180,150
  140 RIN=PR(1)
      LRI=LR(1)
```

```
      ROUT=PR(2)
      LRO=LR(2)
      RETURN
  150 RIN=PR(2)
      LRI=LR(2)
      ROUT=PR(1)
      LRO=LR(1)
      RETURN
C
  160 IF(L.GE.1)GOTO 180
  170 ROUT=-PINF
      RETURN
  180 RIN=-PINF
      LRI=0
      ROUT=PR(1)
      LRO=LR(1)
      RETURN
C
  200 DO 220 J=1,3
      IF(XB(J).LT.XS(2*J-1))GOTO 170
      IF(XB(J).GT.XS(2*J))GOTO 170
  220 CONTINUE
      GOTO 180
      END
C
C
      SUBROUTINE RPP2(LSURF,XP,IRP)
C          FINDS ABUTING RPP
      DIMENSION XP(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
C
      LOC=LBASE+12*(NASC-1)-2*(LSURF+1)
      CALL UN2(LOC,LOCAT,NC)
      IF(NC-1)10,20,30
   10 IRP=0
      RETURN
   20 CALL UN2(LOCAT,IRP,DUM)
      RETURN
   30 M=1
C
      DO 90 I=1,NC
      M=-M
      IF(M.GT.0)GOTO 50
      CALL UN2(LOCAT,I1,I2)
      LOCAT=LOCAT+1
      IRP=I1
      GOTO 70
   50 IRP=I2
   70 LS=(1-LSURF)/2
      DO 80 J=1,3
      IF(J.EQ.LS)GOTO 80
      IF((S(IRP,2*J-1)-XP(J))*(XP(J)-S(IRP,2*J)).LT.0.)GOTO 90
   80 CONTINUE
      RETURN
   90 CONTINUE
      IRP=0
```

```
      RETURN
      END
C
C
      SUBROUTINE SPH
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
C
      CALL UN2(LOCDA,ITEMP,I2)
      R=ASTER(I2)
      ITEMP=ITEMP+1
      DX=XB(1)-ASTER(ITEMP-1)
      DY=XB(2)-ASTER(ITEMP)
      DZ=XB(3)-ASTER(ITEMP+1)
      B=DX*WB(1)+DY*WB(2)+DZ*WB(3)
      C=DX*DX+DY*DY+DZ*DZ-R*R
      DIS=B*B-C
      IF(C.GT.0.)GOTO 10
      RIN=-PINF
      ROUT=SQRT(DIS)-B
      RETURN
   10 IF(DIS.GT.0.)GOTO 20
      RIN=PINF
      ROUT=-PINF
      RETURN
   20 DIS=SORT(DIS)
      RIN=-B-DIS
      ROUT=-B+DIS
      RETURN
      END
C
C
      SUBROUTINE TEC
      DIMENSION MASTER(30000),DELTA(3),HF(3),AUN(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE (MASTER,ASTER),(GAMMA,SIGMA)
      REAL NF(3),K(3),M,M2,MM,MM2
C
      CALL UN2(LOCDA,IV,IH)
      LOC=LOCDA+1
      CALL UN2(LOC,IN,IA)
      LOC=LOC+1
      CALL UN2(LOC,IR1,IR2)
      IRC=MASTER(LOC+1)
      R1=ASTER(IR1)
      R2=ASTER(IR2)
      R3=R1/ASTER(IRC)
      R4=R2/ASTER(IRC)
      DDN=0.
      WDA=0.
      DDA=0.
      HDA=0.
      HDN=0.
```

```
      WDN=0.
      DO 100 I=1,3
      I1=I-1
      J1=IV+I1
      J2=IH+I1
      J3=IN+I1
      J4=IA+I1
      DELTA(I)=ASTER(J1)-XB(I)
      HF(I)=ASTER(J2)
      NF(I)=ASTER(J3)
      AUN(I)=ASTER(J4)
      DDN=DELTA(I)*NF(I)+DDN
      WDA=WB(I)*AUN(I)+WDA
      DDA=DELTA(I)*AUN(I)+DDA
      HDA=HF(I)*AUN(I)+HDA
      HDN=HF(I)*NF(I)+HDN
      WDN=WB(I)*NF(I)+WDN
  100 CONTINUE
      CALL CROSS(K,AUN,NF)
      WDK=DOT(WB,K)
      DDK=DOT(DELTA,K)
      HDK=DOT(HF,K)
      IF(ABS(WDN).GT.1.0E-7)GOTO 300
      GAMMA=-DDN/HDN
      IF(GAMMA.LT.0.)GOTO 900
      RTP=GAMMA-1.
      IF(RTP.GT.0.)GOTO 900
      M=GAMMA*R3+R1*(1.-GAMMA)
      MM=GAMMA*R4+R2*(1.-GAMMA)
      M2=M*M
      MM2=MM*MM
      T=SIGMA*HDA+DDA
      TT=SIGMA*HDK+DDK
      A=MM2*WDA**2+M2*WDK**2
      B=-(MM2*WDA*T+M2*WDK*TT)
      C=MM2*T**2+M2*TT**2-M2*MM2
      DISC=B*B-A*C
      IF(DISC.LT.0.)GOTO 900
      IF(DISC.GT.0.)DISC=SQRT(DISC)
      RIN=(-B-DISC)/A
      ROUT=(-B+DISC)/A
      LRI=3
      LRO=3
      GOTO 950
C
  300 FLIPD=1.
      IF(WDN.LT.0.)GOTO 310
      FLIPD=-1.
      WDA=-WDA
      WDN=-WDN
      WDK=-WDK
  310 ALPHA=HDN/WDN
      BETA=DDN/WDN
      TAU=(R3/R4)**2
      A=(ALPHA*WDA-HDA)**2+TAU*(ALPHA*WDK-HDK)**2-TAU*(R4-R2)**2
      B=     -(-ALPHA*BETA*WDA**2+ALPHA*WDA*DDA+BETA*WDA*HDA-DDA*HDA
     1  +TAU*(-ALPHA*BETA*WDK**2+ALPHA*WDK*DDK+BETA*WDK*HDK-DDK*HDK
     2  +R2*R4-R2*R2))
      C=(DDA-BETA*WDA)**2+TAU*((DDK-BETA*WDK)**2-R2**2)
      DISC=B*B-A*C
```

```
      IF(DISC.LT.0.)GOTO 900
      IF(DISC.GT.0.)DISC=SQRT(DISC)
      IF(ABS(A).LE.1.0E-7)GOTO 330
      IF(A)320,330,340
  320 SIGMA1=(-B-DISC)/A
      SIGMA2=(-B+DISC)/A
      GOTO 350
  330 SIGMA1=-C/(2.*B)
      SIGMA2=-PINF
      IF(SIGMA1)900,350,350
  340 SIGMA1=(-B+DISC)/A
      SIGMA2=(-B-DISC)/A
  350 SIGMAP=-R1/(R3-R1)
      IF(SIGMA2.GT.1.)GOTO 900
      IF(SIGMA1.LT.0.)GOTO 900
      IF(SIGMA1.GT.1.)GOTO 410
      IF(SIGMA2.GT.0.)GOTO 400
      RIN=ALPHA*SIGMA1+BETA
      LRI=3
      ROUT=BETA
      LRO=1
      GOTO 490
  400 RIN=ALPHA*SIGMA1+BETA
      LRI=3
      ROUT=ALPHA*SIGMA2+BETA
      LRO=3
      GOTO 490
  410 IF(SIGMA2.GT.0.)GOTO 440
      IF(SIGMA1.GT.SIGMAP)GOTO 900
      RIN=ALPHA+BETA
      LRI=2
      ROUT=BETA
      LRO=1
      GOTO 490
  440 IF(SIGMA1.GT.SIGMAP)GOTO 460
      RIN=ALPHA+BETA
      LRI=2
      ROUT=ALPHA*SIGMA2+BETA
      LRO=3
      GOTO 490
  460 RIN=ALPHA*SIGMA2+BETA
      LRI=3
      ROUT=BETA
      LRO=1
C
  490 IF(FLIPD.GE.0.)GOTO 950
      RTP=RIN
      ITP=LRI
      RIN=-ROUT
      LRI=LRO
      ROUT=-RTP
      LRO=ITP
      GOTO 950
  900 RIN=PINF
      ROUT=-PINF
  950 IF(ROUT.GT.0.)GOTO 1000
      RIN=PINF
      ROUT=-PINF
      RETURN
 1000 IF(ABS(ROUT-RIN).LE.RIN*1.0E-6)GOTO 900
```

```
      RETURN
      END
C
C
      SUBROUTINE TOR
      DIMENSION MASTER(30000),XMCV(3),C(4),RT(4),RTS(4),XAW(3),XTRY(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE (MASTER,ASTER),(DIST,STHUS)
      REAL NF(3)
C
      CALL UN2(LOCDA,IV,IN)
      LOC=LOCDA+1
      CALL UN2(LOC,IR1,IR2)
      R1=ASTER(IR1)
      R2=ASTER(IR2)
      WDN=0.
      XMC2=0.
      AW=SQRT(DOT(WB,WB))
      DO 10 I=1,3
      J1=IV+I-1
      XAW(I)=ASTER(J1)-XB(I)
   10 CONTINUE
      RSAVE=ABS(DOT(XAW,WB)/AW)-R1-R2-R2
      IF(NASC.EQ.-2)RSAVE=0.
      DO 20 I=1,3
      XTRY(I)=XB(I)+RSAVE*WB(I)
   20 CONTINUE
      DO 100 I=1,3
      J1=IV+I-1
      J2=IN+I-1
      NF(I)=ASTER(J2)
      XMCV(I)=XTRY(I)-ASTER(J1)
      XMC2=XMCV(I)**2+XMC2
      WDN=WB(I)*ASTER(J2)+WDN
  100 CONTINUE
      WDXMC=DOT(WB,XMCV)
      XMCDN=DOT(XMCV,NF)
      R12=R1*R1
      R22=R2*R2
      TERM=R12+R22-XMC2
      C(1)=4.*WDXMC
      TEMP=4.*WDXMC**2
      C(2)=4.*R12*WDN**2-2.*TERM+TEMP
      C(3)=8.*R12*WDN*XMCDN-4.*WDXMC*TERM
      C(4)=4.*R12*(XMCDN**2-R22)+TERM**2
      CALL QRTIC(C,RT,NR)
      IF(NR-2)110,120,140
C          TOR NOT HIT
  110 RIN=0.
      ROUT=-PINF
      RETURN
C          2 ROOTS
  120 IF(RT(1).GE.RT(2))GOTO 130
      RIN=RT(1)
      ROUT=RT(2)
      GOTO 900
```

```
  130 RIN=RT(2)
      ROUT=RT(1)
      GOTO 900
C         4 ROOTS     SELECT FIRST PAIR .GE. DIST AS RIN AND ROUT
  140 RTS(1)=RT(1)
      IF(RT(2).LT.RTS(1))GOTO 150
      RTS(2)=RT(2)
      GOTO 160
  150 RTS(2)=RTS(1)
      RTS(1)=RT(2)
  160 IF(RT(3).LT.RTS(2))GOTO 170
      RTS(3)=RT(3)
      GOTO 190
  170 RTS(3)=RTS(2)
      IF(RT(3).LT.RTS(1))GOTO 180
      RTS(2)=RT(3)
      GOTO 190
  180 RTS(2)=RTS(1)
      RTS(1)=RT(3)
  190 IF(RT(4).LT.RTS(3))GOTO 200
      RTS(4)=RT(4)
      GOTO 300
  200 RTS(4)=RTS(3)
      IF(RT(4).LT.RTS(2))GOTO 210
      RTS(3)=RT(4)
      GOTO 300
  210 RTS(3)=RTS(2)
      IF(RT(4).LT.RTS(1))GOTO 220
      RTS(2)=RT(4)
      GOTO 300
  220 RTS(2)=RTS(1)
      RTS(1)=RT(4)
C         STHUS=DIST
  300 IF(ABS(STHUS-RTS(2)).LE.1.0E-7)GOTO 310
      IF(STHUS.GE.RTS(2))GOTO 310
      RIN=RTS(1)
      ROUT=RTS(2)
      GOTO 900
  310 RIN=RTS(3)
      ROUT=RTS(4)
C
  900 LRI=1
      LRO=1
      RIN=RIN+RSAVE
      ROUT=ROUT+RSAVE
      IF(ROUT.GE.0.0)GOTO 920
  910 RIN=PINF
      ROUT=-PINF
      RETURN
  920 IF(ABS(ROUT-RIN).LE.RIN*1.0E-6)GOTO 910
      RETURN
      END
C
C
      SUBROUTINE TRC
      DIMENSION MASTER(30000),V(3),H(3)
      COMMON ASTER(30000)
      COMMON/PAREM/XB(3),WB(3),IR
      COMMON/GEOM/LBASE,RIN,ROUT,LRI,LRO,PINF,IERR,DIST
      COMMON/UNCGEM/NRPP,NTRIP,NSCAL,NBODY,NRMAX,LTRIP,LSCAL,LREGD,
```

```
     1  LDATA,LRIN,LROT,LIO,LOCDA,I15,I30,LBODY,NASC,KLOOP
      EQUIVALENCE(MASTER,ASTER)
C
      CALL UN2(LOCDA,IV,IH)
      LOC=LOCDA+1
      CALL UN2(LOC,IRB,IRTOP)
      V(1)=ASTER(IV)
      V(2)=ASTER(IV+1)
      V(3)=ASTER(IV+2)
      H(1)=ASTER(IH)
      H(2)=ASTER(IH+1)
      H(3)=ASTER(IH+2)
      RB=ASTER(IRB)
      RT=ASTER(IRTOP)
      RIN=-PINF
      ROUT=PINF
      LRO=0
      LRI=0
      INTSEC=0
      INTR1=0
      INTR2=0
      V1XB1=V(1)-XB(1)
      V2XB2=V(2)-XB(2)
      V3XB3=V(3)-XB(3)
      PVPV=V1XB1*V1XB1+V2XB2*V2XB2+V3XB3*V3XB3
      VPW=V1XB1*WB(1)+V2XB2*WB(2)+V3XB3*WB(3)
      WH =WB(1)*H(1)+WB(2)*H(2)+WB(3)*H(3)
      VPH=V1XB1*H(1)+V2XB2*H(2)+V3XB3*H(3)
      HH=H(1)*H(1)+H(2)*H(2)+H(3)*H(3)
      RTRB=RT-RB
      RBRTVP=RB-VPH*RTRB/HH
      VPHHH=VPH+HH
      UM=HH*(PVPV-RBRTVP**2)-VPH*VPH
      AMBD=HH*VPW-WH*(VPH-RTRB*RBRTVP)
      DEN=HH-WH**2*(1.+RTRB**2/HH)
      IF(ABS(DEN).GT.1.0E-6)GOTO 40
      IF(RTRB.EQ.0.)GOTO 200
      R2=UM/(2.*AMBD)
      F1=R2*WH-VPH
      IF(F1.LT.0.)GOTO 200
      IF(F1.GT.HH)GOTO 200
      INTSEC=INTSEC+1
      IF(WH.LE.0.)GOTO 10
      IF(RTRB)20,20,30
   10 IF(RTRB)30,30,20
   20 LRO=3
      ROUT=R2
      GOTO 250
   30 LRI=3
      RIN=R2
      INTSEC=INTSEC+1
      GOTO 210
C
   40 AMBDA=AMBD/DEN
      UMU=UM/DEN
      DISC=AMBDA**2-UMU
      IF(DISC)350,200,50
      GOTO 50
   50 SD=SQRT(DISC)
      R1=AMBDA-SD
```

```
      R2=AMBDA+SD
      F1=R2*WH-VPH
      IF(F1.LT.0.)GOTO 60
      IF(F1.LE.HH)INTR2=INTR2+1
   60 F1=R1*WH-VPH
      IF(F1.LT.0.)GOTO 70
      IF(F1.LE.HH)GOTO 80
   70 IF(INTR2.LT.1)GOTO 200
      ROUT=R2
      RIN=R2
      LRO=3
      LRI=3
      INTSEC=INTSEC+1
      GOTO 200
   80 INTR1=INTR1+1
      IF(INTR2.GE.1)GOTO 90
      ROUT=R1
      RIN=R1
      LRO=3
      LRI=3
      INTSEC=INTSEC+1
      GOTO 200
   90 IF(R1-R2)100,350,110
  100 RIN=R1
      ROUT=R2
      LRO=3
      LRI=3
      GOTO 300
  110 RIN=R2
      ROUT=R1
      LRO=3
      LRI=3
      GOTO 300
C
  200 IF(WH)210,350,250
  210 IF(VPH.GE.0.)GOTO 350
      CP=VPH/WH
      F1=CP*CP-2.*CP*VPW+PVPV-RB*RB
      IF(F1.GT.0.)GOTO 220
      INTSEC=INTSEC+1
      ROUT=CP
      LRO=1
      IF(INTSEC.GE.2)GOTO 300
  220 CM=VPHHH/WH
      F1=CM*CM-2.*((VPW+WH)*CM-VPH)+HH+PVPV-RT*RT
      IF(F1.GT.0.)GOTO 350
      RIN=CM
      LRI=2
      GOTO 300
  250 IF(VPHHH.LT.0.)GOTO 350
      CP=VPHHH/WH
      F1=CP*CP-2.*((VPW+WH)*CP-VPH)+HH+PVPV-RT*RT
      IF(F1.GT.0.)GOTO 260
      INTSEC=INTSEC+1
      ROUT=CP
      LRO=2
  260 IF(INTSEC.GE.2)GOTO 300
      CM=VPH/WH
      F1=CM*CM-2.*CM*VPW+PVPV-RB*RB
      IF(F1.GT.0.)GOTO 350
```

```
      RIN=CM
      LRI=1
C
  300 IF(ABS(ROUT-RIN)-ROUT*1.0E-5)350,350,360
  350 RIN=PINF
      ROUT=-PINF
      LRI=0
      LRO=0
  360 RETURN
      END
C
C
END
```


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