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TITLE: SABRINA - AN INTERACTIVE SOLID GEOMETRY MODELING PROGRAM FOR MONTE CARLO

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**SABRINA - AN INTERACTIVE SOLID GEOMETRY  
MODELING PROGRAM FOR MONTE CARLO**

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**ABSTRACT**

SABRINA is a fully interactive three-dimensional geometry modeling program for MCNP. In SABRINA, a user interactively constructs either body geometry, or surface geometry models, and interactively debugs spatial descriptions for the resulting objects. This enhanced capability significantly reduces the effort in constructing and debugging complicated three-dimensional geometry models for Monte Carlo Analysis.

## INTRODUCTION

The goal of this effort is to provide a convenient tool for interactive geometry construction and debugging. The main strength of the Monte Carlo Method is its ability to model both physics and geometry in detail. It is only when the Monte Carlo User can easily generate complex geometries that Monte Carlo Programs can realize their full geometric modeling potential. SABRINA is an attempt to take the pain out of complex geometry modeling, and make the process both interesting and rewarding to the user. The interactive dialogue used in SABRINA is forgiving and attempts to verify user input as it is entered. The input for SABRINA requires only a basic knowledge of three-dimensional geometry, and should be useful to people with only a limited technical background.

Geometry construction with SABRINA may be accomplished using either body geometry, or surface geometry. For users familiar with MCNP surface geometry, body geometry may be thought of as simple geometric macros, where a body is a predefined combination of geometric surfaces. For instance, when a user describes a Right Circular Cylinder (RCC), the user obtains two planes and a quadratic. This body macro notation is convenient for graphical display and for efficiently fully defining the contents of space.

For the more experienced MCNP user, MCNP surface geometry is available. Users may interactively construct, debug, and modify standard MCNP geometry models. This gives users greater control over surface and geometric cell definitions than available in body geometry descriptions. This capability is especially important to the user when old MCNP input files containing complicated models exist and require extensive modification. It is usually preferable to modify an old proven geometry model, than to start from scratch creating a new model.

Spatial zones or cells in SABRINA are described with boolean expressions using unions and intersections. The boolean logic rules are basically the same for both body geometry and for surface geometry. Body zone descriptions are expanded into surface expressions to produce MCNP surface cell definitions. A user may develop a geometry model initially with body geometry, convert the model to an MCNP surface model, and continue to develop the model in SABRINA as a surface model. SABRINA does not require a user to know MCNP surface geometry, but a user can produce a more efficient model for particle tracking if the user is aware of MCNP surface cell logic.

An important feature in SABRINA is the "TEST" option to check for space that has either been left undefined or has been overdefined. Many of the commercially available solid geometry modelers make over definition of space an easy mistake, and a mistake difficult to discover. SABRINA gives the user the ability to quickly and easily locate geometry modeling errors, and then the flexibility to immediately attempt a correction. This instant feedback is important to the modeling process. Most users in describing a complicated geometry model will inevitably make mistakes. It is unrealistic to believe otherwise. SABRINA was written to expect user errors, and allow the modeling development to proceed with minimal difficulty. Complicated three-dimensional definition of space need not be intimidating or cumbersome.

A properly written interactive geometry modeler should make the modeling process both interesting and rewarding.

### GEOMETRY MODELING CAPABILITIES

SABRINA is a fully interactive three-dimensional solid geometry modeling program utilizing both constructive solid geometry, CSG, (body geometry) and boundary representation, BR, (surface geometry) capabilities. Both methods have both advantages and disadvantages and advocates exists for both approaches. SABRINA combines both methods, and supports a hybrid combination called boundary solid geometry, BSG.

The constructive solid geometry method utilizes simple geometric body primitives. Body primitives define from one to six surfaces automatically. Spatial regions may then be described with boolean expressions using the union and the intersection operators. This method is easy to visualize and allows the user to quickly describe complicated geometry using simple body primitives. This approach yields a rich and powerful approach to the manipulation and definition of complex geometric objects. However, a serious logical inconsistency is found in most CSG body modeling systems, the common surface problem. When several CSG bodies contain the same surface, common CSG logic fails to recognize this situation. The resulting pitfall causes particle tracks to become lost when no real error exists in the geometry model. The common CSG approach is to treat surfaces as unique integral parts of a body primitive, instead of treating the body primitive as the result of a boolean combination of non-unique surfaces.

Objects in space are described in body logic as the union or the intersection of individual bodies. Since a body describes an enclosed volume, users can quickly define objects and maintain an understanding of the space being described. For instance, the walls of a finite pipe is the difference of two concentric right circular cylinders. The walls of a room is the difference of two concentric right parallelepipeds. This model describes twelve surfaces with two bodies, and gives a concise wall description with two body numbers. The descriptive power of body geometry is recognized in many different commercial solid geometry modelers. In the future, three-dimensional solid geometry standards will emerge - probably based largely on body primitives. It is important to recognize the significance of body geometry as a tool in describing complicated geometric systems. Body geometry has many strong advocates and is a rich technique that will be around for a long time in the future.

The boundary representation method utilizes a more general surface description approach, where a user defines each individual surface. The range of surfaces definable extends from simple planes to complicated general quadratic surfaces. Space surrounding a surface has a property known as "sense". When spatial coordinate points are substituted into a surface equation, the result will be positive, zero, or negative. Points, where the result is positive, have a positive sense with respect to the surface. Points, where the result is negative, have a negative sense with respect to the surface.

Points, where the result is zero, are on the surface, and the trajectory determines the sense. Spatial regions are described relative to the sense of the surfaces using boolean operations, such as unions, intersections, and complements. This approach yields an exact concise definition of spatial regions relative to surface definitions. This requires more work on the part of the user, and has some definite graphical disadvantages, such as the problem of displaying infinite surface extents. Boolean descriptions of space using surfaces often yields a more concise condensed definition, than possible with body logic. Surface tracking logic provides a richer menu of boolean operators than body logic. While this enhances the user interface, it places a difficult task on the tracking logic, and reduces the tracking efficiency. The tracking speedup achieved from a concise spatial definition using surfaces is in effect, canceled out by the increased logic required to evaluate the complex boolean expressions possible in surface tracking logic.

SABRINA is a synthesis of both the CSG body approach and the BR surface approach to geometry modeling. When a user enters a CSG body, SABRINA generates automatically surface descriptions and the boolean BR description for the volume inside the CSG body. The SABRINA approach to CSG simplifies down to a BR approach with a few exceptions. Both the CSG method and the BR method have certain advantages and disadvantages. While the two methods are different, the internal logic of each is very similar. The result in SABRINA is a program containing both the CSG solid geometry, the BR method, and a third true hybrid capability, called boundary solid geometry, BSG, combining the best features of both methods. In the BSG approach new bodies are easily added to the program by defining arbitrary combinations of surfaces describing enclosed volumes. The result preserves the general surface capability of the BR approach and the rich descriptive capability of the CSG approach. The ray tracing in the BSG approach utilizes simple boolean expressions for the body primitives, and simple boolean descriptions for the spatial regions. The resulting logic is partially vectorized, and takes advantage of boolean expressions in the FORTRAN programming language for increased speed and efficiency.

#### PROGRAM FEATURES

SABRINA contains three commands to display a geometry plot. The three commands are not available for all types of geometry input. The three commands are the DRAW, COLOR, and ETCH. The DRAW command works on body geometry input, and on a limited subset of MCNP surface geometry. The COLOR and the ETCH commands work on both body geometry models and MCNP surface geometry models. The DRAW and the ETCH commands both provide line plot capability, with the difference that transparent cells do not appear on an ETCH plot. Both transparent and non-transparent cells appear on a DRAW plot. In both the ETCH and the DRAW line plots, non-transparent cells hide lines. In a DRAW line plot, rays are traced from points on the lines being drawn to the viewpoint. In a COLOR plot and in an ETCH line plot, rays are traced from the viewpoint to the non-transparent, or opaque objects in the geometry model.

The COLOR and ETCH displays allow a user to use a cutter body to cut into a geometry model to view the geometry inside. This capability allows non-transparent cells to be in a geometry display with the geometry the non-transparent cells would normally hide. A cutter body is any body geometry primitive. Users may use up to twenty cutter bodies in a single display. The presence of a cutter body is independent of the geometry model, and independent of the viewpoint location. When a cutter body is in the line of sight between the viewpoint and the geometry, the geometry displayed is the geometry viewed by exiting the cutter body. The cutter body may be used with both body geometry models and with surface geometry models. It is a viewing technique that does not alter the geometry model.

SABRINA gives the user the option of rotating the display image arbitrarily. The program by default assumes the positive z axis to be vertically up in a display. Using the VERT command the user may reset the default to any arbitrary vector. This allows images to be rotated to display at arbitrary orientations. It is important that a user be able to obtain a desirable display without modifying the geometry model.

A geometry test option exists for both the color shaded plots and the line plots. The test option, as applied to the DRAW command, makes all geometry transparent except for space that is either undefined or overdefined. The test option, as applied to the COLOR command, makes space that is either undefined or overdefined appear red. Red is the default error color, but SABRINA gives the user the ability to define the error color. The test option, as applied to ETCH line plots, simply shows the outline of the undefined or overdefined space over the regular geometry line plot. In all cases, after a plot has been generated with the test option in effect, SABRINA informs the user the result of the geometry test. If errors were found in the geometry, SABRINA tells the user to read the ERRFILE for more information. The ERRFILE contains very simple geometry error messages, which with the picture, give clear indications of the location and source of the geometry errors. The test option in SABRINA makes complicated geometry development less painful.

All commands in SABRINA have free form input. Commands may be stacked on a line with the semicolon character or with the escape character, as command separators. The comma, the slash, and the space character are all acceptable input delimiters. A user need only type enough characters to uniquely define a command to have the command recognized. This minimizes user typing of input.

The body commands allow the user to reference user symbols for the body definition. Frequently in describing geometry models, common dimensions appear throughout a model. To reduce the inputting of these dimensions at every occurrence, it is possible for a user to assign a value to a symbolic variable in SABRINA for later reference. Symbols may be added or subtracted with other symbols to create new symbols. One advantage of this approach, is to define a geometry model with symbols and modify the model by changing symbol definitions. This reduces the effort in updating old models with current dimensions.

Several important cursor commands are available in SABRINA. For line plots generated with the DRAW command, users may generate blowups of selected portions of a display. This is useful in viewing small detail in a large model. A three dimensional cursor command exists for all graphical displays. This is valuable in querying a geometry display. Since a cursor exists on a two-dimensional screen, the third dimension of the three-dimensional cursor is orthogonal into the screen. When a user executes the three-dimensional cursor, SABRINA gives the trajectory and cell where the trace begins. The cursor trace is then tracked through the geometry, with SABRINA giving at each boundary crossing the coordinate of the boundary crossing, the surface number of the boundary, and the cell number being entered on the other side of the boundary. The trace stops when a non-transparent cell is encountered or when the trace exits the geometry. If tracking errors occur during the trace, the error information is given to the user. This is useful for understanding a geometry error and for querying a complicated model to determine what is being viewed.

SABRINA commands are programmed in a structured manner, making it possible to add or change commands with minimal effort. An important attribute of SABRINA is the minimal number of commands necessary to use the program. Interactive programs become bulky and cumbersome when the quantity of commands begins to saturate the user. Most users will use less than five to ten commands during an interactive session. The philosophy in SABRINA has been to default as many parameters as possible to allow users to obtain plots with minimal effort. Commands exist optionally to allow users to override program defaults. Most users have a large amount of lethargy in using new commands. Interactive programs are more appealing, when the interaction is accomplished successfully with a very limited amount of knowledge. Users know what they want to accomplish and they will start running SABRINA not knowing how to obtain their goals. The burden is therefore on the program, to meet the users needs, knowing the user has initially a very limited knowledge base with which to work.

A HELP command exists to act as a quick referencer on SABRINA commands and to aid the novice user in becoming proficient with the capabilities of the program. Inside the help package is a description of each of the program commands accompanied with several illustrations using the command. While the internal help package in SABRINA, does not replace the need for good program documentation, it provides a quick ready reference which complements the program documentation. Users normally dislike studying program manuals as bad as program developers dislike maintaining current program documentation. A complete help package is an important requirement for an interactive program like SABRINA. Users are more receptive to executing a help command, than to reading the program manual. The help package is a convenient way to keep users informed on current program developments. The help package can be updated far more frequently than a new program manual can be released; therefore, as new commands are added to the production version of SABRINA, the help package is expanded, and users are kept informed.



## FILE CREATION

SABRINA creates several files which are available for later processing. All user input is written to a journal file for later reference. The journal file can be modified with any standard text editor, and is available as a record of a SABRINA session. Geometry models read into SABRINA may be saved with either the DUMP, or the SAVE commands. The DUMP command is available for body geometry only, and the SAVE command is available to produce MGNP input files from either body or surface geometry models. The journal file, the DUMP file, and the SAVE file may be read back into SABRINA. All three files are text files and SABRINA will accept commands from any standard text file. Users may construct command files, geometry files, or symbol definition files in any standard text editor to be read into SABRINA to reduce typing. While reading an external file, SABRINA will halt when it encounters an error in a command. At that time, the program gives the user the option of continuing reading from the external file, or transferring control to the user terminal. While reading from an external file, the program output may all be suppressed until the reading is complete. This is desirable when reading external files of several hundred lines.

Graphical device independent metafiles may be produced by SABRINA for slide generation. The color metafiles produced by SABRINA have been synchronized to produce color shaded plots similar to the color shaded plots displayed at the user terminal. It is possible to generate either glossy prints, or transparencies from the color slides. This is useful for reports and for presentations. The color shading available from the color shaded slides is far more continuous than possible from a color terminal. This provides for a higher quality display with a color slide, than possible from a color computer terminal.

## COLOR SHADED PLOTS

The light source in the present version of SABRINA is at the user viewpoint. Colors in a display may be set by either media or by cell. Setting the colors by media allows the color for many cells to be set with a single command. The cosine of the angle subtended between the viewpoint and a surface normal raised to a power of 1.05, when the cosine is positive, and raised to the power of 1.0, when the cosine is negative, determine the light intensity at a pixel. This technique allows visual differentiation between the inside and the outside of a surface, when they are adjacent in a display. The minimum color intensity may be controlled either by media or by cell number. This gives the user the ability to fine tune the color brightness for a geometry model.

Frequently, color contrast is an important consideration in creating a color shaded display. The QBRIT command allows a user to determine the minimum brightness by either media or cell. This provides the capability for highlighting various portions of a geometry model to make selected features more distinctive.

It is very expensive to trace rays through a complicated geometry model. SABRINA presently does not allow for a secondary light source location. To provide the secondary light source capability would require tracking rays from the viewpoint to an object and from the object to the light source. The second half of the ray trace to the secondary light source is necessary to draw shadows. While this capability would create more artistic displays, the object of SABRINA is to develop complicated three dimensional geometry models for MCNP with a minimum of computer time; therefore, the secondary light source capability is not currently provided or contemplated. To further minimize the number of rays traced, an interpolation scheme is invoked on color shading. The size of the interpolation grid may be set at either 9 pixels by 9 pixels for fine intensity variation or at 17 pixels by 17 pixels for a coarse (default) intensity variation. The coarse shading reduces the amount of continuity and smoothness in the intensity variation on a surface. Coarse shading is similar to painting a small object with a large brush. For manipulating a geometry model's viewpoint, transparent cells, or setting colors, the computer time saved with the coarse shading is beneficial. The fine shading algorithm requires about twice the computer time as the coarse shading. The ability to control the shading algorithm allows computer resources to be conserved until they are needed.

The number of scan lines used to generate a color shaded or an etch line plot can be controlled by the user. The user may use high resolution with 1070 scan lines having 1390 points per line, or medium resolution with 535 scan lines having 695 points per line, or low resolution with 267 scan lines having 347 points per line. The default plot resolution is a medium number of scan lines with coarse intensity interpolation. High resolution requires twice the computation time as medium resolution. Low resolution requires half the computation time as medium resolution. The advantage of plot resolution control is to allow a user to define the amount of computer time invested in each plot. This approach places the decision on the user instead of an arbitrary rule built into the program. The user should know the plot detail required much better than the program.

SABRINA is written in Fortran 77 and runs on both the CRAY CTSS and the VAX VMS operating systems. The program makes extensive use of character type variables and the file status commands available in Fortran 77. The program is based on the Los Alamos Common Graphics System, CGS. The CGS system is efficient and has minimal memory requirements. The CGS system has been implemented on many different computer systems at Los Alamos and use of CGS gives SABRINA a greater degree of control of the graphics picture than available in other commercial graphics systems.

Color shaded plots produced by SABRINA may be either written to a CGS metafile, for later processing, or sent directly to a Tektronix 4115 terminal. Currently, the Tektronix 4115 is the only color terminal SABRINA supports. As other color terminals appear on the market, the color terminal support in SABRINA will expand accordingly. When performing color shaded plots on the Tek 4115, SABRINA will download the color map to the terminal. This allows users to vary the number of colors, and the number of levels of shading on each color to the maximum number of colors available on the user's Tek 4115 and to the users momentary needs.

### ILLUSTRATIVE EXAMPLES

As examples of using SABRINA, four figures are provided. Figure 1 is a display of the MCNP FISH sample problem. This problem is symmetric about the z-axis and is a surface geometry model containing several ellipses, toroids, and cones. Figure 2 is a cut-away of the FISH model, showing the detail of the surfaces and the internal orientation of the surfaces. Notice in Figure 2, the cut-away technique shows the non-transparent outer cells and the internal surface intersections. Comparing Figure 1 and Figure 2, the power of the cutter body is evident. The difference in SABRINA instructions between the two figures is two lines of input. One line defining the cutter body, and one line defining the body number as a cutter body. The geometry model is unchanged by the cutter body.

Figure 3 is a body geometry model of a plexiglas pipe cross experiment performed at the criticality facility at Oak Ridge National Laboratory. This body model is composed of 10 right circular cylinders, 1 right parallelepiped, and 1 box. The horizontal legs of the pipe cross are tilted up at the ends to drain the fissile liquid used in the experiment into the center cylindrical pipe. The purpose of the experiment was to compare Monte Carlo criticality calculations with experimental criticality measurements of various fissile solutions at a given pipe intersection geometry. The results of this experiment aids in the design of many processing plants.

Figure 4 illustrates the possibilities for creativity using an interactive three dimensional geometry modeler. Figure 4 depicts a typical Monte Carlo user in Los Alamos on holidays. This is a body geometry model composed of 10 right circular cylinders and 2 right parallelepipeds. This model was created in about an hour using body primitives. Modeling the skier with surface geometry would have taken the fun out of the model. The skewed right circular cylinders describing the arms and legs in this figure, produce complicated general quadratic surfaces with 10 coefficients each.

### FUTURE POSSIBILITIES

Future developments for SABRINA include displaying selective particle tracks, or collision sites, merging the MCNP two-dimensional plotting capability into SABRINA, developing a dynamic memory management scheme, interfacing SABRINA to the PADL family of CAD systems, adding the new MCNP lattice geometry capability, optimizing the MCNP cell description produced by SABRINA from body geometry models, having user definable body primitives composed of arbitrary combinations of MCNP surfaces describing a closed volume, making the rest of the MCNP input (source, tally, etc.) interactive in SABRINA, and utilizing advanced geometry graphics hardware available in the next generation of scientific work stations. These are just a few of the possible developments which could occur. Every worthwhile development and well asked question often leads to a cascade of further improvements and raises more questions. The development of SABRINA is dynamic and fluid and is pushed by the Los Alamos user community needs. Without meeting the needs of the MCNP user, the further development of SABRINA would be unnecessary. SABRINA is an important tool in supporting and enhancing the capabilities of

MCNP, and with success will provide a mechanism for more complicated problems to be analyzed in MCNP.

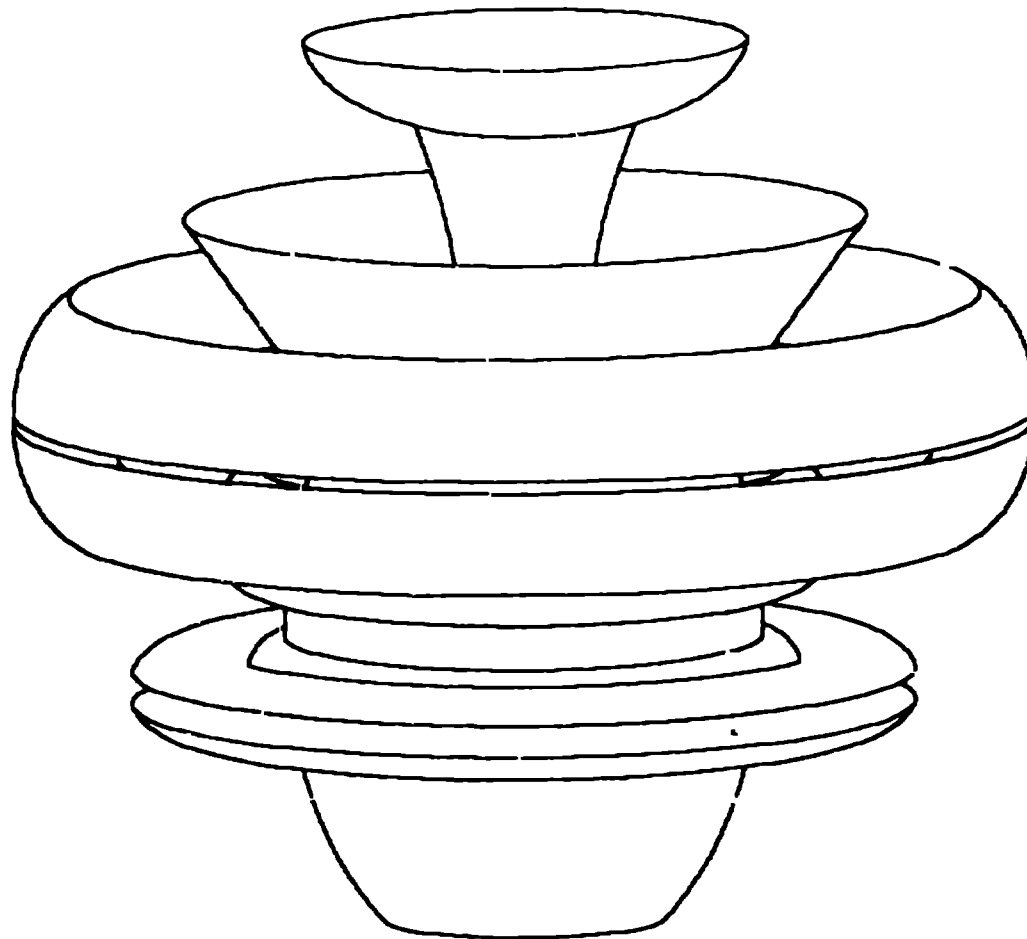


Fig. 1. MCNP Fish Sample Problem

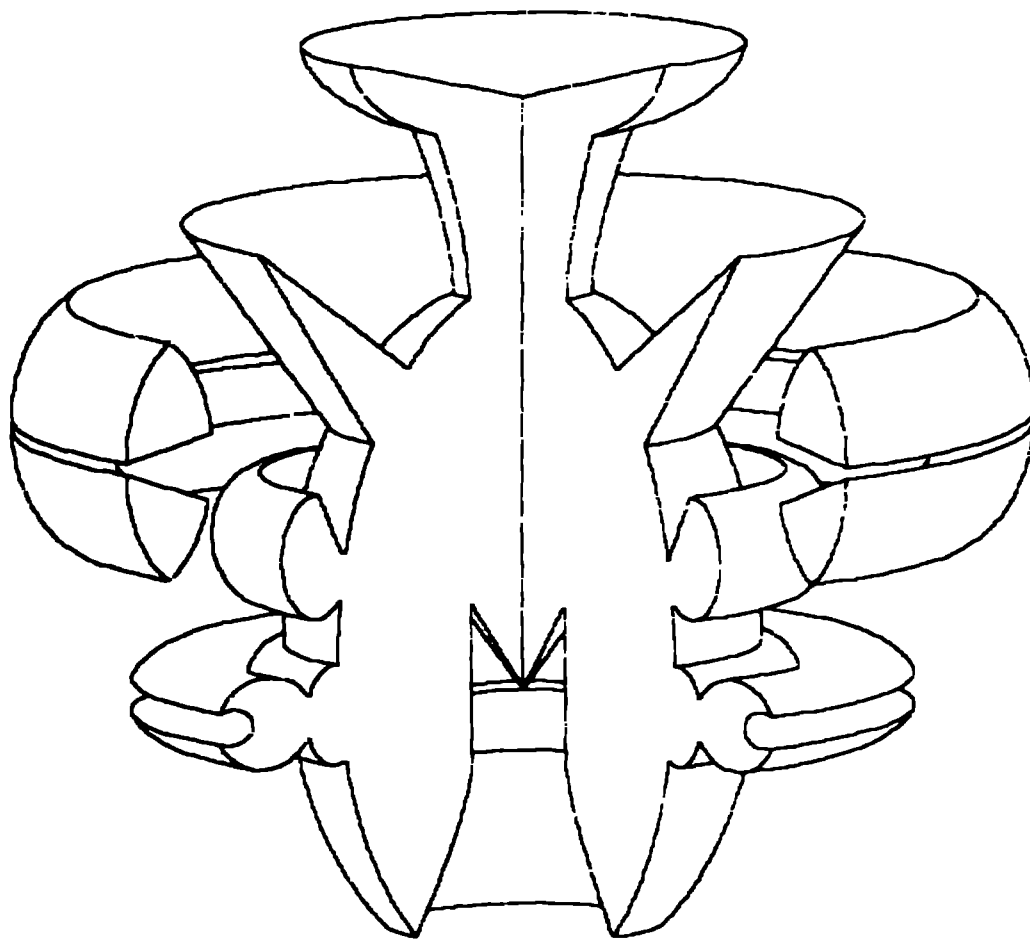


Fig. 2. Cut-Away View of MCNP Fish Model

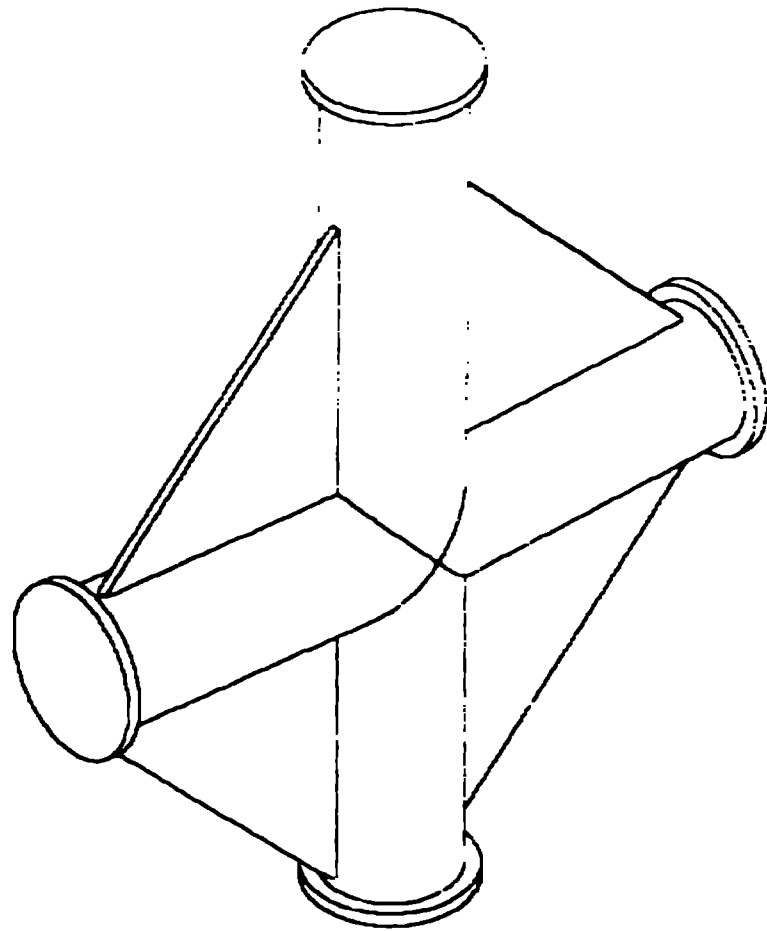


Fig. 3. Plexiglas Pipe Cross Criticality Model

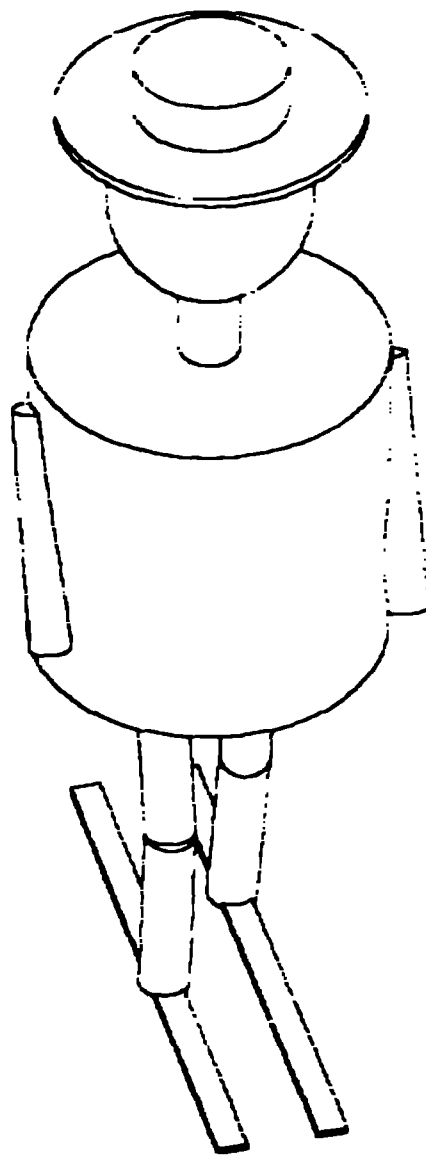


Fig. 4. Los Alamos Monte Carlo User on Holiday