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System Analysis and Risk Assessment System (SARA) Version 4.0

Tutorial

Prepared by
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Prepared for
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SYSTEM (SARA) VERSION 4.0

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ABSTRACT

This NUREG is the tutorial for the System Analysis and Risk Assessment System (SARA) Version 4.0, a microcomputer-based system used to analyze the safety issues of a family [i.e., a power plant, a manufacturing facility, any facility on which a probabilistic risk assessment (PRA) might be performed]. A series of lessons are provided that walk the user through some basic steps common to most analyses performed with SARA. The example problems presented in the lessons build on one another, and in combination, lead the user through all aspects of SARA sensitivity analysis.

FIN No. L1429 - SARA, IRRAS and MAR-D Maintenance and User Support

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FOREWORD

The U. S. Nuclear Regulatory Commission has developed a powerful suite of computer programs for the performance of Probabilistic Risk Assessments (PRAs). This suite of programs allows an analyst to perform many of the functions necessary to create, quantify, and evaluate the risk associated with a facility or process being analyzed. These programs include software to define the data base structure, to create, analyze, and quantify the data, and to display results and perform sensitivity analysis. The programs included in this suite are as follows; Models And Results Database (MAR-D) software, Integrated Reliability and Risk Analysis System (IRRAS) software, Systems Analysis and Risk Assessment (SARA) software, and Fault tree, Event tree, and P&ID (FEP) graphical editor software. Each of these programs perform a specific function in taking a PRA from the conceptual state all the way to publication.

MAR-D is a program that is used primarily for PRA data loading. This program defines a common relational database structure that is used by the entire suite of programs. This structure allows all of the software to access and manipulate data created by other software in the system without performing a lengthy conversion. Hence, data created by IRRAS is immediately available to SARA for sensitivity analysis. The MAR-D program also provides the facilities for loading and unloading of PRA data from the relational database structure used to store the data to an ASCII format for interchange with other PRA software not included in NRC's suite of programs. This feature allows for compatibility with previously developed software systems and allows for maximum data interchange. Elements of this software are included with both IRRAS and SARA to allow these programs to load and unload data in the MAR-D format. Normally, the entire MAR-D software is used only by those performing a data loading function and is not required by the end user. Documentation for MAR-D, Version 4.0 is in draft form and will be finalized.

IRRAS is a program developed for the purpose of performing those functions necessary to create and analyze a complete PRA. This program includes functions to allow the user to create event trees and fault trees, to define accident sequences and basic event failure data, to solve system and accident sequence fault trees, to quantify cut sets, and to perform uncertainty analysis on the results. Also included in this program are features to allow the analyst to generate reports and displays that can be used to document the results of an analysis. Since this software is a very detailed technical tool, the user of this program should be familiar with PRA concepts and the methods used to perform these analyses. Although IRRAS has been designed to be user friendly and makes the process of performing a PRA easier, the complexity of this type of analysis requires a user with a more detailed understanding of PRA concepts than is required by other tools in this suite. The IRRAS 4.0 reference manual is available as NUREG/CR-5813, Volume 1. The IRRAS 4.0 tutorial, Volume 2, is in preparation.

SARA is a program that allows the user to review the results of a PRA and to perform limited sensitivity analysis on these results. It is limited primarily to the extent that changes in the plant model can be accommodated by using the cut set editor. If other than simple changes are being simulated, then IRRAS should be used so that new cut sets can be accurately generated. This tool is intended to be used by a less technical oriented user and does not require the level of understanding of PRA concepts required by IRRAS. With this program a user can review the information generated by a PRA analyst and compare the results to those generated by making limited modifications to the data in the PRA. Also included in this program is the ability to graphical display the information stored in the MAR-D database. This information includes event trees, fault trees, P&IDs and uncertainty distributions. The user of this program can gain a better understanding of the results of a PRA without getting into the details of the construction and analysis work behind the PRA. The SARA reference manual and tutorial are available as NUREG/CR-5303, Volumes 1 and 2, respectively.

FEP is a program developed to provide a common access to the suite of graphical tools developed for performing risk assessment. These tools include the graphical event tree, fault tree, and P&ID editors. The event tree and fault tree editors are available through IRRAS; however, the P&ID editor is only accessible through FEP. The event tree editor allows the analyst to construct and modify graphical event trees. The fault tree editor allows the user to construct and modify graphical fault trees. The P&ID editor allows the user to construct and modify plant drawings. These drawings can then be used to document the modeling used in a PRA. These editors are an integral part of a PRA. With the FEP tool, the user need not be concerned with the complexity of the IRRAS program if the need is only to generate one of these graphical displays. Documentation for FEP, Version 4.0 is in draft form and will be finalized.

SYSTEM ANALYSIS AND RISK ASSESSMENT SYSTEM (SARA) VERSION 4.0 VOLUME 2 - TUTORIAL

EXECUTIVE SUMMARY

The System Analysis and Risk Assessment (SARA) system provides the capability to examine the risk impact of a "family" [i.e., a power plant, a manufacturing facility, an activity on which a probabilistic risk assessment (PRA) might be performed] dealing with such items as regulatory issues, plant design, and operational changes. It is a flexible PRA tool that can be used in the evaluation and prioritization of physical and operational changes.

SARA is a computer program that is designed to access data generated by other programs. It contains no data , but can automatically access PRAs stored in the Models and Results Database (MAR-D). These PRAs could have been generated using the Integrated Reliability and Risk Analysis System (IRRAS) or loaded using the MAR-D program. MAR-D serves as a repository of models and results from completed PRAs, and has no analysis capabilities. SARA can select for analysis, any family database loaded in MAR-D. This data includes, event failure data, dominant accident sequences, descriptive information about the facility, event trees, fault trees, and plant system model diagrams.

Family modifications and accident scenarios are simulated by changing basic event unavailabilities, accident initiator frequencies, and/or cut set structures. Accident sequences, total sequence frequencies, sequence uncertainty values, event importance measures, and facility end states are recalculated and the results of the calculations are displayed numerically and graphically, and compared with the base case. There are also special features for performing sensitivity analyse All data displays may be saved in disk files and/or sent to an attached hard copy device.

This manual is the tutorial for SARA 4.0 and contains a series of lessons that walk the user through some steps common to most analyses performed with SARA.

1. INTRODUCTION

This volume of the user's manual provides a series of tutorials that walk the user through some basic steps common to most analyses performed with the System Analysis and Risk Assessment (SARA) system. Specific instructions for individual commands and options in SARA are provided in Volume 1 (*SARA Version 4.0, Volume 1 - Reference Manual*).

SARA provides the capability to examine and use the results of a probabilistic risk assessment (PRA) in a variety of situations. The ability to manipulate initiating event frequencies and basic event probabilities gives the user the ability to explore plant changes (actual or proposed) that impact component reliability. SARA also has the capability of modeling minor configuration changes such as adding new components to existing systems or adding recovery or common-cause failures to the models. These capabilities make SARA a versatile tool for risk-based management and day-to-day decision making.

The strength of SARA is the ability to perform these sensitivity analyses and display the results in a side-by-side comparison with the original models. Another strength is the ability to conduct uncertainty analyses, thereby giving a more realistic picture of the results.

This manual provides basic lessons on the use of SARA through example problems. These problems build on one another and, in combination, lead the user through all aspects of SARA sensitivity analyses. The lessons cover the following:

Lesson 1. Loading the SARA 4.0 Software and Data.

This lesson shows the user how to get the SARA program and data loaded into the computer and setup for use.

Lesson 2. Exploring SARA 4.0.

This lesson familiarizes the user with the various features of SARA 4.0 and explains the mechanics of using the software.

Lesson 3. Using Change Sets.

This lesson shows the user how to create Change Sets and apply them to the base case model to establish a sensitivity model. SARA allows the user to define sets of changes that may be applied separately or in combination to model changes in component reliabilities or initiating event frequencies.

Lesson 4. Creating Change Sets Using the Graphics Interface.

This lesson shows the user how to create Change Sets using interactive graphics. Basic events can be automatically searched and called out of the database by moving a cursor around on Piping & Instrumentation Drawings (P&IDs).

Lesson 5. Applying Changes to the Models.

This lesson shows the user how to apply the model changes created in Lessons 3 and 4 to create a sensitivity analysis.

Lesson 6. Using the Cut Set Editor.

This lesson shows the user how to model changes to the logic of a system or accident sequence by direct manipulation of the cut sets contained in SARA.

Lesson 7. Displaying Results and Calculating Importance Measures.

This lesson shows the user how to display the results of a sensitivity analysis and calculate importance measures based on those results. The importance measures calculated include the Fussell-Vesely importance, the risk reduction ratio, and the risk increase ratio.

Lesson 8. Conducting Uncertainty Analysis.

This lesson shows the user how to assign uncertainty distribution data to basic events and initiating events and how to perform Monte Carlo/Latin Hypercube uncertainty analysis on the sensitivity models.

2. USING THE LESSONS

The lessons provided in this volume build upon the previous lessons and are intended to be used in order. Lesson 1 should be used to perform the initial program and data loading. It may also be referred to when additional database loads are needed. Lessons 3, 4, and 5 teach different ways in which sensitivity models can be created in SARA. These lessons can be performed in any order and all three lessons need not be done; however, at least one of them must be performed before going on to Lesson 6. Lessons 6 and 7 go hand-in-hand and must be conducted in order. Lesson 8, Conducting Uncertainty Analysis, is not necessary to complete unless the user is interested in calculating uncertainties.

2.1 The LEARN-SARA Database

The lessons use the demonstration database contained in the family called *LEARN-SARA*, which is included in the SARA package. This database contains all the basic elements of a full Level I PRA but only depicts a small portion of a complete PRA. The database is derived from work performed at the Idaho National Engineering Laboratory (INEL) for Westinghouse Pressurized Water Reactors (W PWRs). The models are generic in nature and do not represent any particular plant.

The LEARN-SARA database consists of two event trees [turbine trip initiated anticipated transient without scram (ATWS) and other transients initiated ATWS], a reliability block diagram of a generic solid state protection system (SSPS), fault trees models of the SSPS, and component and human reliability data.

The event tree and fault tree models were created and originally quantified with IRRAS 4.0. The reliability block diagram was created with the P&ID Editor. The outputs of these two programs were then loaded into the LEARN-SARA database through the Models and Results Database (MAR-D) interface in the SARA utility options. The creation of new databases is the objective of an NRC-sponsored project at the INEL and is not usually done by the typical SARA user.

Figures 2-1 and 2-2 show the event tree models used in the lessons. Figure 2-1 is the turbine trip initiated ATWS tree and Figure 2-2 is the non-turbine trip initiated event tree. The trees are identical except for the initiating event and probability of an unfavorable moderator temperature coefficient. Table 2.1 provides a brief description of each top event.

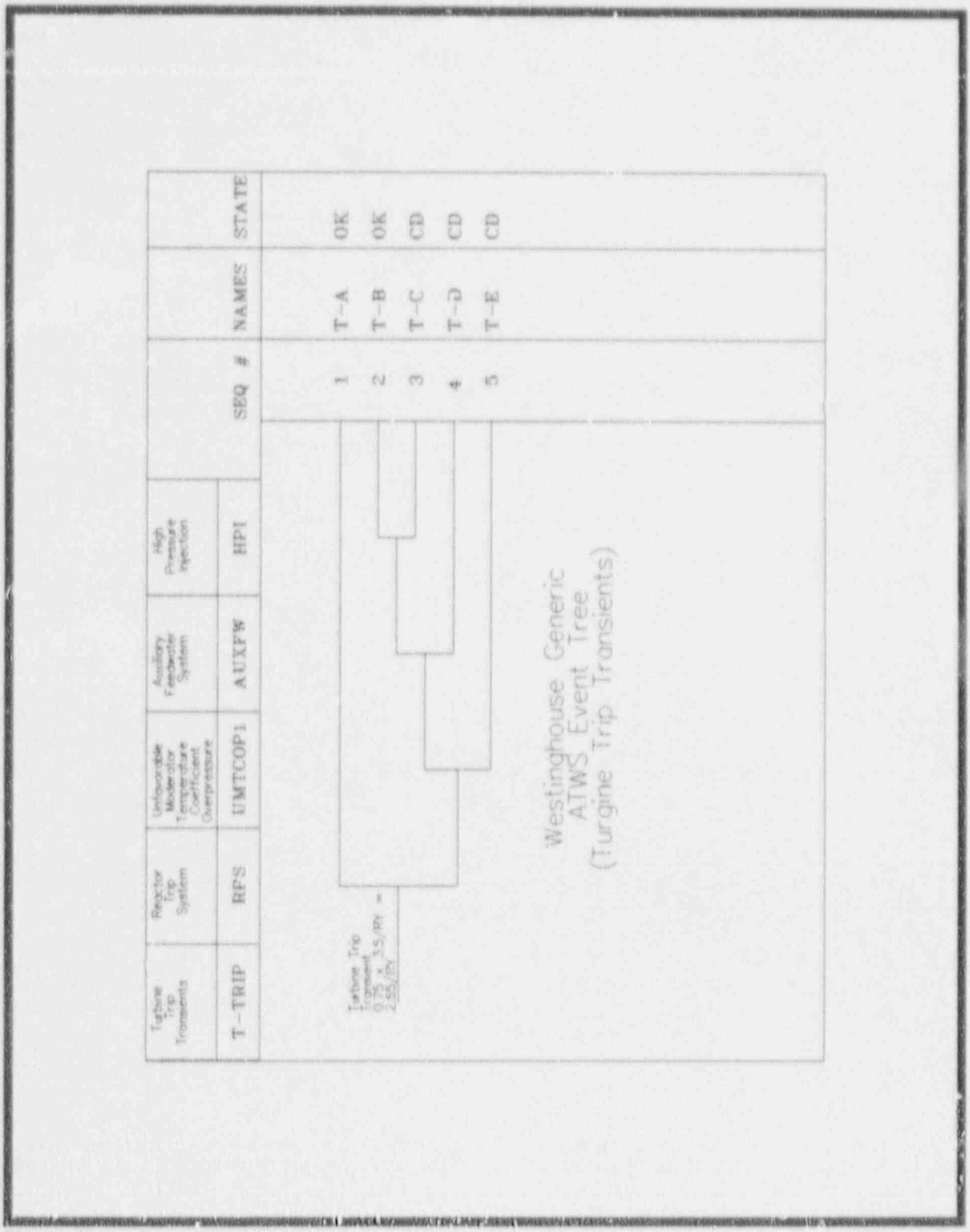


Figure 2-1. Generic turbine trip event tree.

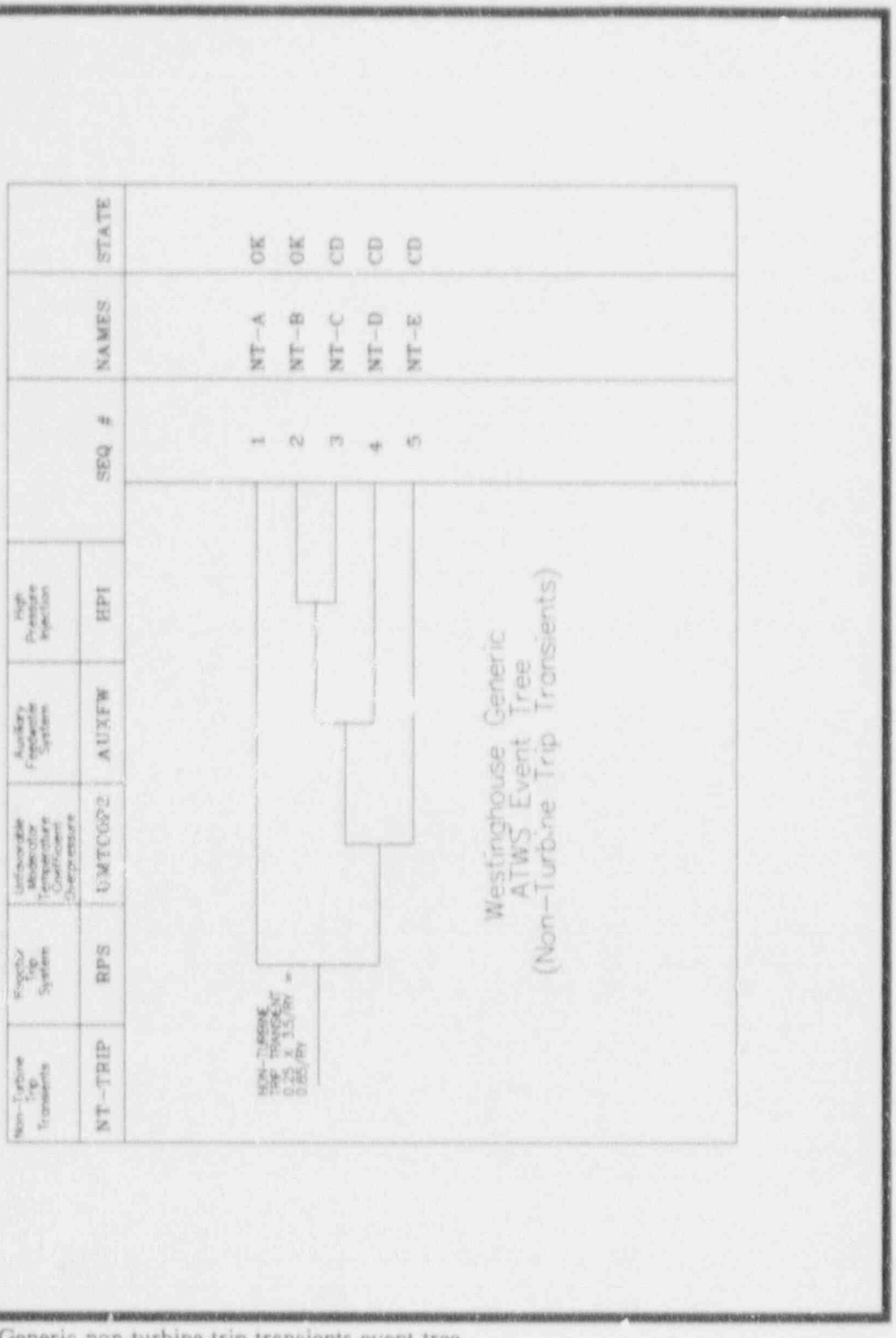


Figure 2-2. Generic non-turbine trip transients event tree.

Table 2-1. Event tree top event information.

Event Tree Top Event	Description
Transient initiating frequency (75% turbine trip, 25% non-turbine trip)	Frequency of transient events from greater than 25% event power.
Reactor Trip System	Probability of failure of the reactor trip function. Model includes the analog instrumentation input, the SSPS logic, the reactor trip breakers, and the operator action.
Unfavorable Moderator Temperature Coefficient	Percentage of the time that the moderator temperature coefficient is unfavorable (not negative enough) and cannot turn power fast enough to prevent an excessive pressure transient.
Auxiliary Feedwater	Failure of the AFW system to operate on demand (1 pump injecting to 2 steam generators, automatic actuation).
High Pressure Injection	Failure of HPI to operate on demand (1 pump injecting into the core).

The sensitivity analyses presented in the lessons are centered around the reactor trip function. A detailed fault tree was constructed for this top event (see Figure 2-3). The other top events were modeled by generic data from an ATWS rulemaking analysis[2] and NUREG-75/014[3].

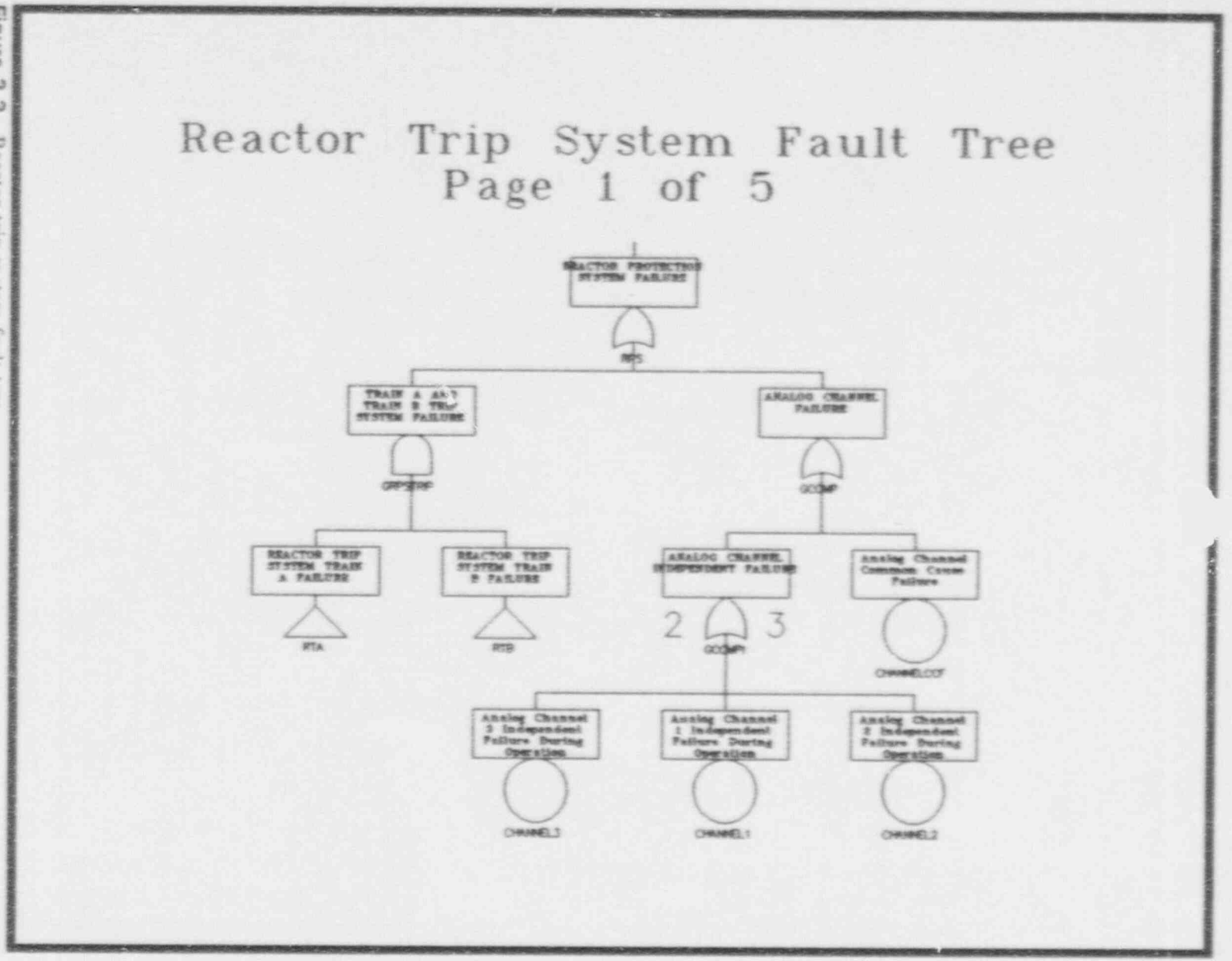
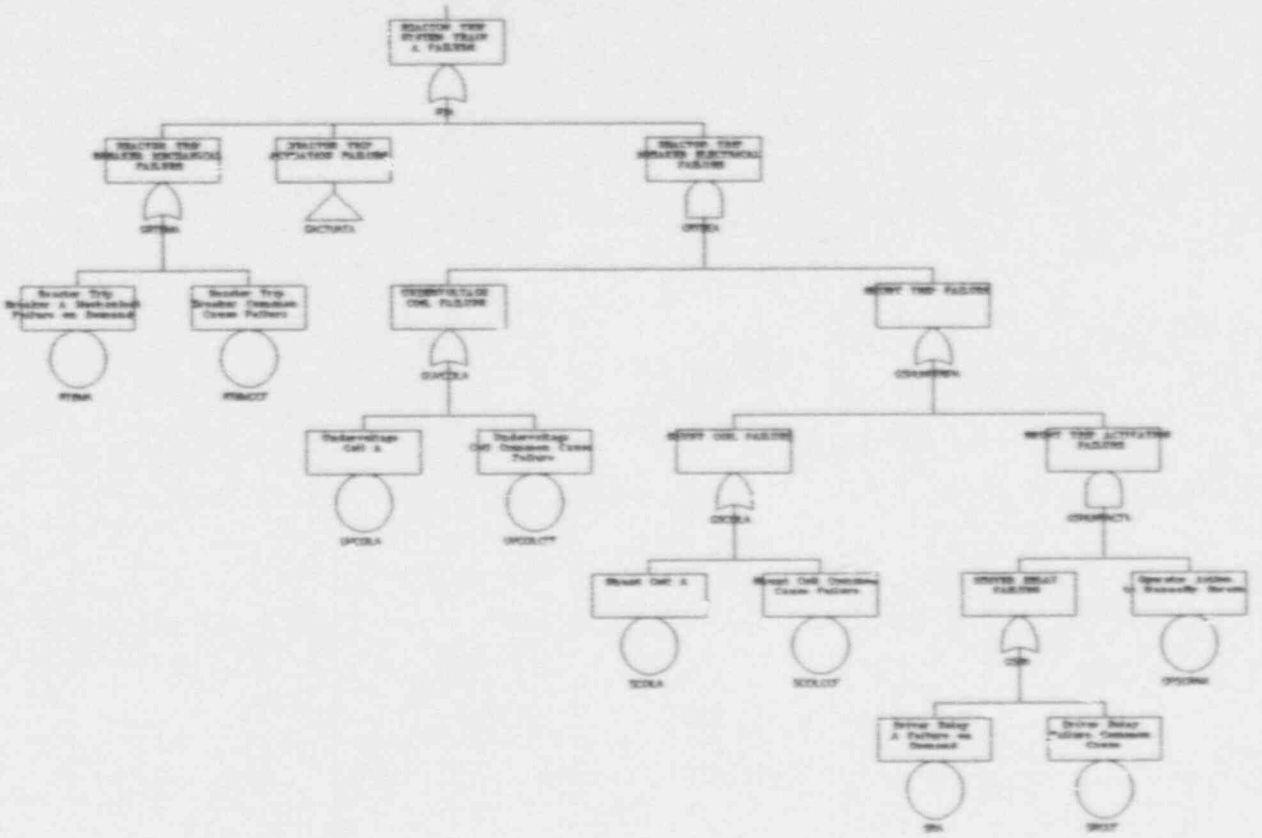


Figure 2-3. Reactor trip system fault tree.

Figure 2-3. (continued).

Reactor Trip System Fault Tree
Page 2 of 5



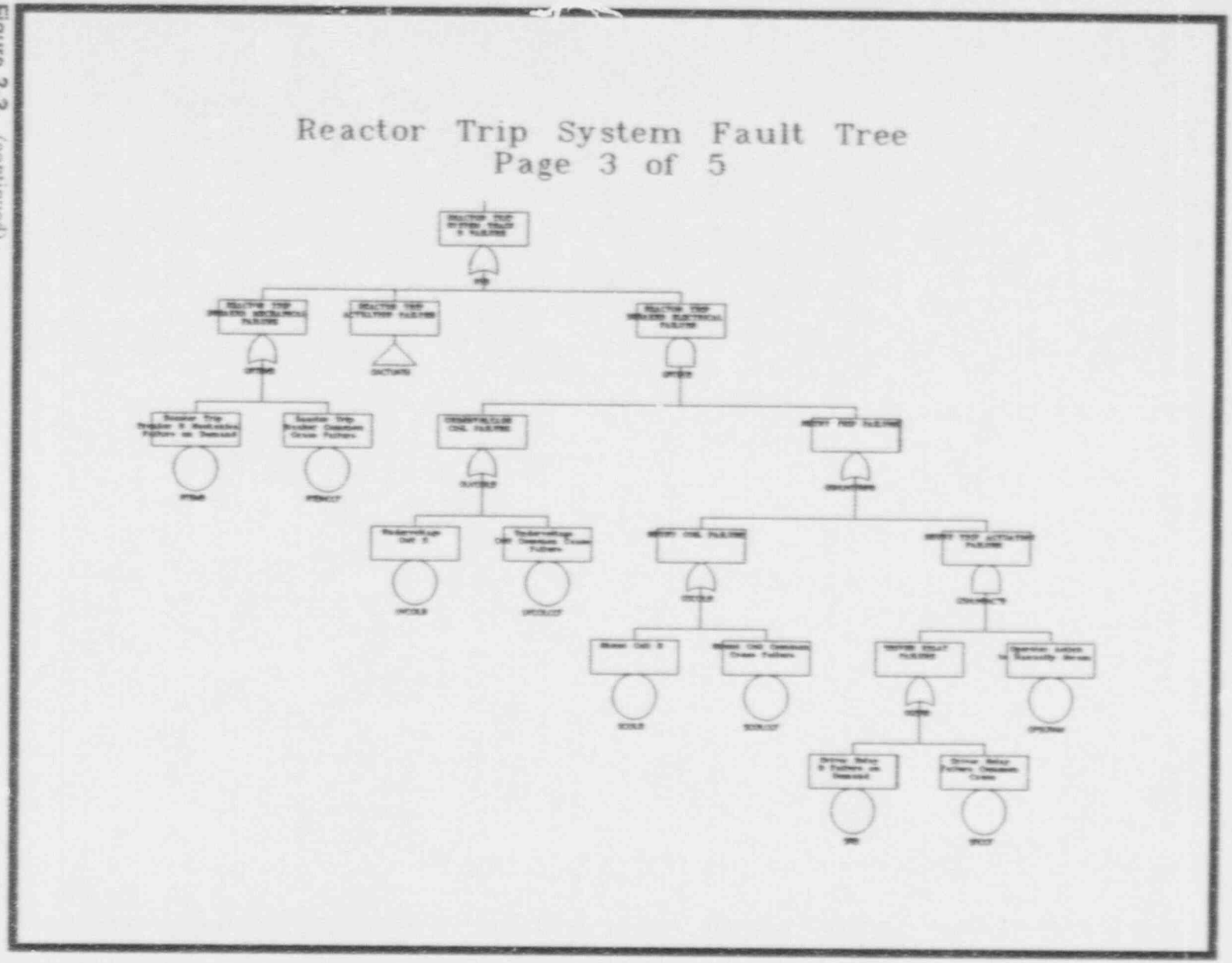


Figure 2-3. (continued).

Reactor Trip System Fault Tree
Page 4 of 5

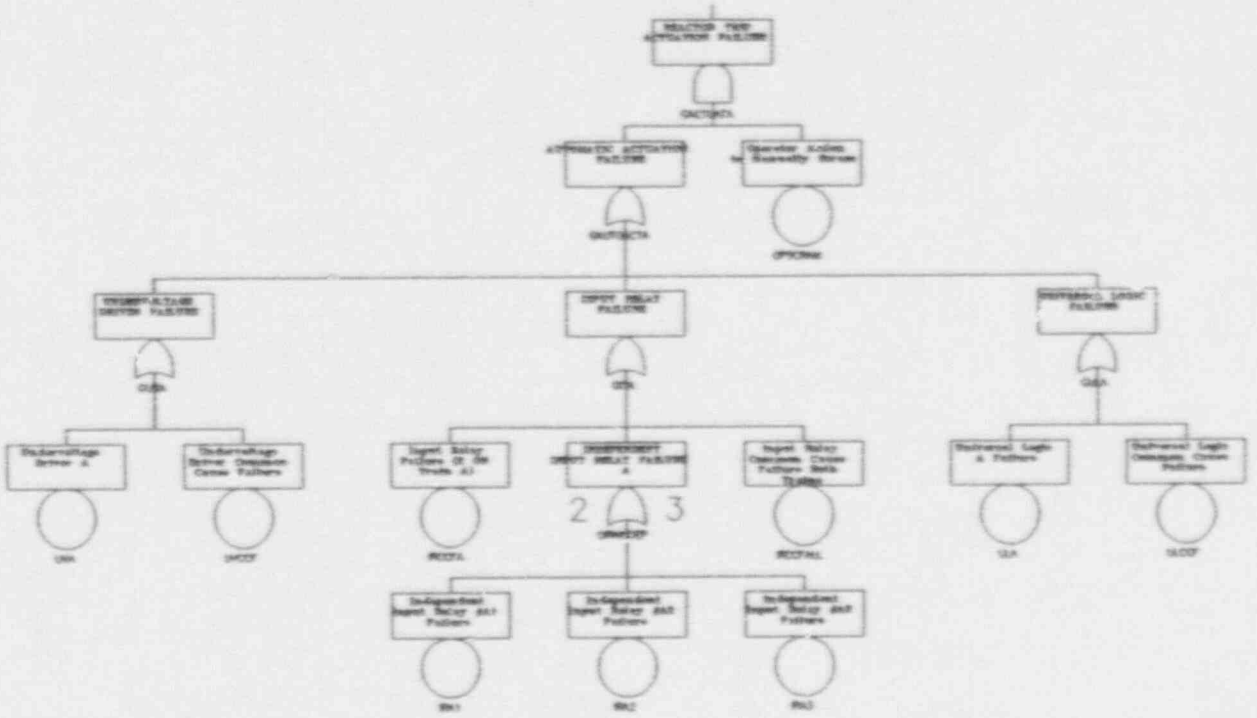


Figure 2-3. (continued).

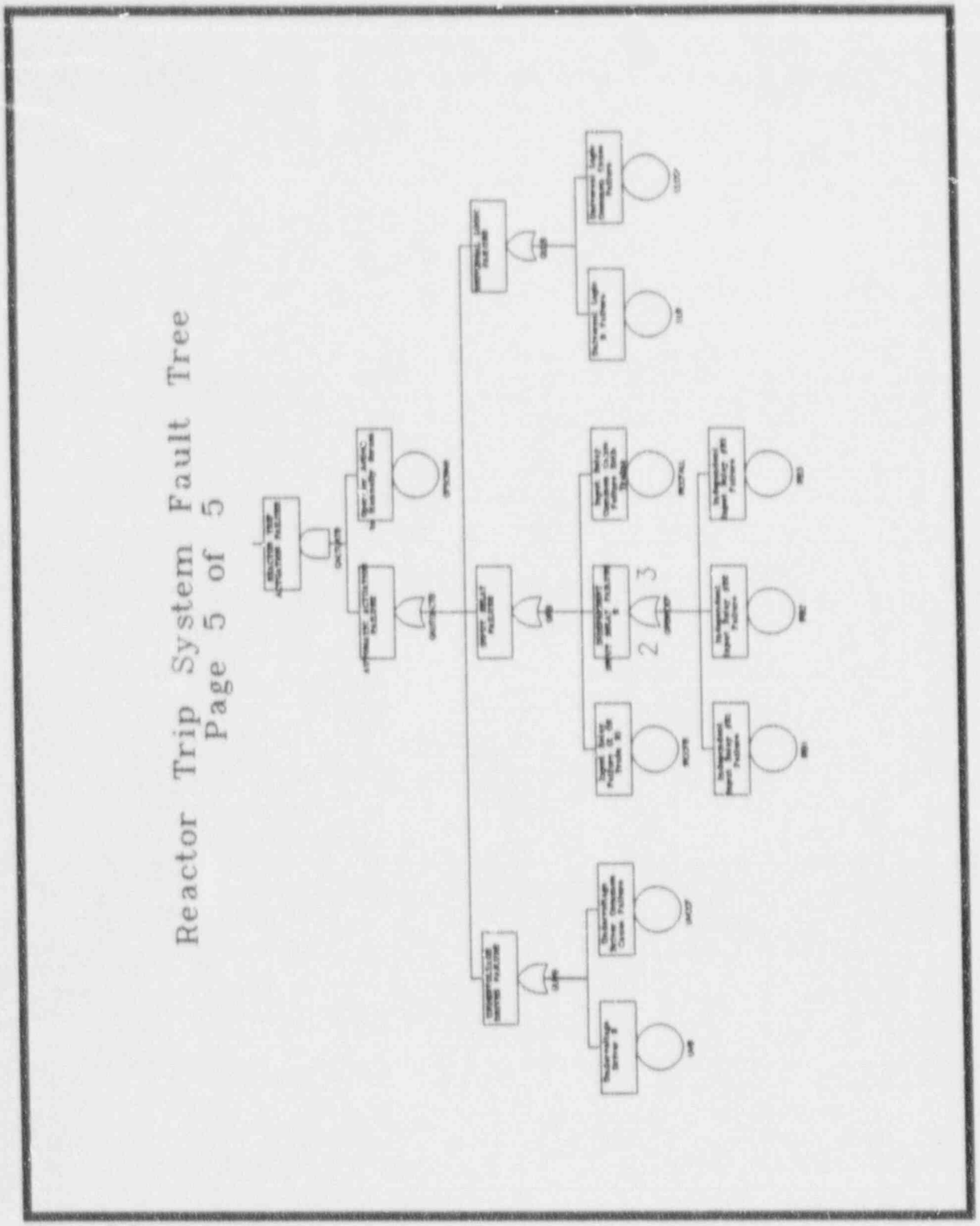


Figure 2-3. (continued).

2.2 After the Lessons

When you complete these eight lessons, you'll find that your SARA knowledge has increased greatly. However, if you still want to know more (and there **is** more to be known), refer to the *System Analysis and Risk Assessment System (SARA), Version 4.0, Volume 1 - Reference Manual* to get a handle on SARA's additional features.

3. TRAINING LESSONS

3.1 Lesson 1 - Loading the SARA 4.0 Software and Data

This lesson shows you how to perform the following functions:

A. Install the SARA 4.0 software on your hard disk.

B. Configure your system and SARA 4.0 for operation.

C. Install PRA databases for use with SARA 4.0.

3.1.1 Install the SARA 4.0 Software

You're ready to go. The SARA 4.0 package you received should contain the SARA software diskette(s), the *SARA 4.0 Volume 1 - Reference Manual*, and this Tutorial Manual. PRA databases for use with SARA may or may not be included as part of this package.

If your SARA 4.0 package is for a high density drive (1.2Mb 5-1/4" or 1.44Mb 3-1/2" floppy diskettes), the SARA 4.0 software is contained on a two installation diskettes. If your package is for a medium density drive (720Kb 3-1/2" floppy diskettes), the SARA 4.0 software is contained on three diskettes. If your package is for a low density drive (360Kb 5-1/4" floppy diskettes), the SARA 4.0 software is contained on six diskettes.

To install the SARA 4.0 software on your computer, perform the following procedures:

1. Verify that your computer is capable of running SARA 4.0. If you have run previous versions of SARA on your system, then you will have no problems with SARA 4.0. If SARA has never been installed before, the following requirements must be met for SARA 4.0 to operate:

   - IBM or 100% compatible with at least 640K main memory
   - 16 color EGA or VGA monitor and driver card
   - Hard disk drive with 7.5Mb free memory.

   See Appendix A of the *SARA 4.0, Volume 1 - Reference Manual* for more details and information on the SARA 4.0 hardware requirements.

   If your hard disk has less than 7.5Mb but more than 4Mb free, you can still load SARA 4.0 on your computer by temporarily removing enough files to free up 7.5Mb. After SARA 4.0 is loaded the removed files may be reloaded into your computer.

2. Insert the first SARA 4.0 installation diskette into your floppy drive. The SARA 4.0 installation procedure requires that this drive be designated A:. If the SARA 4.0 diskettes are incompatible with your A: drive, use the DOS command ASSIGN to designate the

appropriate drive as A:. If you do not have the ability to change the drive designation, contact your SARA supplier to obtain a compatible SARA 4.0 package.

3. Type **A:INSTALL x: <Enter>**, where x is the designation for the destination hard drive (usually C:). The SARA 4.0 installation will create \PRATOOLS.B1, \PRADATA.B1, and \HALO88 directories. If any of these directories already exist, DOS will display the message, "**Unable to create directory.**" This will not interfere with the installation process.

   The program files on the installation diskette(s) are archived. The installation procedure copies the archive files to the hard drive and begins the unarchiving process. During this time, the archive files and the unarchived files both exist, taking up more hard drive memory than after the installation is completed. Thus, while SARA 4.0 requires about 4Mb of memory, 7.5Mb is required to get it installed.

   The unarchiving process is indicated by the listing of files being "exploded" or "unshrunk." These terms are used by the archiving software to indicate the process used when the files were archived.

4. Insert the remaining installation diskettes (if any) in the proper order when prompted. After the last diskette is read, the SARA 4.0 files will be unarchived, the archive files will be deleted and the installation batch file will be removed from the directory. The SARA 4.0 installation procedure will display the message, "**Installation of SARA4.0 is complete. SARA4.0 sample data is installed separately.**" Then, DOS will display the message, "**Batch file missing.**" This is the normal response and indicates that the loading procedure is completed. The current directory will now be \PRADATA.B1.

3.1.2 Configure the System and SARA 4.0

Now that SARA 4.0 is installed on your computer, the system configuration must be setup to accommodate the needs of SARA. This is done through the CONFIG.SYS file located in the root directory. The following steps guide you through the required procedure.

1. Examine the CONFIG.SYS file to determine if the following parameters are specified:

   ```
   FILES=30
   BUFFERS=15
   DEVICE=c:\dos\ANSI.SYS
   ```

   To do this, change directory to the root by typing **CD\ <Enter>**. Then, type **TYPE CONFIG.SYS <Enter>**. The CONFIG.SYS file will be listed on the screen. If any of the above parameters are missing or are less than required, proceed to Step 2. If the CONFIG.SYS file is adequate, skip to Step 3.

2. Using an ASCII text editor, modify the CONFIG.SYS file to include the necessary parameters. The EDLIN line editor provided with DOS may be used. See your DOS Reference Manual for instructions.

3. The SARA 4.0 installation procedure creates a batch procedure (SARA.BAT) in the

\PRADATA.B1 directory for executing SARA 4.0. This file can be moved to your \BATCH directory, if your computer is setup in this manner. Otherwise, the \PRADATA.B1 directory can be put in the PATH (see your DOS manual for information on PATH) or the user can always execute SARA 4.0 from the \PRADATA.B1 directory exclusively.

4. This step explains how to configure SARA 4.0 for your hardware. This is done through the constants menus within SARA 4.0. To enter SARA 4.0, type **SARA <Enter>**. For the first time entry into SARA 4.0, the Constants screen shown in Figure 3-1 will appear. Subsequent entries into SARA 4.0 will go directly to the SARA 4.0 Main Menu.

   The fill-in-the-blank form of Figure 3-1 shows various constants used by SARA 4.0. The User Information section is used to tell SARA 4.0 how your hardware system is configured. The other sections will be discussed in the lessons devoted to their purposes, but for now we will forego explaining them.

   The form of Figure 3-1, like all other fill-in-the-blank SARA 4.0 forms, can be traversed by using the arrow keys. When the highlight is located in the field where information is to be added or changed, type in the desired data. **DO NOT PRESS <ENTER> UNTIL ALL FIELDS ON THE FORM ARE PROPERLY FILLED IN.** Pressing <Enter> tells SARA 4.0 that all the information on the form is correct and sends it to the database.

   Table 3-1 provides a brief description of each of the fields in the User Information section.

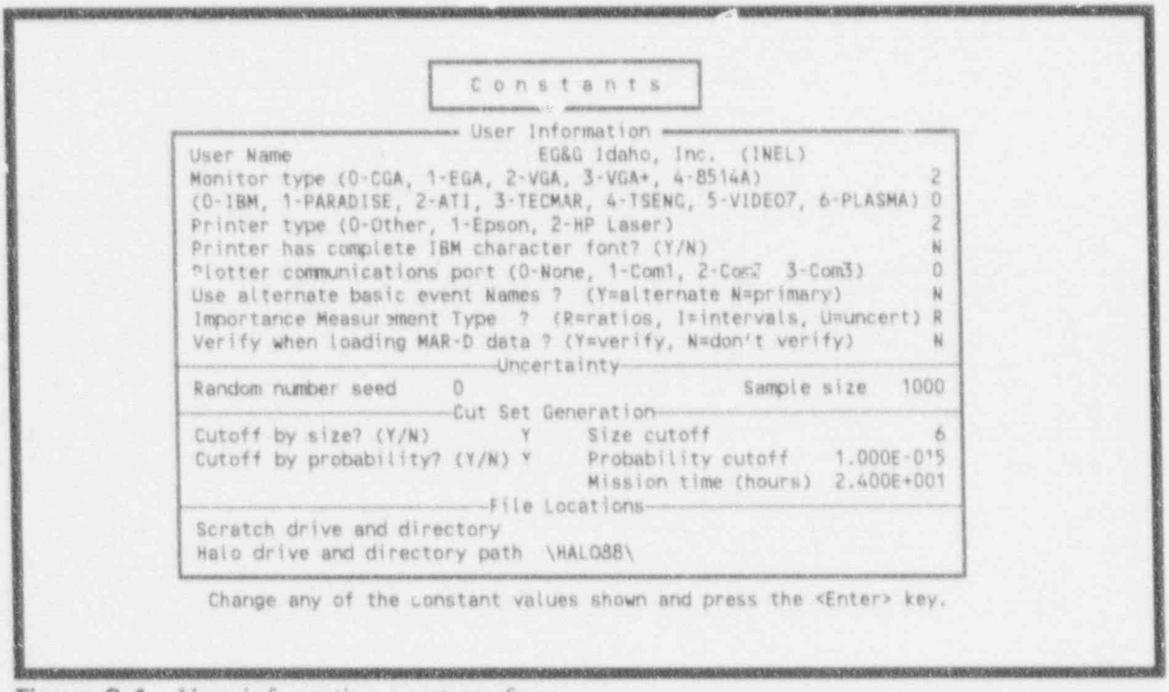


Figure 3-1. User information constants form.

Table 3-1. User Information field descriptions for constants option.

FIELD	DESCRIPTION
User Name	36 character user identification (optional) field
Monitor type	0 - Enhanced graphics monitor. 1 - DEFAULT - Standard color graphics monitor 2 - Video graphics monitor (2640 x 480) 3 - Video graphics monitor plus (800 x 600) 4 - 8514A
Card type	0 - IBM 1 - Paradise 2 - ATI 3 - TECMAR 4 - TSENG 5 - VIDEO-7 6 - PLASMA
Printer type	0 - Other 1 - Epson 2 - HP LaserJet (DEFAULT)
Printer has complete IBM character font?	Y - Yes. N - No (DEFAULT)
Plotter communications port	0 - No Plotter connected to port (DEFAULT). 1 - Plotter connected to Com1 port. 2 - Plotter connected to Com2 port. 3 - Plotter connected to Com3 port.
Use alternate basic event names?	Y - Alternate name will be used. N - Primary name will be used (DEFAULT).
Importance Measurement Type?	R - Ratios (DEFAULT) I - Intervals U - Uncertainty
Verify when loading MAR-D data?	Y - File dependency will be checked. N - No file cross checking will done. (DEFAULT)
Random number seed	5 digit numeric field indicating the first random number in the seed to be used in the Monte Carlo calculation. 0 (DEFAULT) indicates that the random number will be the current value of the real clock.
Sample size	6 digit numeric field indicating the default number of Monte Carlo samples to be run in the uncertainty analyses. Sample size may range from 1 to 999999 (DEFAULT = 1,000).

Table 3-1. (continued).

FIELD	DESCRIPTION
Cutoff by size?	Y - Do not generate fault tree or sequence cut sets containing more basic events then indicated in the Size cutoff field (DEFAULT). N - Generate all cut sets for the fault tree or sequence that meet the probability cutoff criteria (if in effect).
Size cutoff	The default maximum number of basic events allowed in cut set generation when size cutoff is in effect. DEFAULT = 6
Cutoff by probability?	Y - Do not generate fault tree or sequence cut sets that have a probability less than the cutoff indicated in the probability cutoff field (DEFAULT) N - Generate all cut sets that meet the size cutoff criteria (if in effect) regardless of the cut set probability.
Probability cutoff	The default minimum cut set probability allowed in cut set generation when probability cutoff is in effect. (DEFAULT = 000E-015)
Mission time (hours)	The default mission time to be used in the calculation of basic event probabilities (when appropriate). DEFAULT = 2.400E+001
Scratch drive and directory	36 character field indicating the drive and path to the scratch directory where files will be stored (DEFAULT set to blanks)
Halo drive and directory path	36 character field indicating the drive and path to the Halo graphics that SARA 4.0 should use (/HALOBB/)

Several notes are worth mentioning here. While SARA 4.0 is compatible with the standard color graphics monitor and board, the low resolution graphics are really inadequate for PRA applications.

SARA 4.0 can use a mouse in the graphical displays. Any two-, three-, or four-button mouse may be used. SARA 4.0 uses the mouse driver that was supplied with your mouse, therefore, the mouse driver should be loaded before entering SARA 4.0.

The last three fields in the User Information section will be addressed in other lessons and need not be of concern here.

5. When the first five fields are properly set, press **<Enter>**. This will bring up the fault tree graphics constants form. This form will be discussed in Lesson 4. Press **<Enter>** again. This brings up the event tree graphics constants form. This form will also be discussed in Lesson 4. Press **<Enter>** one more time. This brings up the SARA 4.0 Main Menu. SARA 4.0 is now configured properly for use with your hardware setup. The **Exit** option should be highlighted. If not, use the **<Up Arrow>** key to place the highlight on **Exit** and press **<Enter>**. You should now be back to DOS.

3.1.3 Install PRA Databases

Now that SARA 4.0 is installed and setup, it's time to load data that SARA 4.0 can use. These data are the results of probabilistic risk assessment work: fault trees, event trees, accident sequences, basic events, and the associated probabilistic failure and uncertainty data. This data can come from IRRAS databases through the MAR-D interface or it can come as part of your SARA 4.0 package. This latter source contains databases developed for the NRC through a research project at the Idaho National Engineering Laboratory. This project uses the MAR-D software to convert PRAs available to the NRC for use with IRRAS and SARA. The following steps explain how to load these databases into your computer.

1. Insert the first Database diskette into your floppy drive. The data installation procedure requires that this drive be designated A:. If the Database diskettes are incompatible with your A: drive, use the DOS command ASSIGN to designate the appropriate drive as A:. If you do not have the ability to change the drive designation, contact your SARA supplier to obtain a compatible data package.

2. Type **A:INSTALL x: <Enter>**, where x is the designation of the destination hard drive (usually the drive containing the SARA 4.0 software). The database installation will create the appropriate data subdirectories to \PRADATA.B1 and copy the database files into them.

   The database files on the installation diskettes are archived. The installation procedure copies the archive files to the hard drive and begins the unarchiving process. During this time, the archive files and the unarchived files both exist, taking up more hard drive memory than after the installation is completed. The amount of hard drive memory required for the loading of databases varies from database to database and depends on the extent of the original PRA models.

The unarchiving process is indicated by the listing of files being "exploded," or "unshrunk." These terms are used by the archiving software to indicate the process used when the files were archived.

3 Insert the remaining database diskettes in the proper order when prompted. After the last diskette is read, the database files will be unarchived, the archive files will be deleted, and the installation batch file will be removed from the subdirectory. The database installation procedure will display the message, "**Installation of data is complete.**" Then DOS will display the message, "**Batch file missing.**" This is the normal response and indicates that the loading procedure is completed. The current directory will be the last \PRADATA.B1 subdirectory loaded.

This completes Lesson 1. You should have SARA 4.0 loaded on your computer and configured for operation. You should also have databases loaded for use with the software. The SARA 4.0 loading procedure should not be required again unless you off-load it and need to reinstall or you receive an update. The database loading procedure should only be needed if additional databases are received.

3.2 Lesson 2. Exploring SARA 4.0

This lesson teaches you the basic operation of SARA 4.0 and how to perform the following functions:

A. Select menu options.

B. Use of families.

C. Use of the function keys.

3.2.1 Menus and Families

SARA 4.0 is a completely menu-driven system. All system operations are performed from the menus and all information is supplied through fill-in-the-blank forms, eliminating the need for specially-formatted input files. The power of this type of system can be fully realized only after becoming familiar with the mechanics of moving around the menus and providing input data. The best way to gain this familiarity is to dig right in and play with SARA 4.0.

The following steps will show you how to get around inside SARA 4.0, and how to select a specific family of information.

1. To invoke SARA 4.0, you must be in the \PRADATA.BI directory. Type **SARA** and press **<Enter>**. This will bring up the SARA 4.0 copyright screen as shown in Figure 3-2.

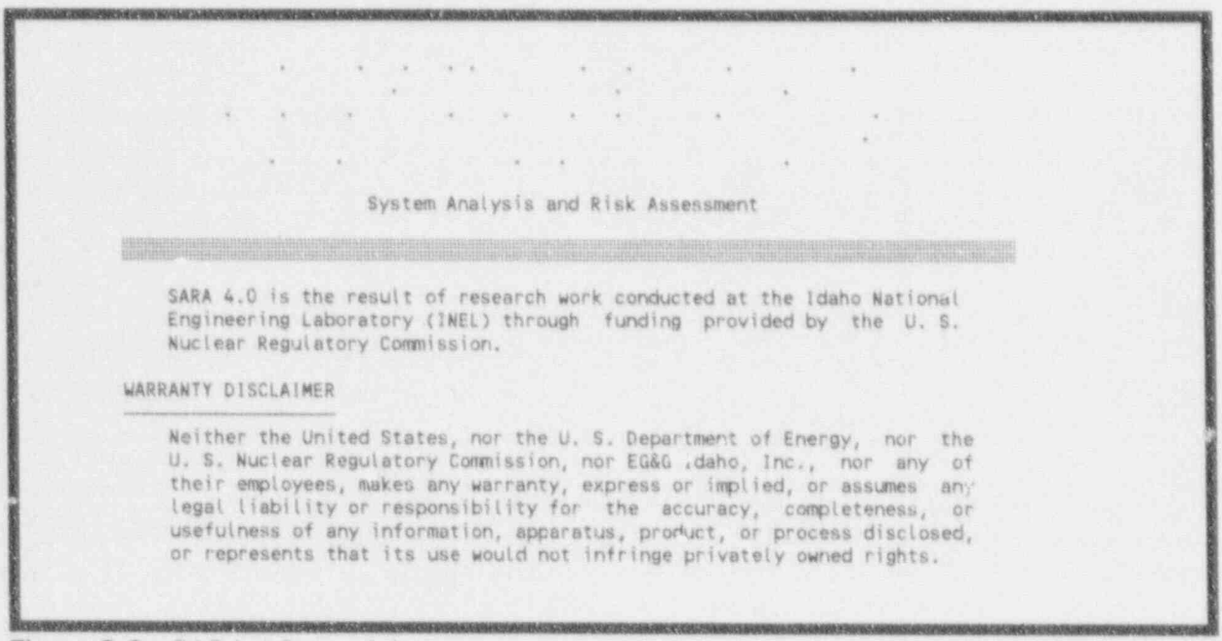


Figure 3-2. SARA 4.0 copyright screen.

2. After a short period the SARA 4.0 Main Menu shown in Figure 3-3 will appear. This menu provides access to each of the major functions of SARA 4.0. The user can select an option from this menu in two ways. First, the user can move the green highlight from option to option using the **<Up Arrow>**, **<Down Arrow>**, **<Space Bar>**, or **<Tab>** key. When the desired option is highlighted, it is executed by pressing **<Enter>**. Secondly, the user can press the letter designator for the desired option (usually the first letter of the option name, but always the light green capital letter) and then pressing **<Enter>**.

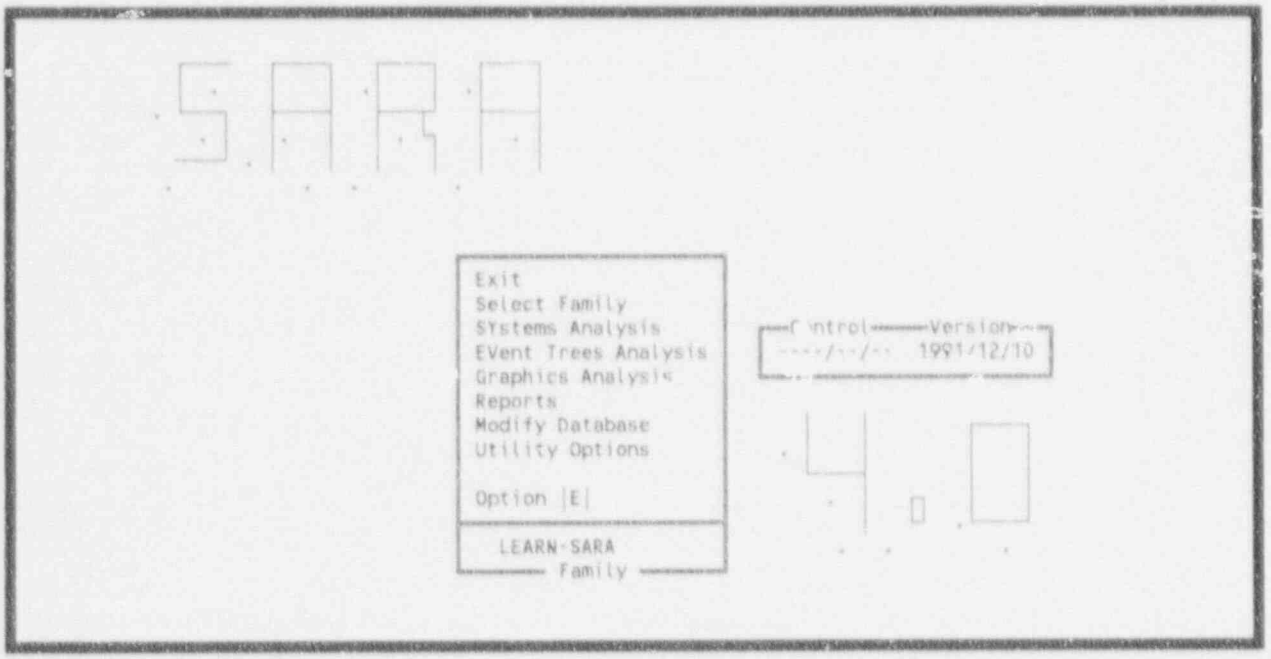


Figure 3-3. SARA 4.1 main menu.

3. Execute the "Select Family" option by pressing the **<Down Arrow>** key to highlight "Select Family" and pressing **<Enter>**. This will bring up the Select Family menu shown in Figure 3-4. This menu provides several options and a list of items on which you can perform those options. The procedure for using this type of menu is to first select the function to be performed and then select the item on which the function will be performed. This is done by pressing the letter for the option at the top of the screen (uppercase light green letter), moving the highlight to the desired item on the list, and pressing **<Enter>**.

Whenever a SARA 4.0 menu requires that an entity be selected to be the object of a function, select the function first and then highlight the object on which the function is to be performed.

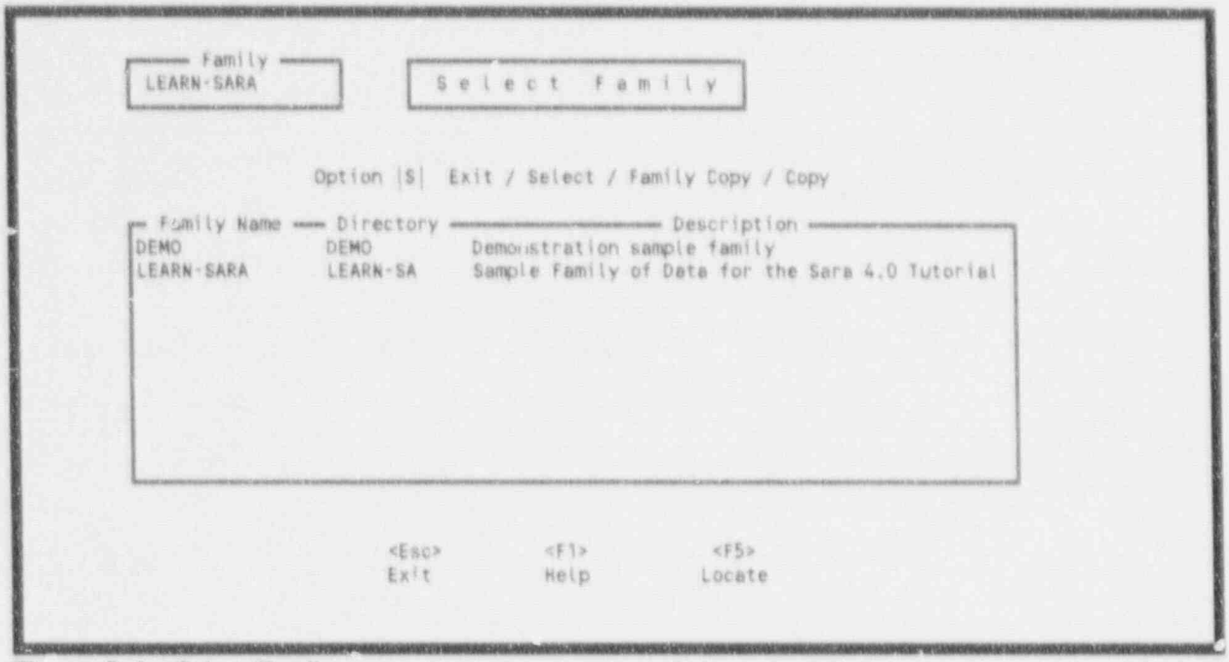


Figure 3-4. Select Family menu.

4. Select the LEARN-SARA family by pressing **<S>** (not required if the **S** already shows in the Option block), move the highlight down to the LEARN-SARA family with the **<Down Arrow>** key and press **<Enter>**. This will select LEARN-SARA as the current family of data and return you back to the SARA 4.0 Main Menu. The selected family name will be displayed at the bottom of the menu.

   A family of data is defined as the system models, event tree models, basic events, and all associated information pertaining to a single PRA study. For instance, each of the NUREG/CR-4550 analyses is contained in a separate family. Each family of information is stored in its own subdirectory on the hard drive. The subdirectory name is identical to the family name. Thus, the LEARN-SARA family information is contained in the \PRADATA.B1\LEARN-SA subdirectory. More information about families is contained in Section 2 of the *SARA 4.0 Volume 1 - Reference Manual*.

This section showed you how to get SARA 4.0 running, how to move around the menus, and how to select a family of information on which you would like to perform analyses, obtain reports, or display results. Steps 3 and 4 may be repeated at any time to change the current family.

3.2.2 Major Functions

The SARA 4.0 Main Menu lists the major functions provided. This section walks you through each of these areas as an exercise in moving around inside SARA and to familiarize you with the various capabilities of the software.

Begin by selecting the SYstems Analysis option:

1. Use the **<Down Arrow>** key to highlight the SYstems Analysis option and press **<Enter>**.

   This will bring up the Systems Analysis menu shown in Figure 3-5. From this menu you can select options to modify basic event probability and initiating event frequency data (including uncertainty distribution data), to analyze systems in the PRA, to display the current results for systems, and to edit the system cut sets. We will explore each of these areas now and in more detail in later lessons.

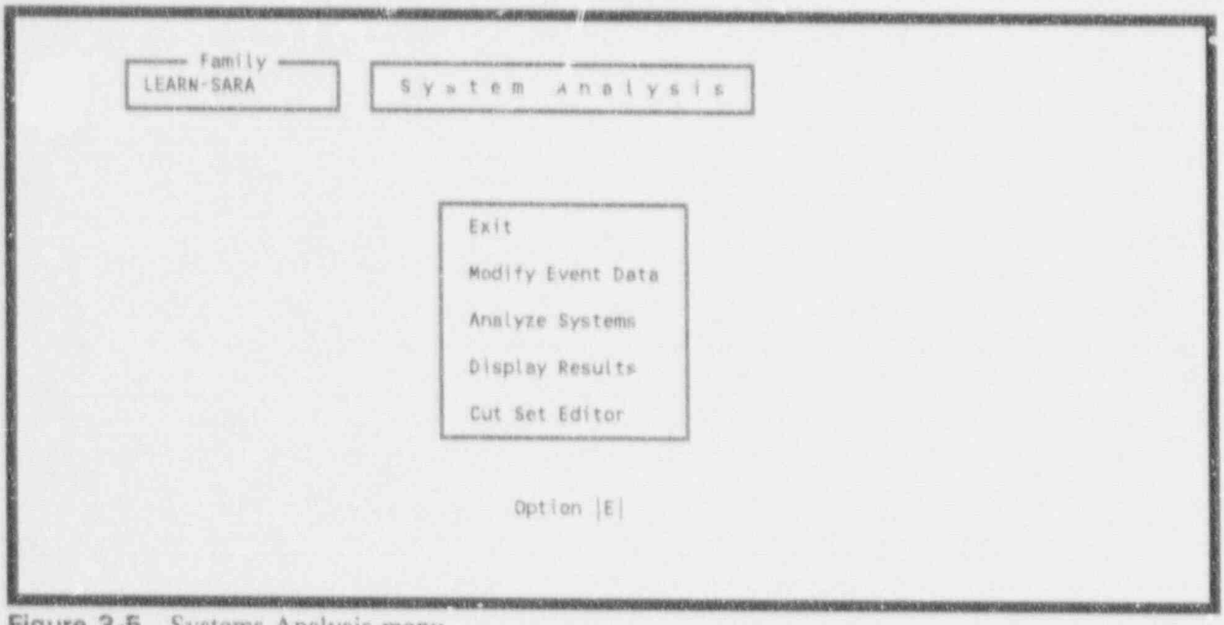


Figure 3-5. Systems Analysis menu.

2. Press **<M> <Enter>** to select Modify Event Data.

   This brings up the Change Sets menu shown in Figure 3-6. This menu allows the user to define any number of sensitivity data sets for the basic events and initiating events in the selected family. Each definition of a sensitivity set is called a "change set." The following operations may be performed with change sets:

   a. Add - creates a new change set. A description may also be added.

   b. Modify - allows the user to rename a change set or modify the description.

   c. Delete - removes a change set from the database.

   d. Probability - allows the user to define a probability or uncertainty data change to an individual basic event or initiating event.

   e. Class - allows the user to define a probability or uncertainty data change to a class of basic events or initiating events.

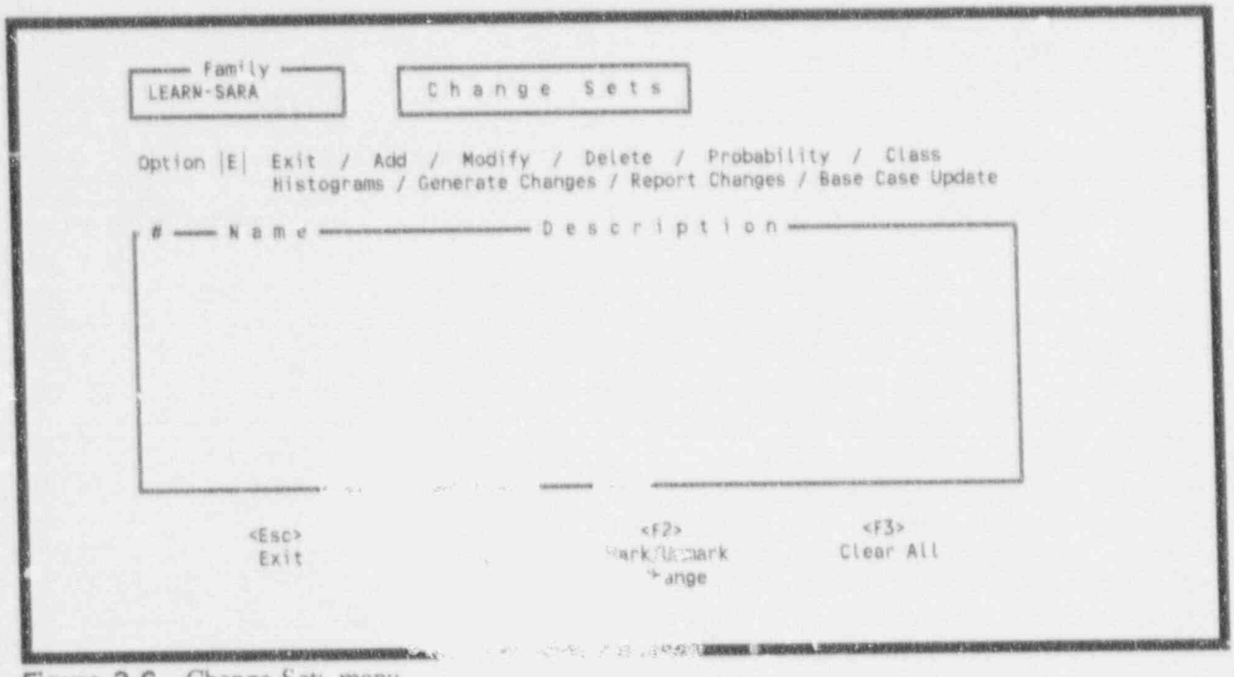


Figure 3-6. Change Sets menu.

f. Histograms - allows the user to create, modify, and delete user-defined histograms for uncertainty analysis.

g. Generate Changes - applies the selected change sets to the list of basic events and initiating events in the family. Until this option is invoked, the change sets are only defined and do not change the values of the basic events or initiating events used in the calculations.

h. Report Changes - provides a report of the basic event and initiating event changes defined in the selected change set.

i. Base Case Update - updates the base case values for the basic events and initiating events with the last change set(s) applied. **This destroys the base case values originally in the database.** This option provides a warning and an opportunity to escape before overwriting your base case values.

The creation and use of Change Sets is the subject of Lesson 3, where you will be led through the entire process of using Change Sets in the performance of sensitivity analyses.

3. Let's move on to the next area of Systems Analysis by pressing the **<Esc>** key to go back to the Systems Analysis menu.

This does the same thing as selecting the **Exit** option from the menu. **The <Esc> key will exit you out of any form or menu back to the previous form or menu.**

4. Select the Analyze Systems option using the **<Down Arrow>** key and pressing **<Enter>**.

This brings up the Analyze Systems menu shown in Figure 3-7. The options on this menu are:

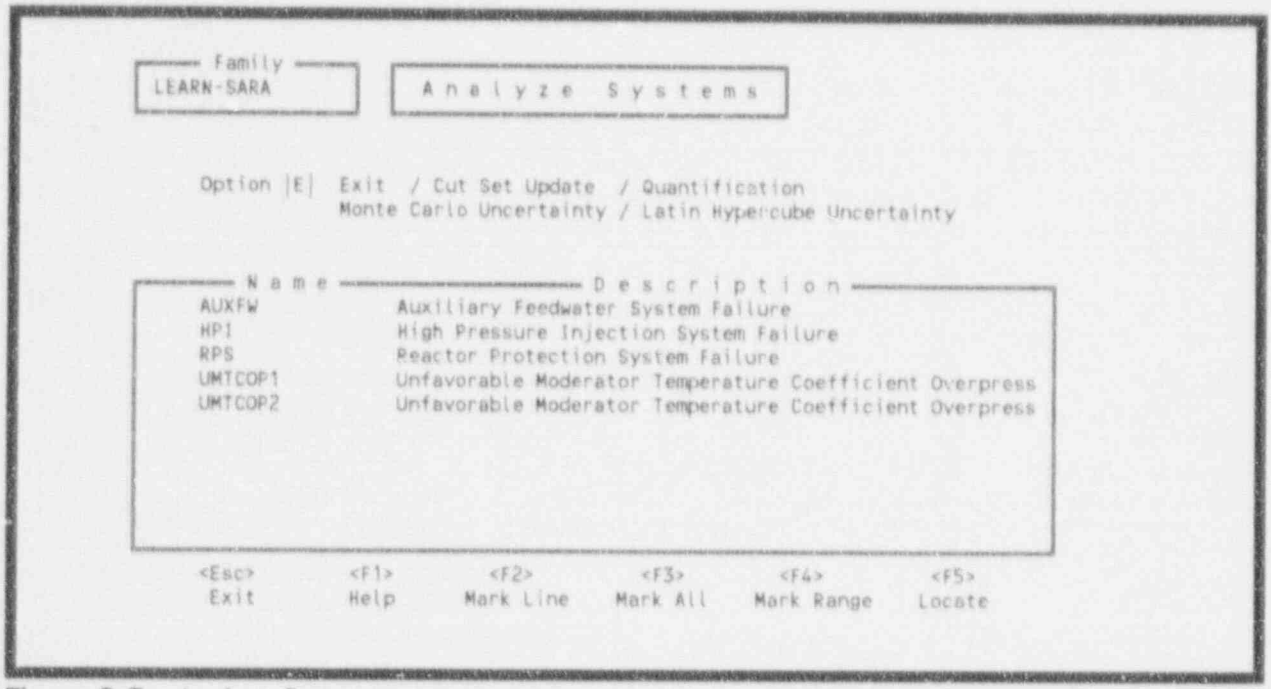


Figure 3-7. Analyze Systems menu.

a. Cut Set Update - performs Boolean reduction and applies the probability and size cutoff criteria to the cut sets for the selected system(s). Boolean reduction may be required due to the creation of non-minimal cut sets with the cut set editor or conversion of an event to a house event. Probability and size truncation may need to be applied due to new basic event probabilities being assigned through the Change Sets.

b. Quantification - calculates the system failure probability based on the cut sets from the last update using the minimal cut set upper bound technique.

c. Monte Carlo Uncertainty - performs an uncertainty analysis on the cut sets for the selected system(s) using the Monte Carlo sampling technique.

d. Latin Hypercube Uncertainty - performs an uncertainty analysis on the cut sets for the selected system(s) using the Latin Hypercube sampling technique.

5. Escape out of the Analyze Systems menu and return back to the Systems Analysis menu by pressing **<Esc>**. Highlight the Display Results option and press **<Enter>**.

This brings up the System Display menu shown in Figure 3-8. This menu lists each of the systems in the family and allows viewing various results and elements of the PRA models. This menu uses several function keys to gain access to various displays. Press:

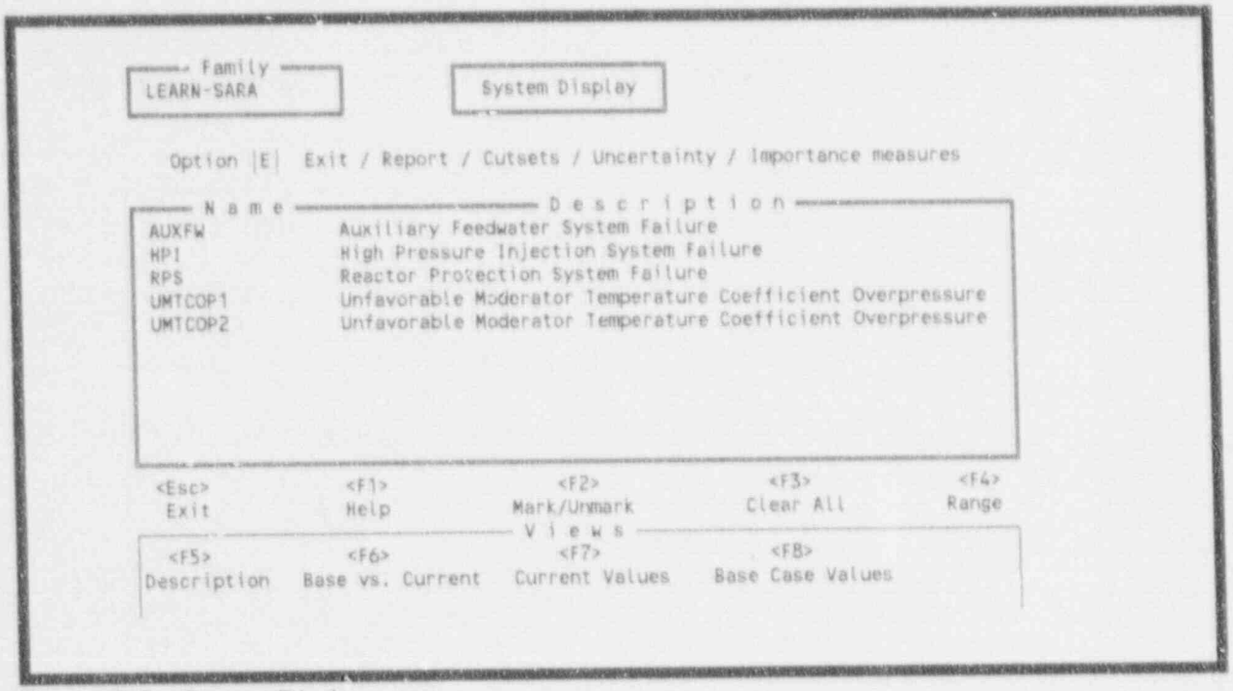


Figure 3-8. System Display menu.

a. **F5** - to obtain a list of the systems in the family with a description for each system.

b. **F6** - to display the base case results along side the current sensitivity results.

c. **F7** - to display the current sensitivity case point estimate and uncertainty results.

d. **F8** - to display the base case point estimate and uncertainty results.

In addition to these displays, the options listed across the top of the menu provide the following:

e. Report - creates a report on any of the displays produced with the function keys. These reports can be sent to a printer or to a file on the hard disk.

f. Cutsets - displays the current quantified sensitivity case cut sets for the selected system. Options on a submenu allow further analyses using the cut sets.

g. Uncertainty - displays a more detailed comparison of the base case and current sensitivity uncertainty results for a selected system.

h. Importance Measures - displays the importance of every basic event in the selected system cut sets to the system failure probability. Importance measures calculated include: Fussell-Vesely, Risk Reduction Ratio, Risk Reduction Interval, Risk Achievement Ratio, Risk Achievement Interval, and the Birnbaum importance.

6. Escape out of the System Display menu and return to the Systems Analysis menu by pressing **<Esc>**. Highlight the Cut Set Editor option and press **<Enter>**.

This brings up the Cut Set Editor menu shown in Figure 3-9. This menu displays the list of systems in the family and indicates the existence of base case and current case cut set lists available for editing. The options are:

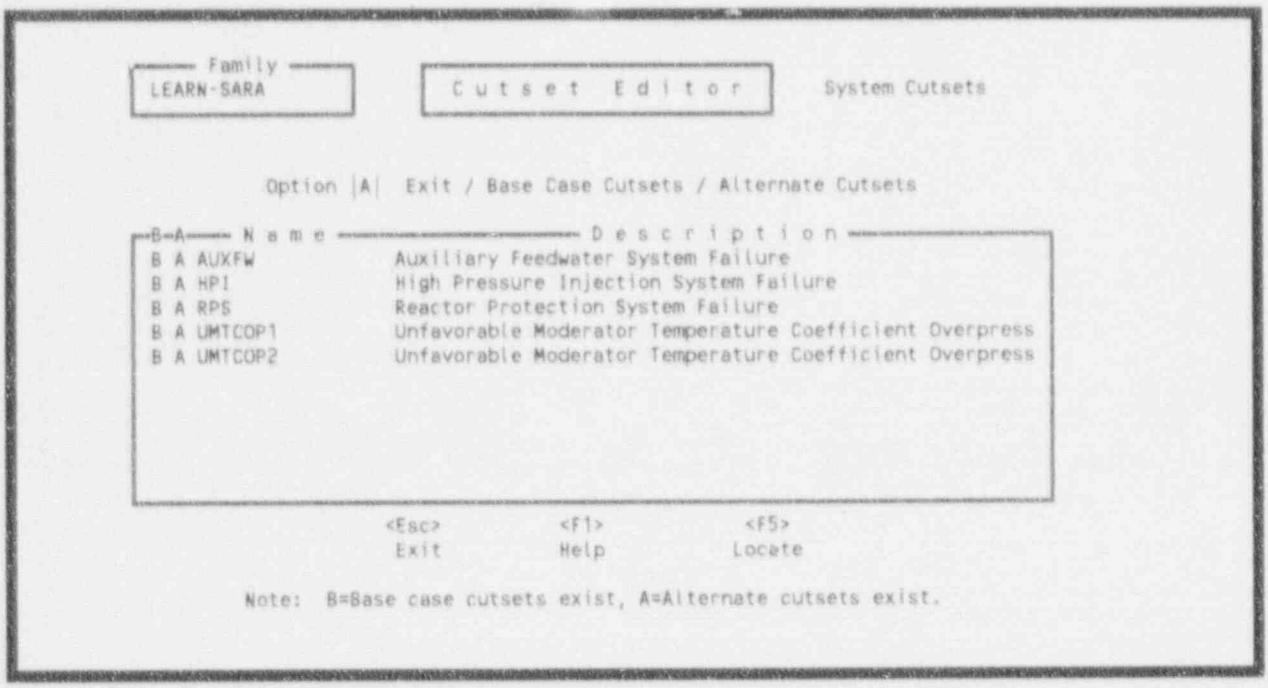


Figure 3-9. Cut Set Editor menu.

a. Base Case Cutsets - allows the analyst to create a sensitivity case cut set list from the base case cut sets to model simple system modifications without redrawing the fault tree logic models. **This does NOT destroy the base case cut sets stored in the system.**

b. Alternate Cut Sets - allows the analyst to create a sensitivity case cut set list from the previous sensitivity case cut sets. **Because SARA contains only the base case and one sensitivity case cut set list, saving the output of the cut set editor will destroy the previous sensitivity case cut set list.**

7. Because this is the last area under Systems Analysis, we will return to the SARA 4.0 Main menu by pressing **<Esc><Esc>**.

8. The next major function listed on the SARA 4.0 Main menu is EVent Trees Analysis. Select this option by highlighting it and pressing **<Enter>** or by pressing **<V> <Enter>**.

   This brings up the Event Tree Analysis menu shown in Figure 3-10. This menu looks almost identical to the Systems Analysis menu. The big difference is that this menu allows the user to perform these options on accident sequences and their cut sets instead of systems.

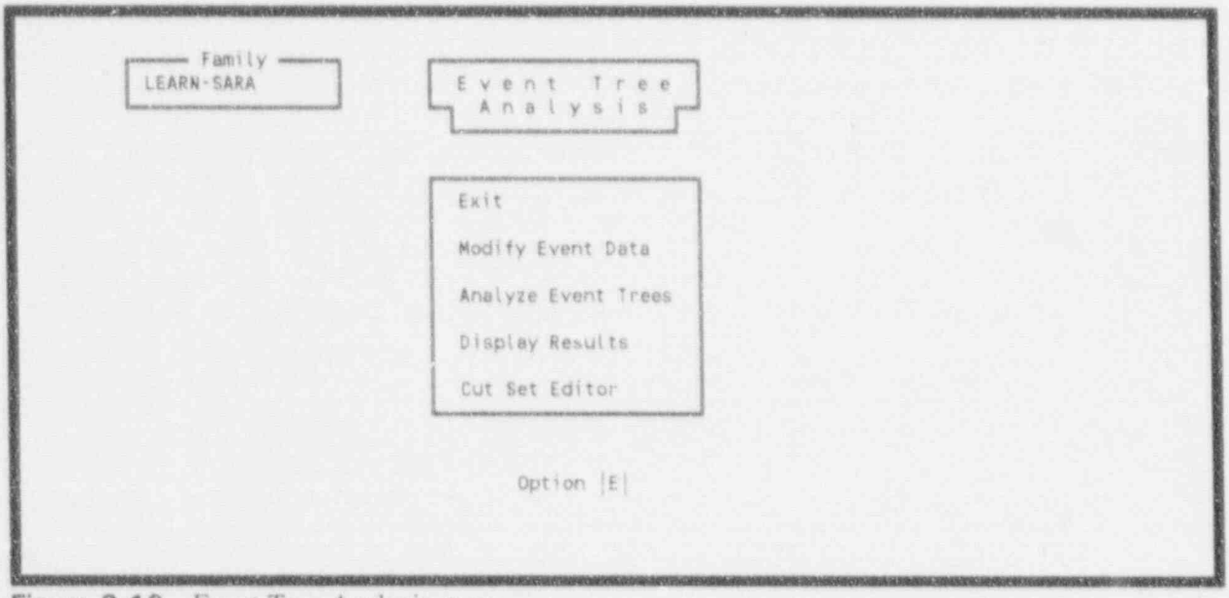


Figure 3-10. Event Tree Analysis menu.

The options are described as follows:

a. Modify Event Data - performs the exact same functions as described above in Step 2 and changes made here or under the Systems Analysis menu have the exact same impact on the PRA models. The options are repeated under the Event Tree Analysis menu for the convenience of the analyst.

b. Analyze Event Trees - performs the same functions as the Analyze Systems menu (described in Step 4) except the displays list accident sequences instead of systems and the operations are performed on the accident sequence cut sets contained in the database.

c. Display Results - displays the same types of information for sequences that Display Results under Systems Analysis did for systems. Additional information is provided for end state groupings (plant damage states) including importance measures of basic events and initiating events with respect to the end state and the family.

d. Cut Set Editor - allows modification of sequence cut sets to model recovery or plant changes, using the same editor used for system cut sets.

9. Once again escape back to the SARA 4.0 Main menu by pressing **<Esc>**.

10. We will now explore the Graphics Analysis module by using the **<Down Arrow>** key to highlight the Graphics Analysis option and pressing **<Enter>**.

This brings up the Graphical Analysis menu shown in Figure 3-11. The options on this menu are described below:

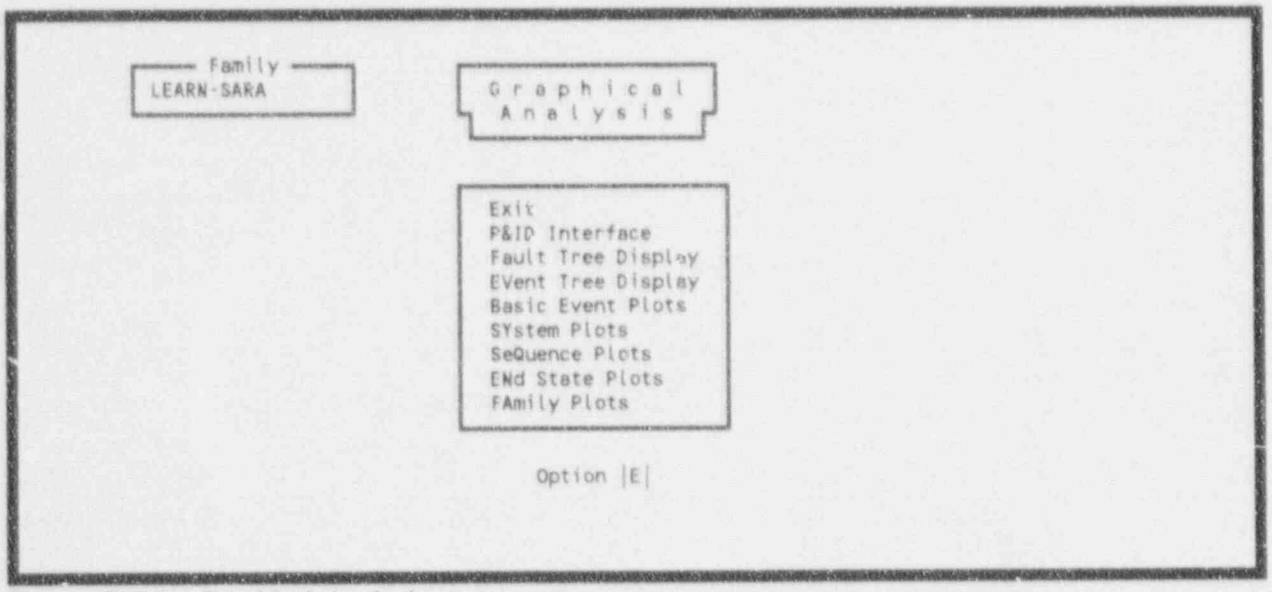


Figure 3-11. Graphical Analysis menu.

a. P&ID Interface - allows for the creation of Change Sets through the interactive use of piping and instrumentation drawings (P&IDs). The analyst can pick components off a P&ID and SARA will display the basic events associated with that component and allow access to make changes to the probability and uncertainty data. Lesson 4 is dedicated to this function.

b. Fault Tree Display - presents a list of fault trees that can be viewed on the screen.

c. EVent Tree Display - presents a list of event trees that can be viewed on the screen.

d. Basic Event Plots - provides access to probability density function and cumulative density function curve plots of the sensitivity cases basic event failure probabilities. Latin Hypercube, Monte Carlo, or an overlay of the two results may be plotted on the screen, sent to the printer, or sent to a plotter file.

e. SYstem Plots - provides access to bar chart and distribution curve plots of base case and sensitivity case system failure probabilities. The plots can be sorted by system name, base case values, sensitivity case values, or the difference between the two.

f. SeQuence Plots - provides access to bar chart and distribution curve plots of base case and sensitivity case accident sequence frequencies. The plots can be sorted by sequence name, base case values, sensitivity case values, or the difference between the two.

g. ENd State Plots - provides access to bar chart plots of base case and sensitivity case end state (plant damage state) frequencies. The plots can be sorted by sequence name, base case values, sensitivity case values, or the difference between the two.

h. FAmily Plots - provides access to probability density function and cumulative density function curve plots of the sensitivity case family results (sum of all accident sequences). Latin Hypercube, Monte Carlo, or an overlay of the two results may be plotted on the screen, sent to the printer, or sent to a plotter file.

11. Return to the SARA 4.0 Main Menu by pressing **<Esc>**.

12. The next major function on the main menu is Reports. Select this option by pressing **<R><Enter>**.

This brings up the Reports menu shown in Figure 3-12. This menu provides access to reports that can be generated on all aspects of the database. These reports can be viewed on the screen, sent directly to a printer, or sent to a file on the hard drive for later use. The menu options show the areas for which reports have been developed:

a. Families - provides summary and detailed reports on the families of data residing in the database. The summary report shows only the family names and descriptions. The detailed report contains information about the facility in the analysis (name, location, operator, A-E, constructor, key dates, etc.) and some very high level results from the base case PRA.

b. EVent Trees - provides summary, detailed, and sequence reports for the event trees in the selected family. The summary report shows only event tree names and descriptions. The detailed report also supplies the event tree initiating event name and any event tree text that is contained in the database to explain the event trees. The sequence reports contain every piece of data for the base case and sensitivity case that resides in the database.

c. Sequences - provides summary and detailed reports for the sequences in the selected family. The summary report contains the sequence names, descriptions, and frequencies. The detailed report contains all the sequence analysis parameters and results for the quantification of the base and sensitivity cases.

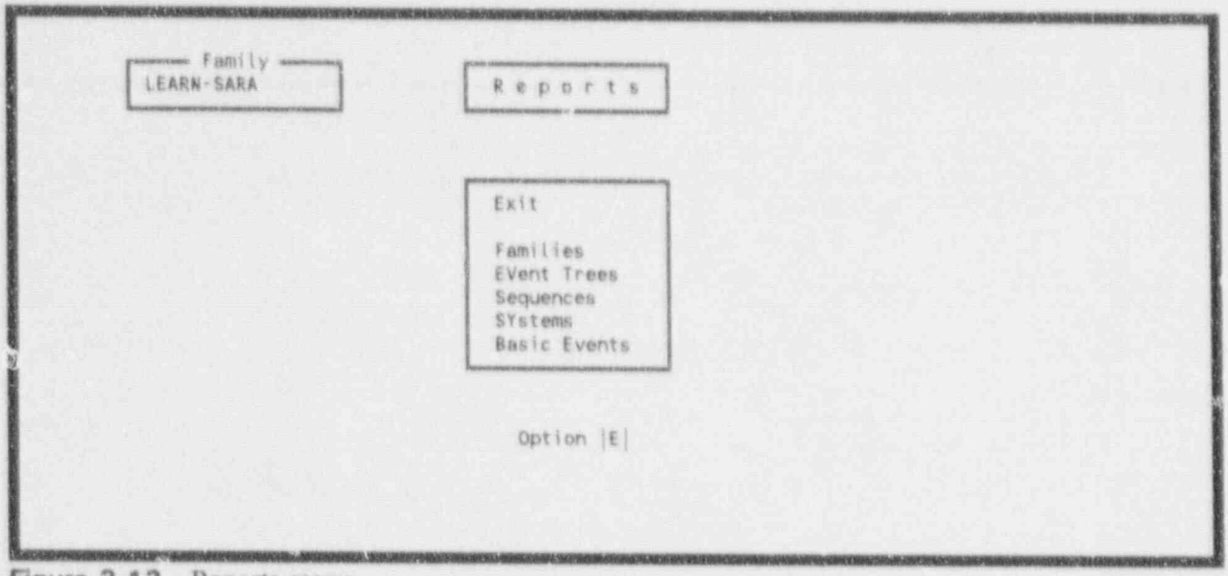


Figure 3-12. Reports menu.

Any additional descriptive text contained in the database pertaining to the sequences is also reported.

d. SYstems - provides summary and detailed reports on the systems contained in the selected family. The summary report contains the system names, descriptions, and minimal cut set upper bound values. The detailed report contains all the base and sensitivity case analysis parameters and results.

e. Basic Events - provides summary, detail, probability, uncertainty, cross-reference, and unused event reports for all the basic events contained in the selected family. The summary report contains the names and descriptions for all the basic events in the selected family. The detail report contains all the probability, uncertainty, and attribute information residing in the database. The probability report contains only the data needed to determine the basic event failure probabilities. The uncertainty report contains the uncertainty distribution information input for each basic event. The cross-reference reports are divided into four different areas: 1) basic events to fault trees, 2) basic events to event trees, 3) basic events to systems, and 4) basic events to sequences. The unused event report lists the basic events in the database that are not used in any system or sequence cut sets. This can occur due to removal by truncation.

13. Escape from the Reports menu back to the SARA 4.0 Main menu by pressing **<Esc>**.

14. The Modify Database module provides access to the base case data for database management. Select this option by highlighting Modify Database and pressing **<Enter>**.

This brings up the Modify Database menu shown in Figure 3-13. The options on this menu represent each of the major data categories in the relational database used by

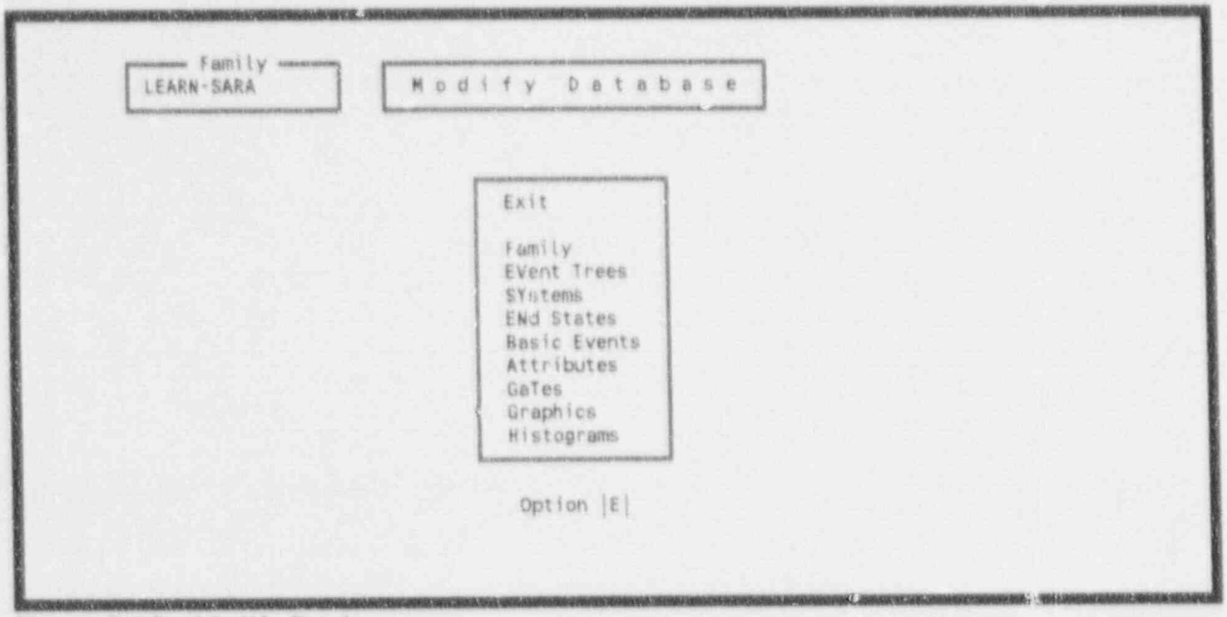


Figure 3-13. Modify Database menu.

The Modify Database module gives the analyst direct access to the base case PRA data. DELETIONS AND MODIFICATIONS IN THIS AREA WILL DESTROY THE BASE CASE PRA AS ORIGINALLY LOADED INTO THE DATABASE.

Descriptions of these options are as follows:

a. Family - allows the analyst to add a new family to the database, modify the name or description of an existing family, or delete a family from the database.

b. EVent Trees - allows the analyst to add new event trees to a family, modify the name or description of an existing event tree, delete an event tree from the database, add textual information about an event tree, or add new sequences to an existing event tree.

c. SYstems - allows the analyst to add new systems to a family, modify the name or description of an existing system, delete a system from the database, or add textual information about a system.

d. ENd States - allows the analyst to add an end state to a family, modify the name or description of an existing end state, delete an end state from a family, or add textual information about an end state.

e. Basic Events - allows the analyst to add a new basic event or initiating event to a family and input base case probability and uncertainty data, modify the base

case data for a basic event in the family, and delete an unused basic event from the database.

f. Attributes - allows the analyst to create, modify, and delete various attribute lists such as system types, locations, failure modes, class attributes, and basic event component types.

g. GaTes - allows the analyst to input, modify, and delete gates.

h. Graphics - allows the analyst to add a new P&ID, fault tree, or event tree graphic to the database, modify the name and description of an existing graphic, and delete a graphic from a family.

i. Histograms - allows the analyst to input, modify, and delete histograms for use in the uncertainty analyses.

15. Escape back to the SARA 4.0 Main Menu and go into the SARA 4.0 Utilities by pressing **<Esc>**, highlighting Utility Options and pressing **<Enter>**.

This brings up the Utility Options menu shown in Figure 3-14. The SARA 4.0 utilities provide menus and forms to customize the SARA software to your computer and personal preferences. It also provides an interface with the Model and Results Database System (MAR-D) to bulk load and extract data to and from the SARA database. And finally, there are utilities to recover a database that has become corrupted due to an aborted process, power failure, or hardware failure. The options are defined below:

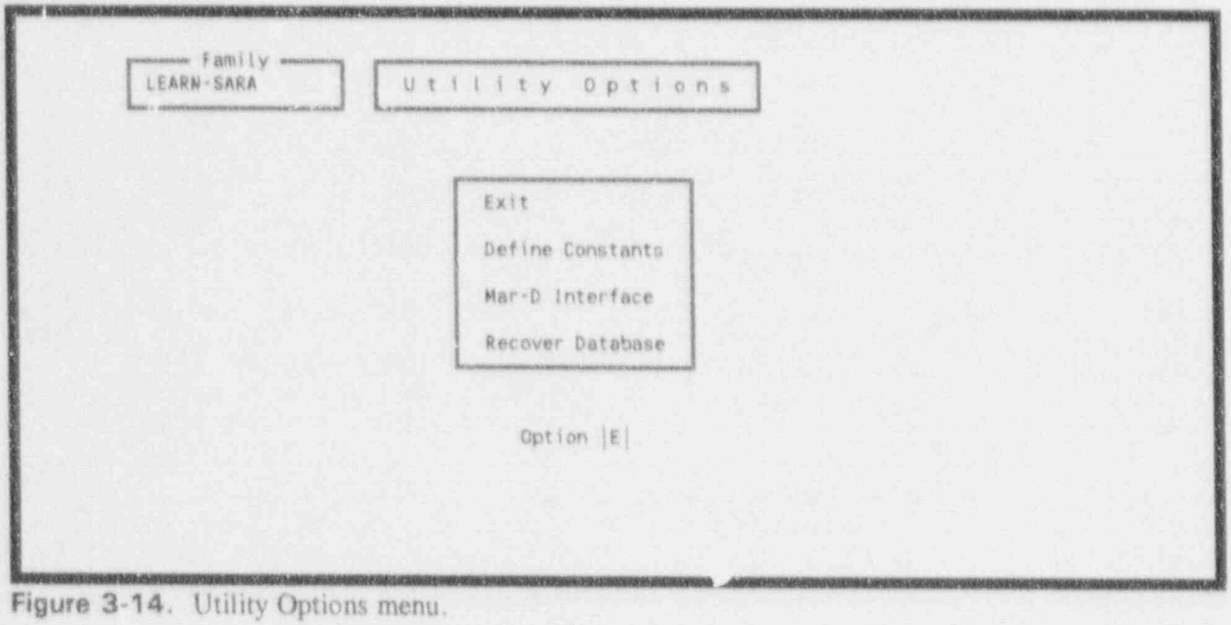


Figure 3-14. Utility Options menu.

a. Define Constants - provides three screens of constants and parameters that the analyst can set to inform SARA about the particulars of the computer and printer

hardware, and preferences for analysis defaults such as cut set generation cutoff criteria, mission time, uncertainty random seed and number of samples. Display set-ups for the graphics can also be made in this area.

b. Mar-D Interface - allows the analyst to load any portion of a PRA into the database from MAR-D formatted ASCII files and extract any portion of the SARA database to ASCII files in MAR-D or SETS formats.

c. Recover Database - allows the analyst to restore a corrupted database. This re-establishes the relational database indices and pointers that can be lost due to memory errors, interrupted calculational processes, hardware failures, and power fluctuations or losses. **For large databases, this can take a long time to complete.**

16. Escape back to the SARA 4.0 Main menu by pressing **<Esc>**.

This concludes Lesson 2. You may leave SARA now or continue with Lesson 3.

3.3 Lesson 3. Using Change Sets

This lesson shows you how to perform the following:

A. Create a change set to define a sensitivity database.

B. Define modifications to the probabilities and uncertainty distributions for the basic events and initiating events in the database.

Before getting into the creation and use of change sets, some background information on the structure and philosophy of the use of SARA 4.0 is required.

The key feature of SARA (and one of its primary reasons for existence) is the ability to take the results of PRA models and conduct sensitivity studies. These studies answer the "What if..." questions that come up when investigating the risk impacts of proposed plant changes or new knowledge about phenomena or reliability.

Sensitivity studies can impact the PRA model in three ways. First, the "What if" question may change the logic of the model, resulting in different accident sequences or different cut sets for existing sequences or systems. Second, the sensitivity issue may involve only a change in the failure probability of a component or operator action or an initiating event frequency. If so, the logic of the models remain the same, but the numbers used in the quantification change. Third, the sensitivity issue may require a combination of logic and reliability changes. While SARA can accommodate all three types of changes, it is the latter two cases that use change sets.

The SARA database contains two sets of information for the key elements of the PRA (basic event probability and uncertainty data, system cut sets, and sequence cut sets). In a new database, the base case and the sensitivity case (usually called the current case) are the same. **All calculations performed in SARA are conducted using the current case database only.** The base case database is used only for comparison and as a starting point for creating a sensitivity analysis.

A change set is the definition of how the base case is to be altered to create a sensitivity analysis. There is no practical limit to the number of change sets that can be created and used in SARA. Change sets can be invoked separately or in combination. For example, one change set may be created to model an improvement in the operation of motor-driven pumps. Another change set may be used to model new information about the failure rate of check valves. From these two change sets, three sensitivity analyses can be performed: 1) improved motor-driven pump operation, 2) different check valve failure rate, and 3) the combined impact of the motor-driven pumps and check valves.

3.3.1 Creating a Change Set

Change sets can be created through the Modify Event Data menu in either the Systems Analysis module or the Event Trees Analysis module. The two paths are equivalent and change sets created in one area will be available in the other area for use and modification. If you are interested in system impacts, then it is most likely more convenient to create change sets in the Systems Analysis module.

This lesson will create a change set called "UV-DRIVER-CARD," simulating a change in the type of undervoltage driver card being used in a Westinghouse solid state protection system (SSPS). The new card is expected to have a failure rate which is 20% of the old card failure rate.

This lesson begins with the analyst at the SARA 4.0 Main Menu with the LEARN-SARA family showing as the current family. From the Main Menu:

1. Enter the SYstems Analysis module by highlighting that option and pressing **<Enter>**.

2. Select the Modify Event Data option (**<M><Enter>**). This brings up the Change Sets menu. Note that there are no Change Sets listed.

3. Add a change set name and description by pressing **<A><Enter>**. This brings up the Add Change Set menu shown in Figure 3-15.

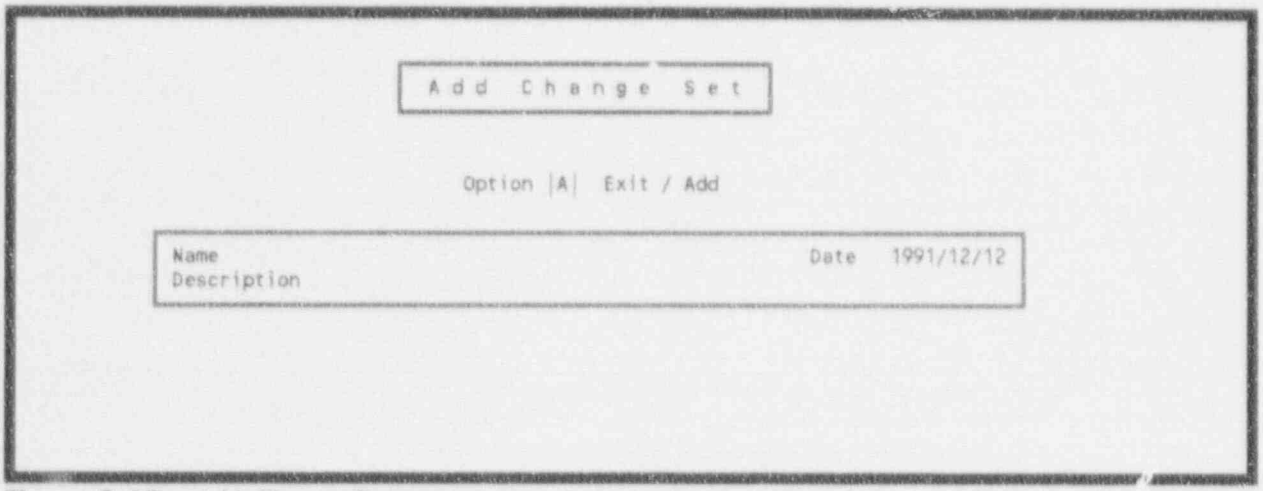


Figure 3-15. Add Change Set menu.

4. On this menu type in the name of our change set, **UV-DRIVER-CARD**.

   Do NOT press <Enter> when a blank field exists, as this tells the software that the entire form is properly completed and sends the data to the database.

   Note that a change set name can be a maximum of 16 characters long.

5. Press **<Tab>** to move the cursor to the date field. Enter the correct date if the date shown is not correct. SARA 4.0 uses the system clock date as the default for this field.

6. Press **<Tab>** again to move the cursor to the description field. Type in the following description: **Improved undervoltage driver card installation.**

   Note that if the date was correct, that field could have been skipped by using the **<Down Arrow>** key to go directly to the description field.

The description field can accept any description up to 60 characters in length including spaces.

The date and description are optional information fields. However, a change set cannot be created without being assigned a name.

7. Now that the form is properly filled out, press **<Enter>** to send the data to the database and return you to the Change Sets menu.

   The message "**New change record added**" should appear at the bottom center of the screen. The Change Sets menu should now look like Figure 3-16.

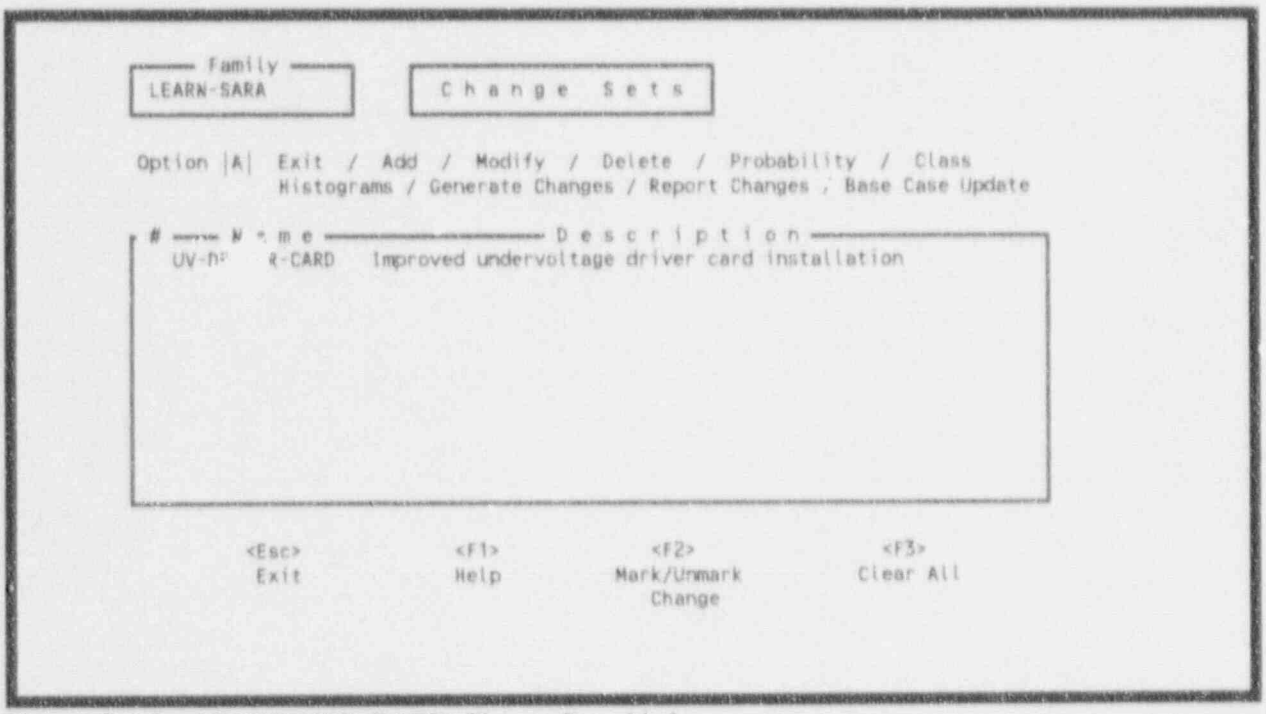


Figure 3-16. UV-DRIVER-CARD Change Set added.

The newly added change set name and description appear on the list on the Change Sets menu. Any errors in the change set name, date, or description can be corrected by using the Modify option on the Change Sets menu.

The change set has been created, but it is void of any information concerning our new undervoltage driver card. The next section teaches how this information is added.

3.3.2 Defining Event Changes Within a Change Set

SARA 4.0 provides three methods of defining event changes within a sensitivity analysis. The determination of which method(s) is appropriate depends on the nature of the issue being addressed by the sensitivity analysis. Each method will be discussed here and demonstrated later in the lesson.

The first method of defining event changes is the direct assignment of new probability and uncertainty data on an event-by-event basis (called the individual probability method). This requires that the analyst move through the entire list of basic and initiating events in the family, individually select the events that need to be changed, and apply the appropriate change definitions one at a time.

The second method is the manual designation of a group of events that need the same change definition (called the tagging method). This requires that the analyst move through the list of basic and initiating events, tag like events that need changes defined, and enter that change definition only once. This saves time and reduces the possibility of input errors because the desired change definition is input once and automatically applied to all tagged events.

The third method of defining event changes (called the class method) is accomplished by establishing search criteria for a class of events, inputting the desired change definition, and allowing the software to search the database for all the events that meet the search criteria and automatically applying the change definition.

The individual probability method is most appropriate when one-of-a-kind events must have changes defined. The tagging method is used when the search criteria for a group of events is difficult to establish or when more than one group of events must reside in a change set. The class method is used when a large number of like events must have changes defined.

A change set may be defined using any combination of these methods. There is no limit to the number of events that can have changes defined. The change set can contain as many individual probability event change definitions as needed by the sensitivity analysis. The tagging method is considered by the database to be another way of making individual probability change definitions; therefore, there is no limit on the number of times this method is used in a change set. The class method has no limit on the number of events in the defined class, but only one class is allowed per change set. This restriction is moot because change sets can be used in combinations and there is no limit to the number of change sets that can be defined. This will be demonstrated in Lesson 5.

3.3.2.1 Creating Individual Probability Change Definitions. In this portion of the lesson, we will define changes for the undervoltage driver card basic events in the LEARN-SARA family.

1. From the Change Sets menu, select the Probability option by pressing **<P>**, highlight the **UV-DRIVER-CARD** Change Set by using the **<Down Arrow>** key, and pressing **<Enter>**.

   This brings up the Select Event menu shown in Figure 3-17. This menu lists every basic event and initiating event in the family in alphabetical order.

2. Select the Probability option by pressing **<P>**.

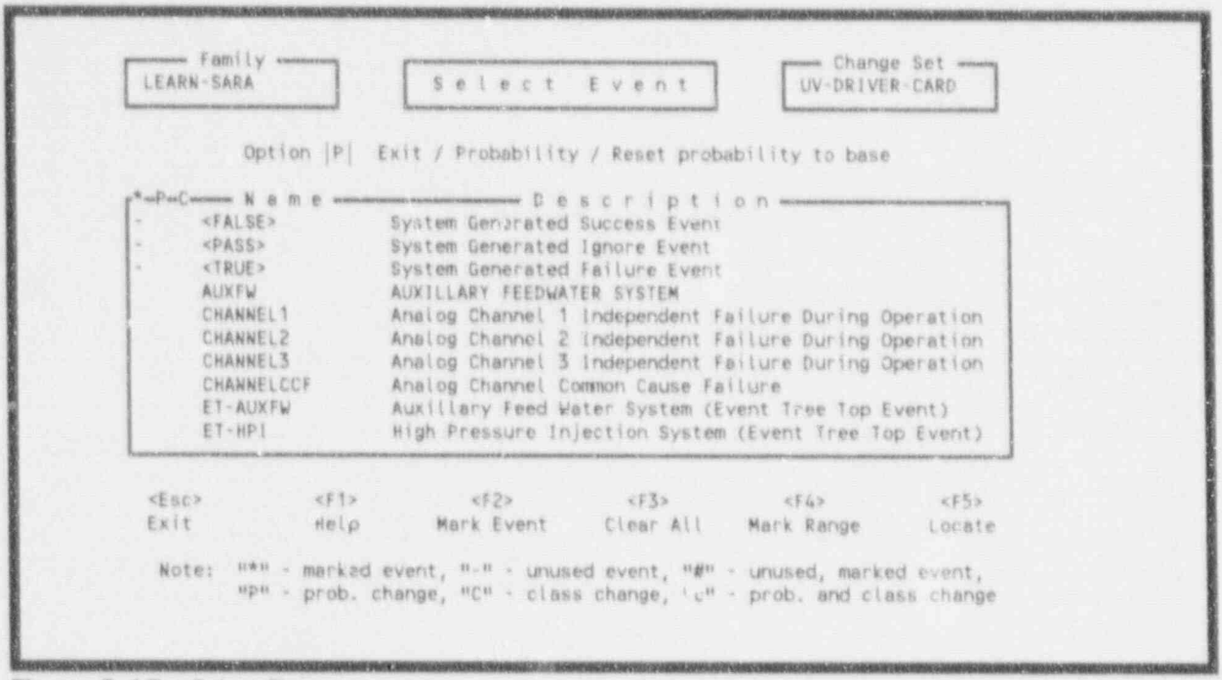


Figure 3-17. Select Event menu.

Note that if you pressed the **<Enter>** key after pressing **<P>**, an error message, "Events must be marked or highlighted" would have appeared at the bottom center of the screen.

3. Using the **<PgDn>** key, move down through the list of basic events until you find the basic events associated with the undervoltage driver cards. These are UVA, UVB, and UVCCF.

4. Highlight basic event UVA using the **<Down Arrow>** key and pressing **<Enter>**.

   This brings up the Event Probability Change menu shown in Figure 3-18. The upper half of this menu shows the attributes associated with this basic event. This portion of the menu is for information purposes only and cannot be accessed from this menu. The lower half of the menu shows the Uncertainty Data and Failure Data for the basic event. The base case data are displayed for information purposes only. The current case fields are where the change definitions are made.

   If the wrong event was selected, press **<Esc>**. This will take you back to the Select Event menu and the "Probability changed aborted" message will be displayed.

   The change definition for this basic event requires lowering the failure probability to a value of 20% of the base case value.

5. The cursor is in the Current Uncertainty Distribution Type field. Move the cursor to the Failure Data Current Calculation Type field by pressing the **<Right Arrow>** key.

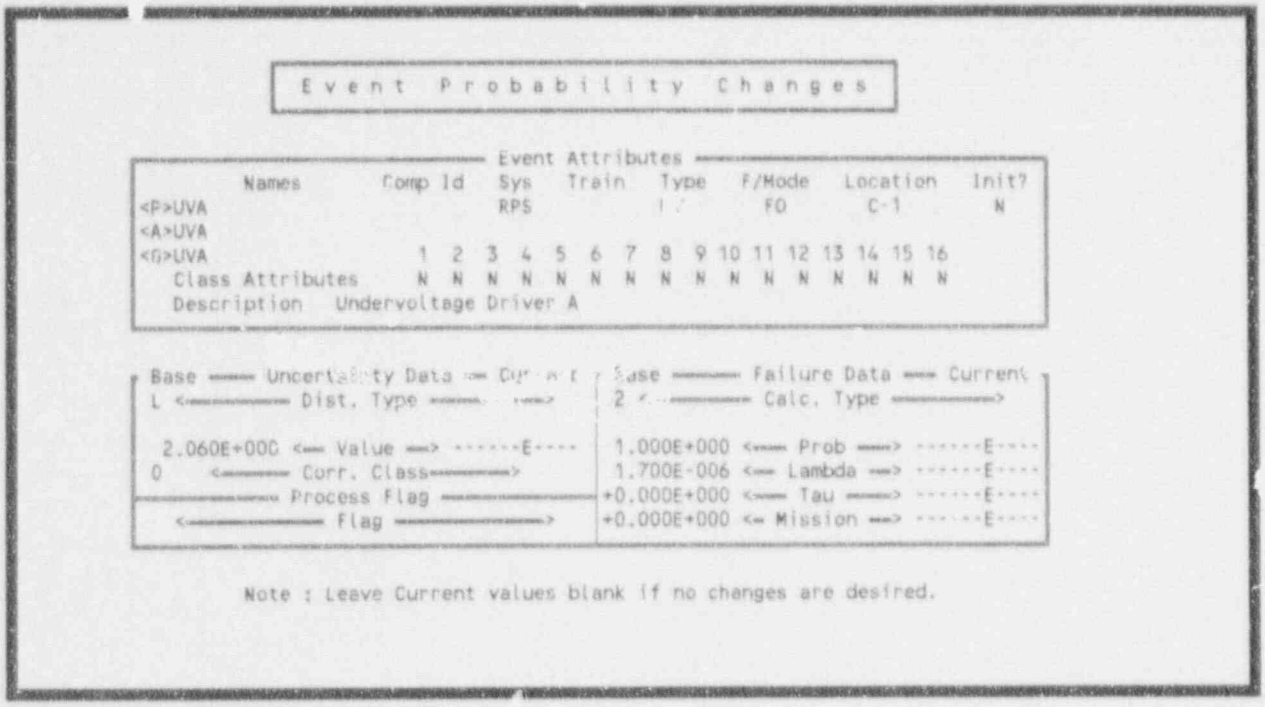


Figure 3-18. Event Probability Changes menu.

6. To obtain help as to what the available calculation types are, press **<F1>**.

   This brings up the help screen shown in Figure 3-19. This screen displays the 13 different ways in which a failure probability change can be defined in SARA 4.0. More information on any given calculation type can be obtained through additional help screens. Calculation Type 9 looks like the one desired to define a change based on a percentage of the base case.

7. Using the **<Down Arrow>** key, highlight calculation type 9 and press **<F1>** to bring up more information about this calculation type.

   The help screen shown in Figure 3-20 appears on the screen. The discussion on this screen confirms that calculation type 9 is the one needed.

8. Press **<Enter>** to remove the last help screen. Press **<9>** **<Enter>** to enter Calculation Type 9 into the Current Failure Data Calculation Type field and remove the help screen from the display.

9. To reduce the probability of basic event UVA to 20% of the base case value, fill in the Prob field under the current case with **0.2** and press **<Enter>**. The Select Event menu returns to the screen and a P appears in front of event UVA, designating that a probability change has been defined for basic event UVA.

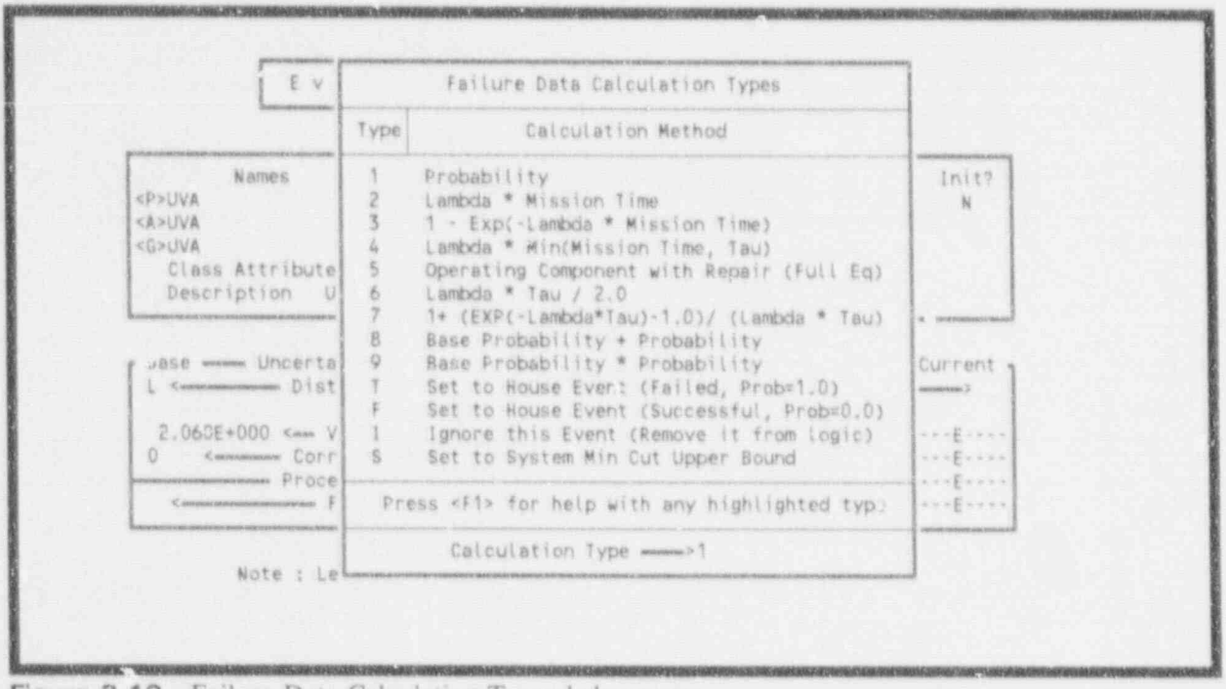


Figure 3-19. Failure Data Calculation Types help screen.

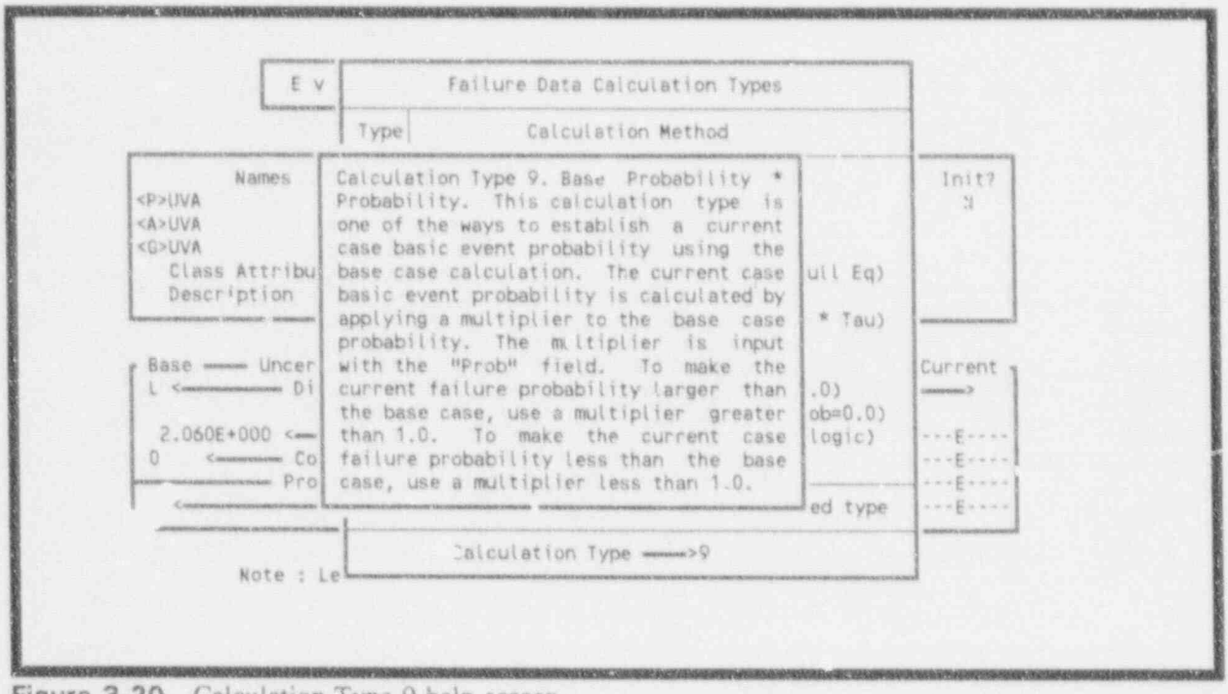


Figure 3-20. Calculation Type 9 help screen.

Note that fields requiring number entries can be input either as a decimal in the format of x.xxx out to as many decimal places as needed, or as scientific notation in the form of x.xE-y. For example, 0.028 can be expressed as 2.8E-2. SARA automatically converts all numbers to this format.

10. Move the highlight down to event UVB and press **<Enter>**. This brings up the Event Probability Change menu for event UVB.

    Note that the cursor is in the Prob field this time. When a form appears on the screen, the cursor will be in the field it was in when the form was last exited.

11. Using the **<Up Arrow>** key, move the cursor to the Current Calc Type field and press **<9>**. A 9 will appear in the field and the cursor will move down to the Current Prob field. Press **<0 2><Enter>**. This defined the probability change for UVB and returned you to the Select Event menu again.

12. Select basic event UVCCF and repeat the above steps to define a current case probability equal to 20% of the base case. When you return to the Select Event menu there should be a P in front of events UVA, UVB, and UVCCF.

13. Press **<Esc>** to get back to the Change Sets menu. This defines a set of changes to reflect installation of an improved undervoltage driver card in the Reactor Protection System.

    Press **<Esc>** two more times to get back to the SARA 4.0 main menu. If you are not going to continue on to the next portion of this lesson, press **<Esc>** once more to exit SARA. If you are continuing with the rest of the lesson, remain at the SARA 4.0 main menu.

Lesson 6 will use this change set to conduct a sensitivity analysis. But before that, this lesson will show you how to define a change set for an entire class of events with only a single probability entry.

3.3.2.2 Creating Class Change Definitions. In this portion of the lesson, we will define a class change for all events associated with the installation of the improved undervoltage driver card. The resulting change set will be identical to the one just created, but much easier to create. To create this new change set:

1. From the SARA 4.0 main menu, select the SYstems Analysis option. This will bring up the System Analysis menu.

2. Select Modify Event Data to bring up the Change Sets menu.

3. Select the Add option by pressing **<A><Enter>**. The Add Change Set form will appear on the screen. In the name field type in the name, "UV-DRIVER-CARD-2" and in the description field type in "Alternate change set for UV driver card installation." When this is completed, press **<Enter>** to add the change set to the database. There should be two change sets listed on the Change Sets menu as shown in Figure 3-21.

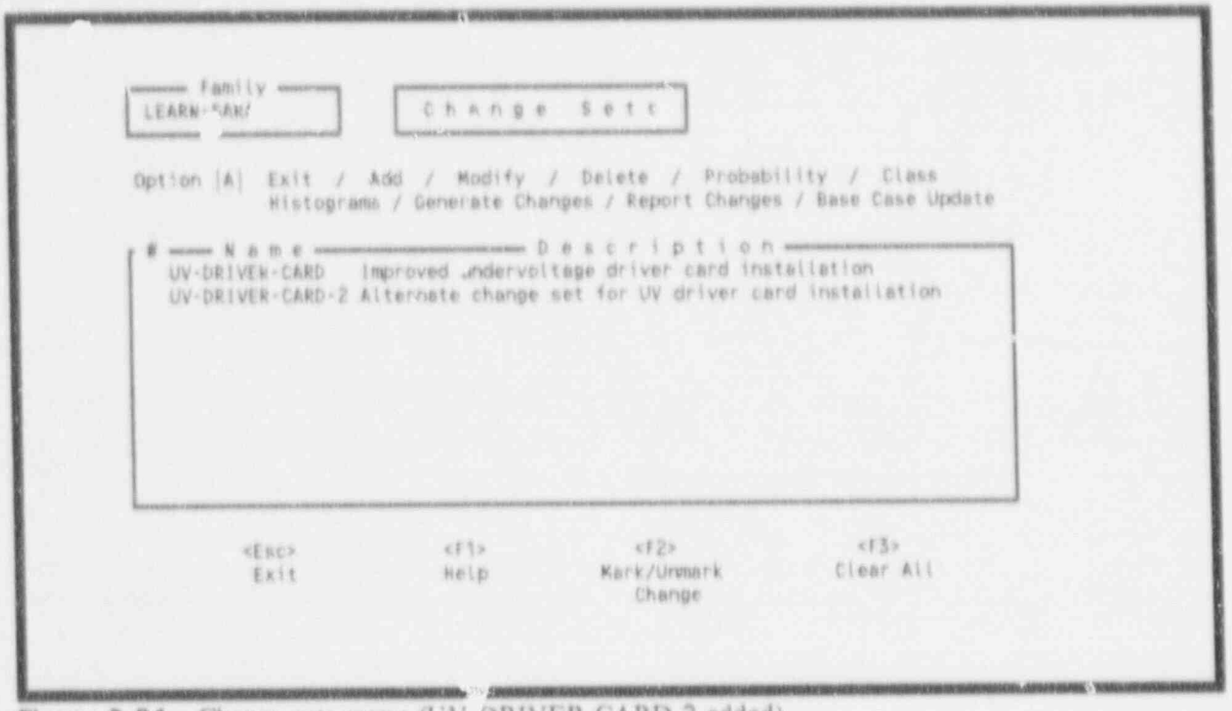


Figure 3-21. Change sets menu (UV-DRIVER-CARD-2 added).

At this time we will define a change to be applied to a class of basic events. In this case, the class of events are all those associated with undervoltage driver cards. The change will be to reduce the failure probability to 20% of the original value. The class option on the Change Sets menu allows the user to define a search criterion and a set of changes. The entire list of basic events in the database will be searched. All basic events matching the search criterion will be tagged for application of the defined change.

4. Select the Class option on the Change Sets menu by pressing **<C>**, moving the highlight down to the UV-DRIVER-CARD-2 change set, and pressing **<Enter>**. This tells the software that a class change is to be defined for the change set UV-DRIVER-CARD-2 and brings up the Class Change Form shown in Figure 3-22.

   This form is divided into four sections. The Event Attributes section at the top displays the various attribute fields for the basic events in the database. These are the fields that are used to establish a search criterion. See the *SARA 4.0 Volume 1 - Reference Manual* for detailed information on each of the various attribute fields. The Uncertainty Data section provides fields to define changes to the uncertainty parameters for the specified class of basic events. The Failure Data section provides fields to define changes to the failure probability calculations for the specified class of basic events. The Process Flag area is a one character field that specifies if certain processes should take special note of the selected event. This field is not used in the tutorial. For more information on the Process Flag field, see *the SARA 4.0 Volume 1 - Reference Manual*.

   For this example problem, we wish to search for all basic events that are failures of the

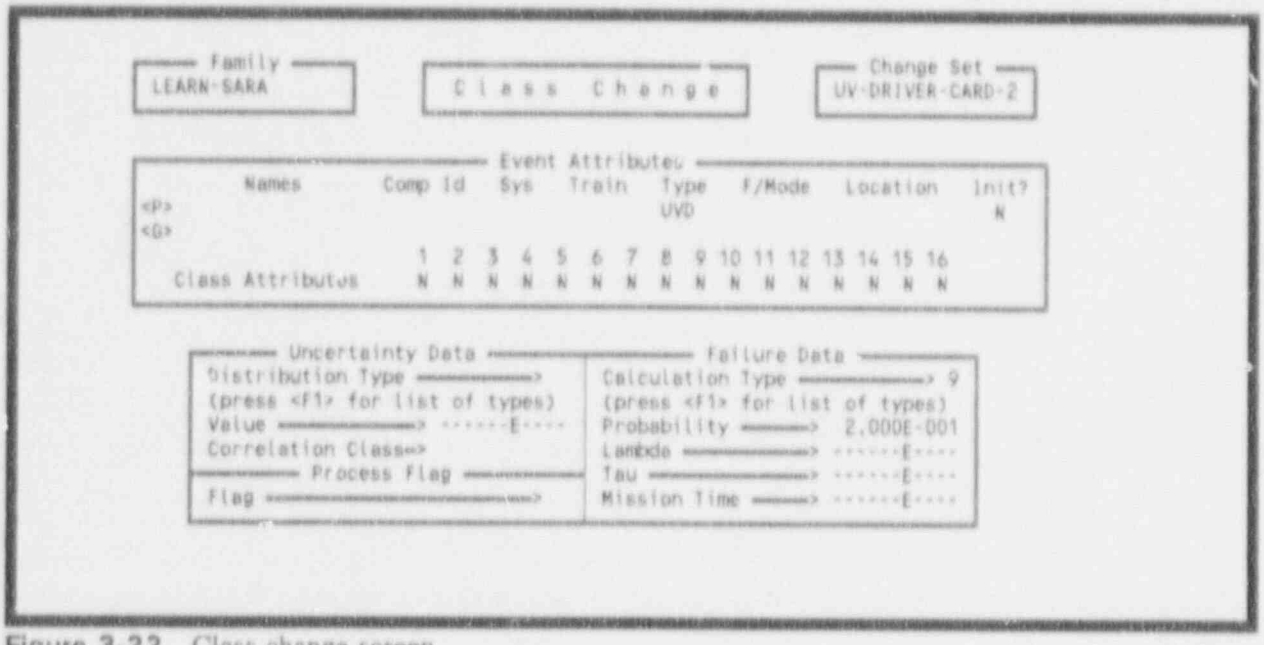


Figure 3-22. Class change screen.

undervoltage driver cards. These events have the designation UVD (for undervoltage driver card) in the Type field in the Event Attributes section. To have the database searched for these events:

5. Move the cursor to the Type field by using the **<Tab>** and **<Arrow>** keys. Type **UVD** in this field. This will cause the changes defined in the Uncertainty and Failure Data sections to be applied to all basic events with the UVD type designation.

6. Move the cursor to the Failure Data Calculation Type field and press **<9>**. This tells the database that the change to be applied is a percentage change to the base case values. (See the *SARA 4.0, Volume 1 - Reference Manual* for more information on calculation types or press **<F1>** for help.)

7. Move the cursor to the Prob field and enter **<2E-1>** or **<0.2>** in this field. This defines the desired changes to the failure probability data. Press **<Enter>** to send the change to the database and return you to the Change Set menu. The message, "Class change added" will appear at the bottom of the screen.

This action has caused the database to be searched for all basic events having the UVD designator in the Type field and tagging them for the defined change. In this way, many like events (in this case only three) can have changes defined with only a single entry. To see which events have been tagged for the class change, select option P on the Change Sets menu, highlight UV-DRIVER-CARD-2, and press **<Enter>**. The letter C will appear in front of the basic events that were found to meet the search criterion. Press **<Esc>** to return to the Change Sets menu.

8. Press **<Esc>** **<Esc>** to get back to the SARA 4.0 main menu. This completes Lesson 3. If you are not going on to the next lesson at this time, you may now exit SARA. If you want to continue, please proceed on to Lesson 4.

3.4 Lesson 4. Creating Change Sets Using the Graphics Interface

In Lesson 3, we created two equivalent change sets by working with lists of basic events in the PRA models. In this lesson, we will learn how to create a third equivalent change set. However, we will use graphics to lead us to the proper basic events to include in the change set.

SARA has the ability to relate elements (basic events) of the PRA models to system drawings. This allows an analyst that is familiar with the facility to pick components from drawings to create a change set without knowing the specific nomenclature used in the PRA. This method always creates a change set called "P&ID."

As in previous lessons, this lesson begins with the analyst at the SARA 4.0 Main Menu with the LEARN-SARA family showing as the current family. From the Main Menu:

1. Highlight the Graphics Analysis option and press **<Enter>**. This brings up the Graphical Analysis menu shown in Figure 3-23.

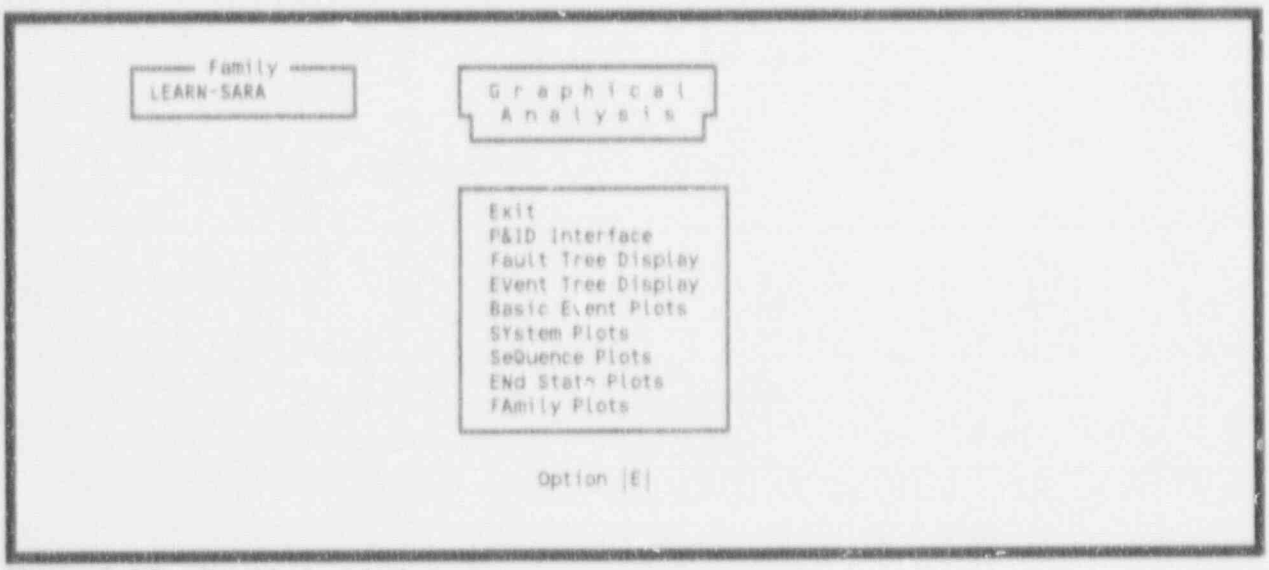


Figure 3-23. Graphical analysis menu.

2. On the Graphical Analysis menu, select the P&ID Interface option. This brings up the Display a Graphic File menu shown in Figure 3-24. This menu lists all the piping and instrumentation drawings (P&IDs) in the data base for the facility analyzed in the PRA. In this example, there is only one P&ID available, RPS.

3. Ensure that the Display option (<D>) is selected in the option field and that the highlight is on the RPS system. If this is not the case, press **<D>** and move the highlight to the RPS drawing. Press **<Enter>** to select the RPS drawing.

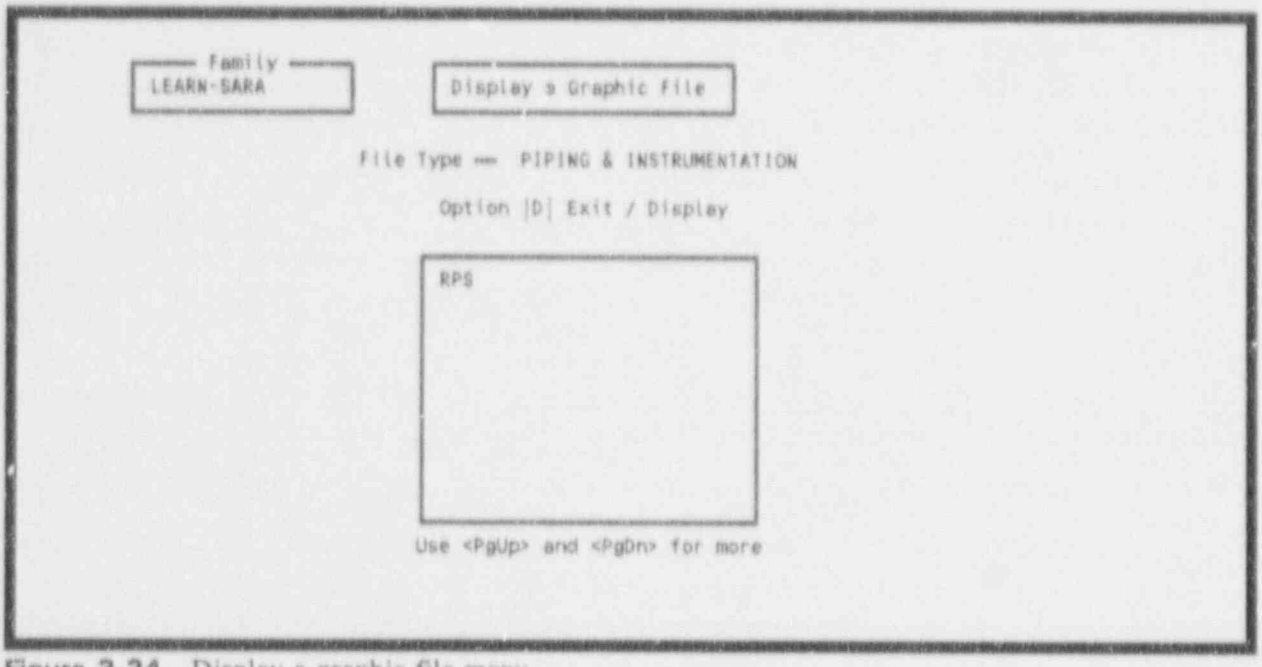


Figure 3-24. Display a graphic file menu.

This will cause the Block Diagram of the Reactor Protection System for Normal Operation to be displayed. This diagram is shown in Figure 3-25. A small blue menu appears on the left side of the screen and an arrow cursor controlled by the mouse or keyboard is available. See the *SARA Version 4.0, Volume 1 - Reference Manual* for operation of the mouse.

This drawing is a simplified block schematic of the Reactor Protection System. It shows the relationship of the major system components one to another. To better see the portion of the drawing concerning the undervoltage driver cards, we can zoom in on the equipment in the logic cabinets. (Note: this is not required to create the change set.)

4. To zoom in, select the View option on the pop-up menu by moving the arrow cursor with the mouse or the arrow keys on the keyboard. If you are using the mouse to control cursor movement, move the arrow over the word VIEW. When a box appears around the word VIEW, press the left mouse button. This will bring up a submenu with a number of options that control the scale and view of the drawing. From the submenu, select the Zin (Zoom-in) option by placing the arrow cursor over the word "Zin" and pressing the left button on the mouse. The computer will next want to know what portion of the drawing you want to zoom in on. This is indicated by drawing a box around the components you want to see up close. In this example we want to see the components in the Logic Cabinet. Move the cursor to the upper left-hand corner of the Logic Cabinet section and press the left button on the mouse. This anchors one corner of a box. Moving the mouse will cause the box to expand and contract about the fixed corner. Move the mouse until the box encompasses all the blocks in the Logic Cabinet and press the left button on the mouse. The drawing will zoom in on the area within the box. Note the boxes on the right side of the screen labeled UVA and UVB. These are

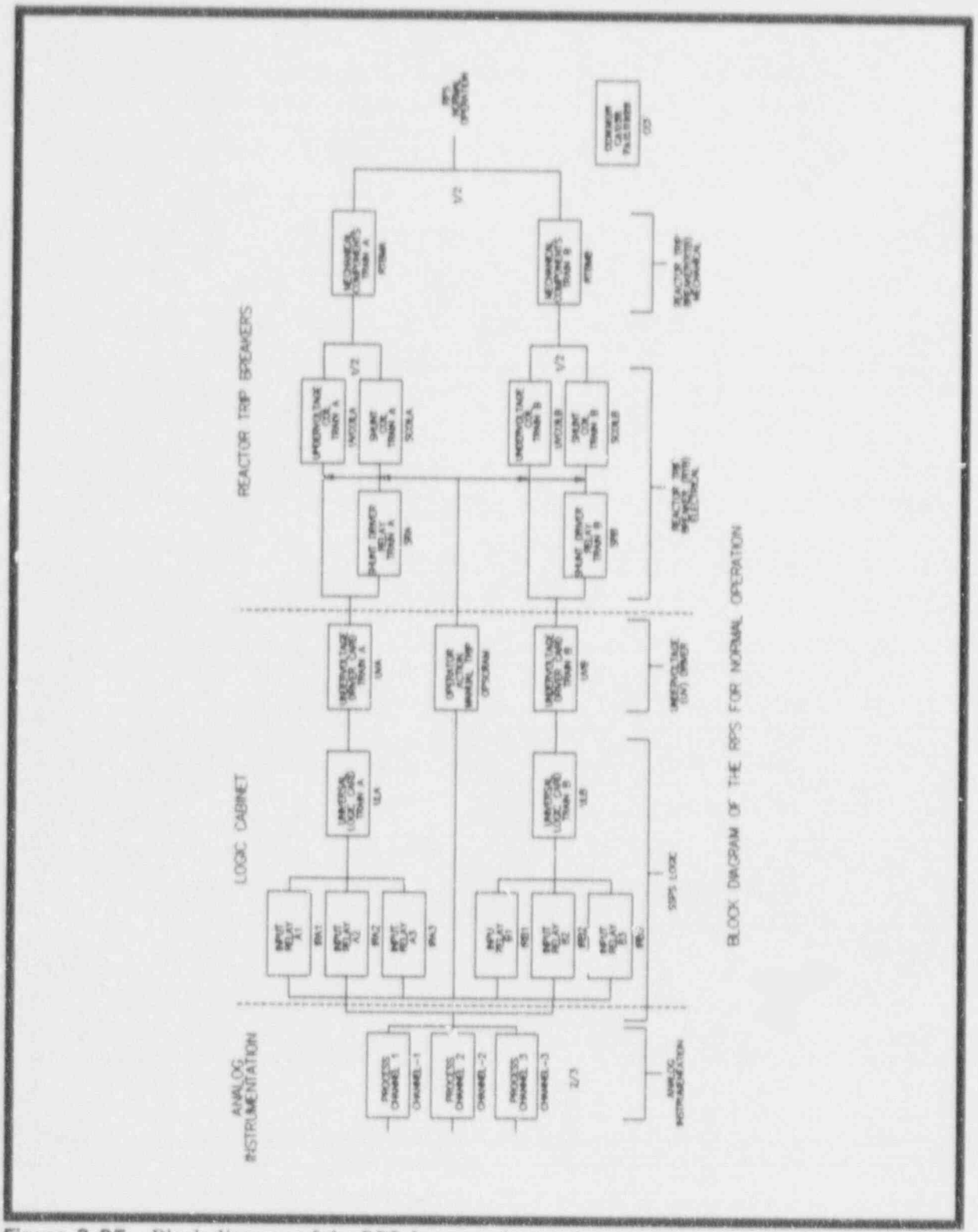


Figure 3-25. Block diagram of the RPS for normal operation.

the blocks containing the undervoltage driver cards.

5. Place the cursor on the block labeled UVA and press the left button on the mouse. The basic events associated with block UVA will appear on a menu as shown in Figure 3-26. In this example, block UVA represents only basic event UVA. Now that we have located one of the basic events that we want to change for the sensitivity analysis, we can make the desired change.

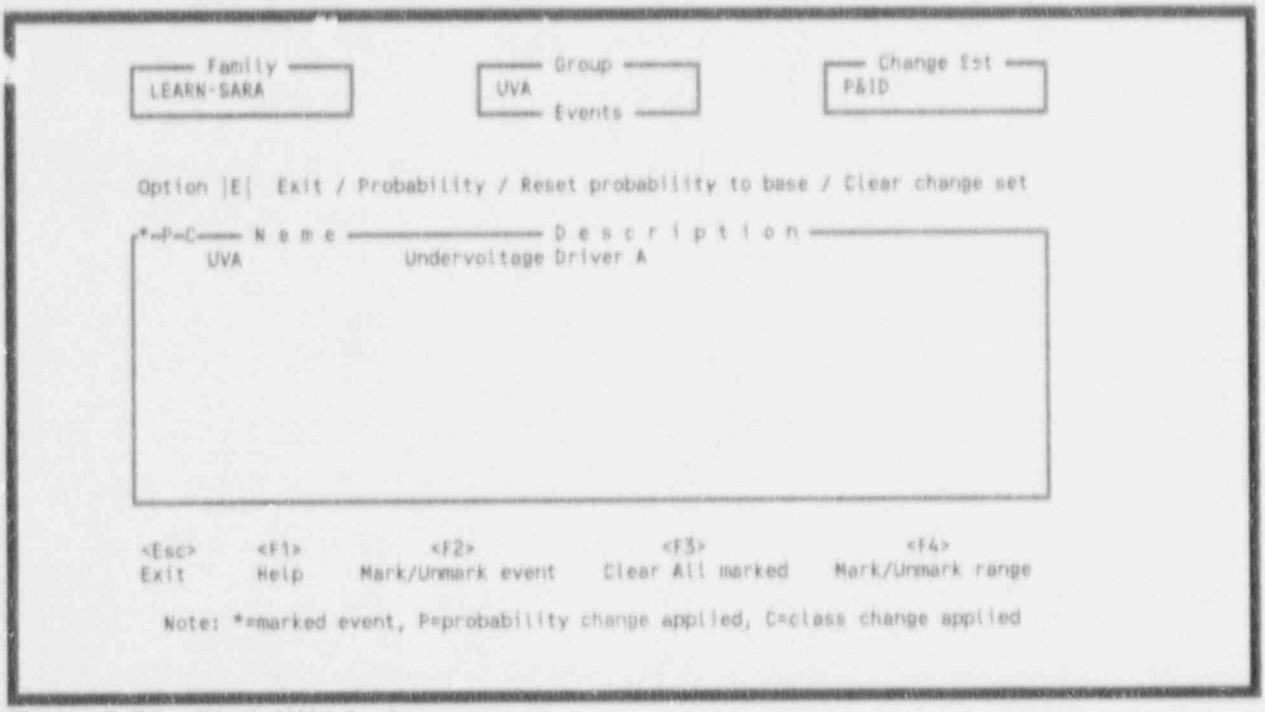


Figure 3-26. Block UVA basic events.

6. Press **<P>** to select the Probability option, highlight basic event UVA and press **<Enter>**. This brings up the Event Probability Changes form.

7. Use the <Tab> key to move the highlight to the Current Calc Type field in the Failure Data Section of the form. We want to change the failure probability to 20% of its original value. This is a calculation type 9 action (NOTE: use the F1 function key to bring up a help screen if you need help remembering the calculation types), so enter a 9 in this field.

8. Using the **<Down Arrow>** key, move the highlight to the Current Prob field and enter **0.2 <Enter>**. This defines the change for basic event UVA and returns you to the list of basic events. Notice that a P is in front of event UVA signifying that a probability change has been defined for that basic event.

9. Exit this form by pressing **<E><Enter>** or **<Esc>**. This returns you to the RPS P&ID.

10. Using the mouse, move the cursor to the UVB block and press the left button on the mouse. This gives you the list of basic events pertaining to block UVB as shown in Figure 3-27. The message at the bottom,

"Note - Changes already exist in change set. Any new ones will be added,"

is displayed to indicate that other events have already been included in the change set being created through the graphics interface.

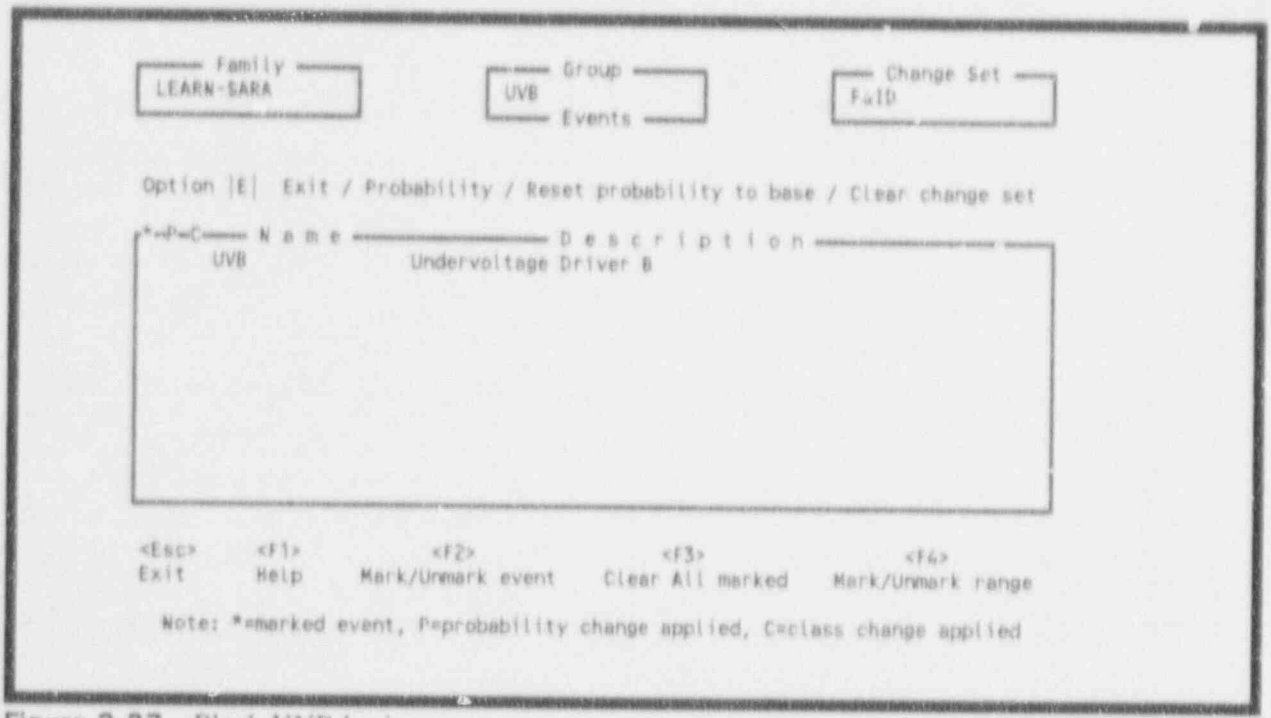


Figure 3-27. Block UVB basic events.

11. Repeat steps 6 through 9 for event UVB. At the completion of this step, changes will have been defined for basic events UVA and UVB.

12. On the RPS P&ID move the cursor to the block in the lower right corner of the drawing labeled CCF. Press the left button on the mouse to show the list of basic events associated with common cause failures of the RPS (Figure 3-28).

13. In this list is the basic event representing the common cause failure of all undervoltage driver cards, UVCCF. This event must also be included in the change set being created. Press **<P>**, highlight UVCCF, and press **<Enter>**.

14. Repeat steps 7 through 9 for event UVCCF. This makes the desired change to basic event UVCCF and returns you to the RPS P&ID.

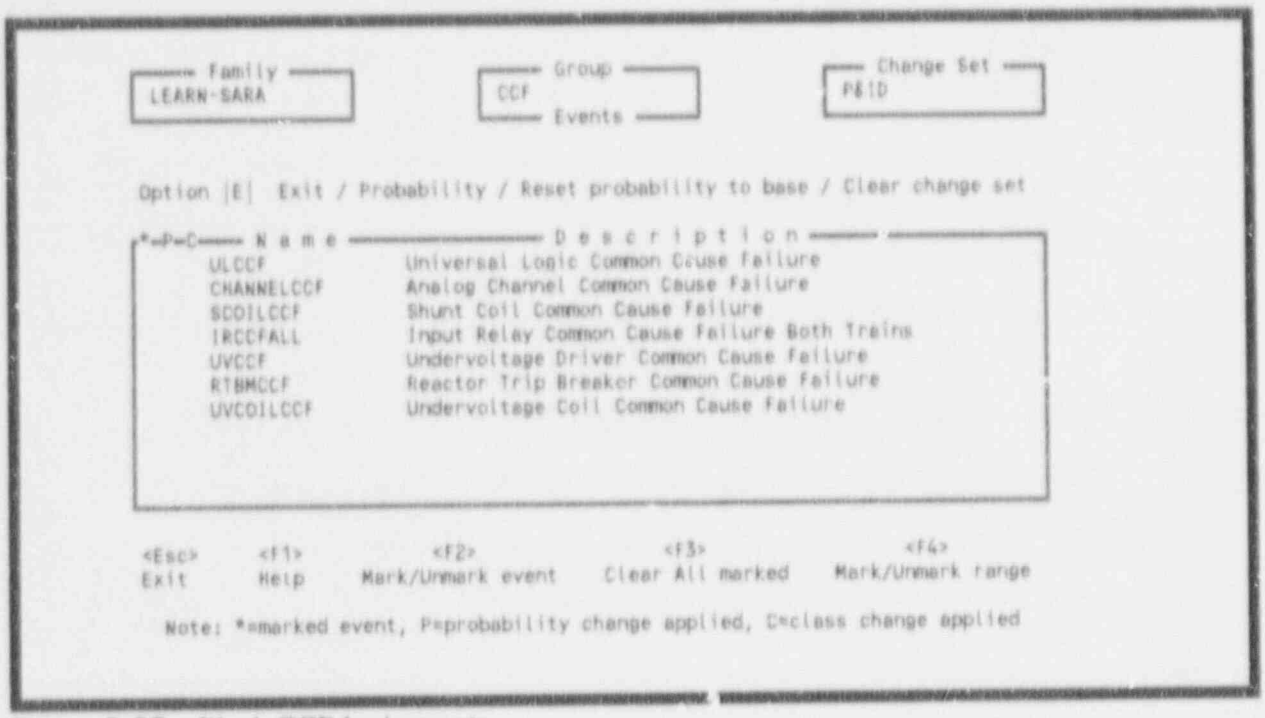


Figure 3-28. Block CCF basic events.

Since this identifies all the basic events that need to be changed for this analysis, we can exit the graphics interface.

15. On the RPS P&ID, use the mouse to move the arrow cursor to the Exit option. When the Exit option is highlighted press the left button on the mouse. This will exit the P&ID and return you to the list of available P&IDs.

16. Press **<Esc><Esc>** to return to the main menu.

You have just created a change set called P&ID that contains changes to basic events UVA, UVB, and UVCCF. If you desire to verify this, continue on with this lesson. Otherwise, proceed to the next lesson or exit the SARA program by pressing **<Esc>**.

17. To see the change set just created, select the SYstems Analysis option from the main menu.

18. Select the Modify Event Data option on the Systems Analysis menu. This brings up the Change Sets menu shown in Figure 3-29. Notice that the three change sets created in these lessons are listed in alphabetical order.

19. To see what the P&ID change set contains, press **<P>**, highlight P&ID, and press **<Enter>**. This brings up the list of all basic events in the family.

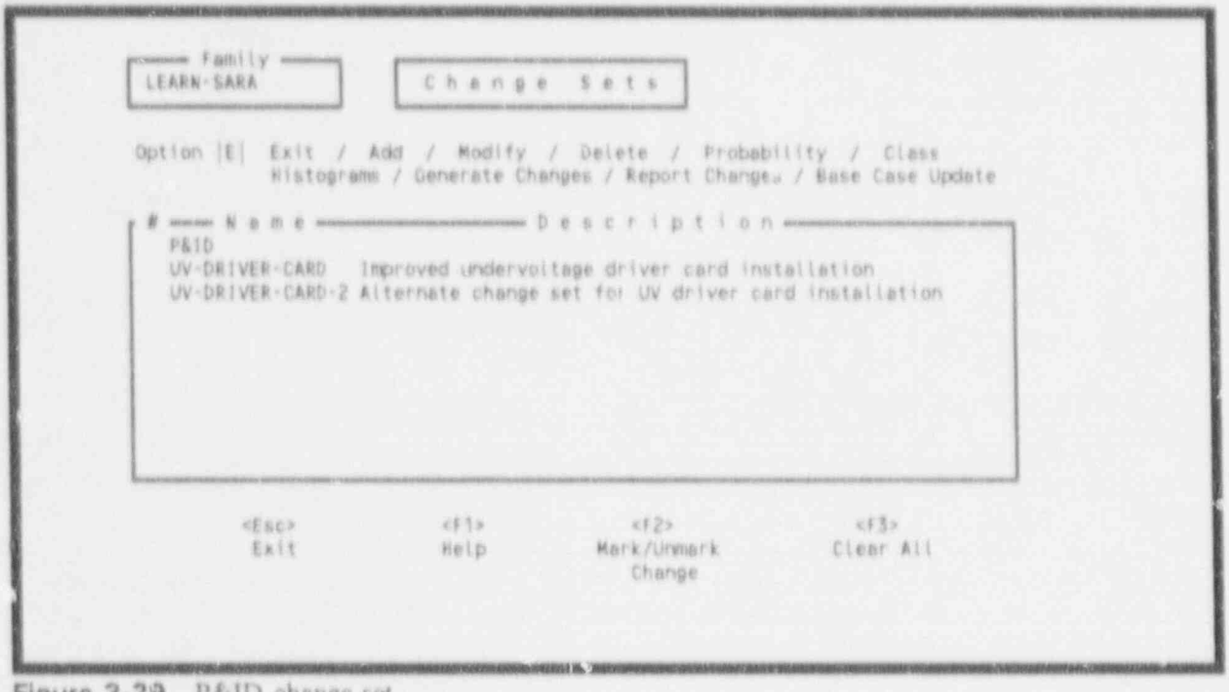


Figure 3-29. P&ID change set.

20. Use the **<PgDn>** key to look through the basic events a screen at a time. Note that only the three events UVA, UVB, and UVCCF have changes defined as indicated by the P to the left of the event name.

21. Highlight basic event UVA and press **<Enter>**. Note that the change definition is correct (Calculation Type 9 and probability of 0.2 entered).

22. Press **<Esc>** four times to return to the main menu.

This completes Lesson 4. You may now proceed to Lesson 5 or you may quit by pressing **<Esc>** to exit SARA.

3.5 Lesson 5. Applying Changes to the Models

This lesson shows you how to perform the following functions:

A. Apply changes made in Lessons 3 and 4 to event data.

B. Apply changes made in Lessons 3 and 4 to system data.

C. Generate reports of the results. You will display the reports on the screen and write them to an output file.

3.5.1 Modifying Event Data

Change sets can be modified through the Modify Event Data menu in the Systems Analysis module.

This lesson begins with the analyst at the SARA 4.0 Main Menu with the LEARN-SARA family showing as the current family. From the Main Menu:

1. Enter the SYstems Analysis module by highlighting that option and pressing **<Enter>**.

2. Select the Modify Event Data option (**<M> <Enter>**). This brings up the Change Sets menu. Note that there are three Change Sets listed: P&ID, UV-DRIVER-CARD, and UV-DRIVER-CARD-2 (see Figure 3-30).

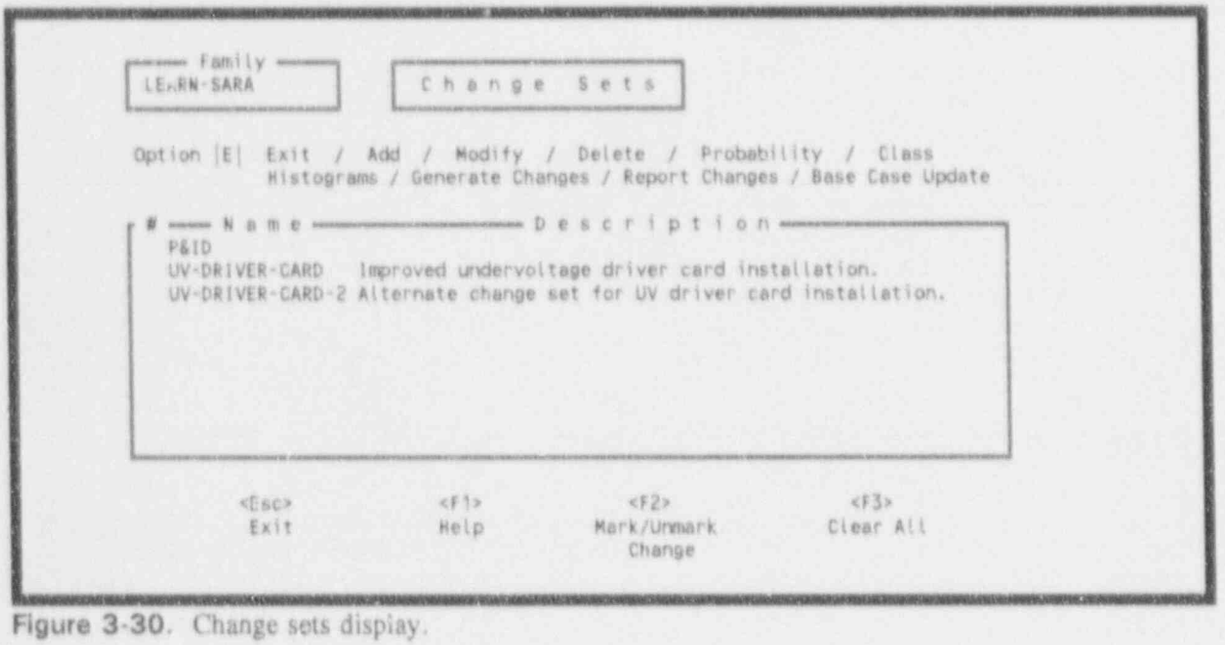


Figure 3-30. Change sets display.

3. Mark the change set to be modified. Press the **<down arrow>** key twice to highlight UV-DRIVER-CARD and press **<F2>**. A '1' appears in the first column under the # symbol. This indicates that this change set is marked for further processing.

4. Type a **G <Enter>**. A window will appear at the bottom of the screen (See Figure 3-31). On this screen, you must enter the mission time and indicate whether or not you wish to propagate event failures. The default values of a 24-hour mission time and a Y to propagate event failure are correct for this lesson. Press **<Enter>**. Several messages will be displayed at the bottom of the screen. When complete, the message "New event data has been generated with changes" will be displayed at the bottom of the screen. Press **<Esc>** to return to the Systems Analysis menu.

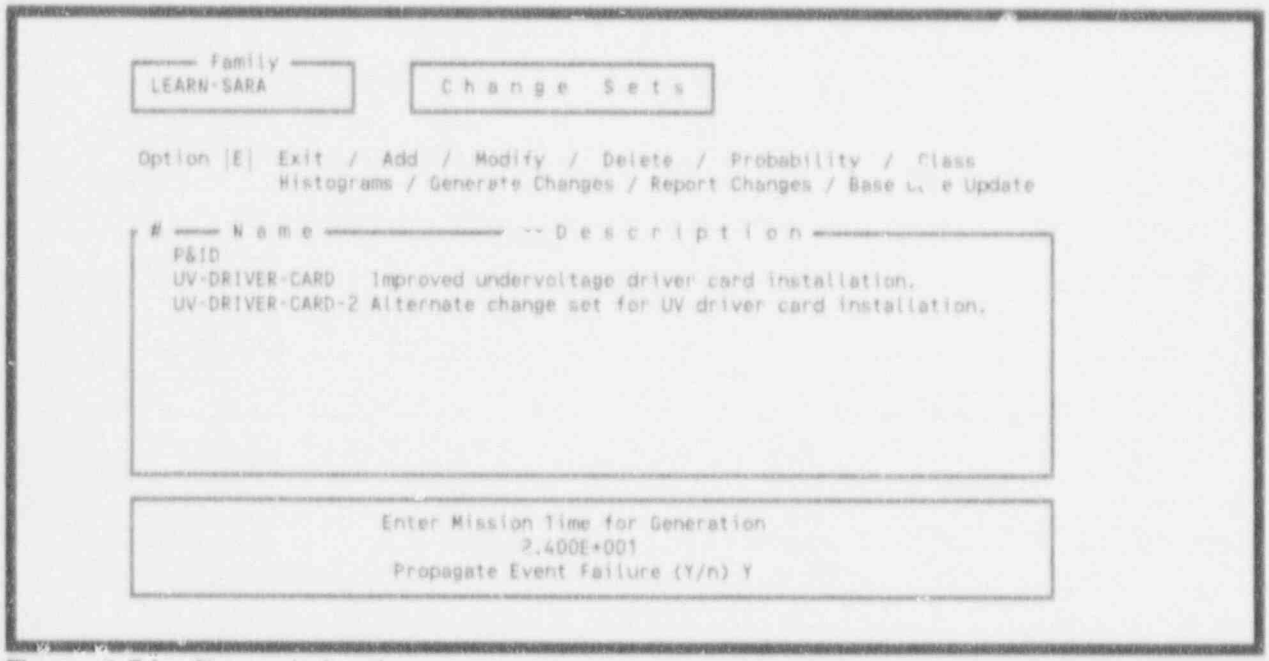


Figure 3-31. Enter mission time.

3.5.2 Apply Changes to the System Data

1. Select the Analyze Systems option by highlighting that option and pressing **<Enter>**. The Analyze Systems screen (see Figure 3-32) will appear.

2. From the Analyze Systems screen, select the quantification option by pressing **<Q>**, highlight the **RPS** system using the **<down arrow>** key, and pressing **<Enter>**. When complete, the quantification screen shown in Figure 3-33 will be displayed. Press **<Esc>** three times to return to the SARA 4.0 Main Menu.

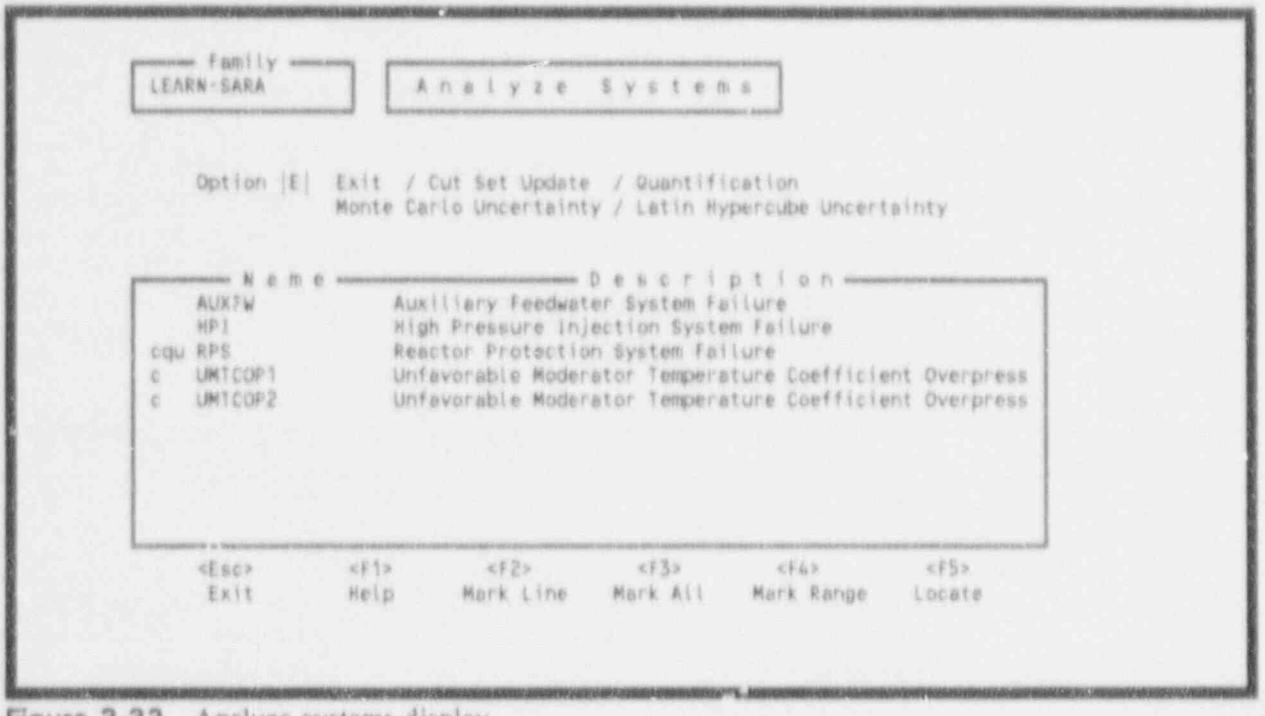


Figure 3-32. Analyze systems display.

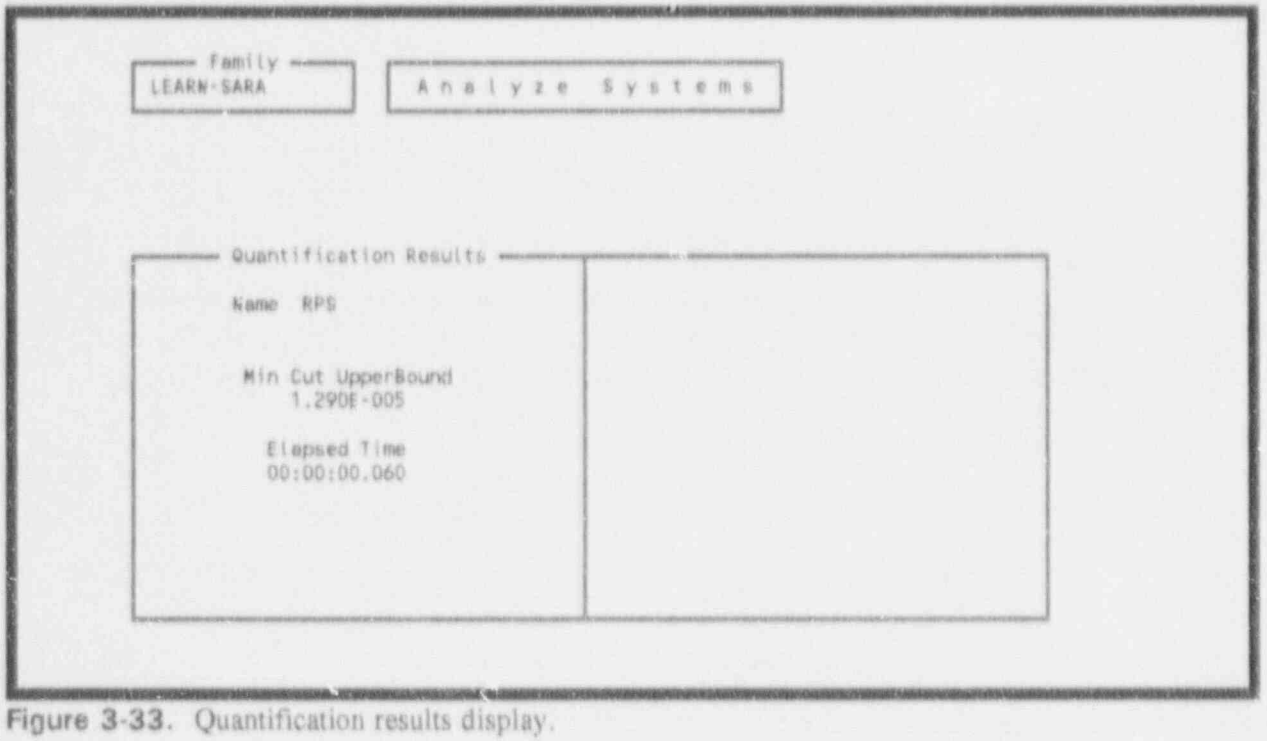


Figure 3-33. Quantification results display.

3.5.3 Apply Changes to Sequences

1. From the M... Menu, select the EVent Tree Analysis menu by typing **<V> <Enter>**. This brings up ... Tree Analysis menu shown in Figure 3-34.

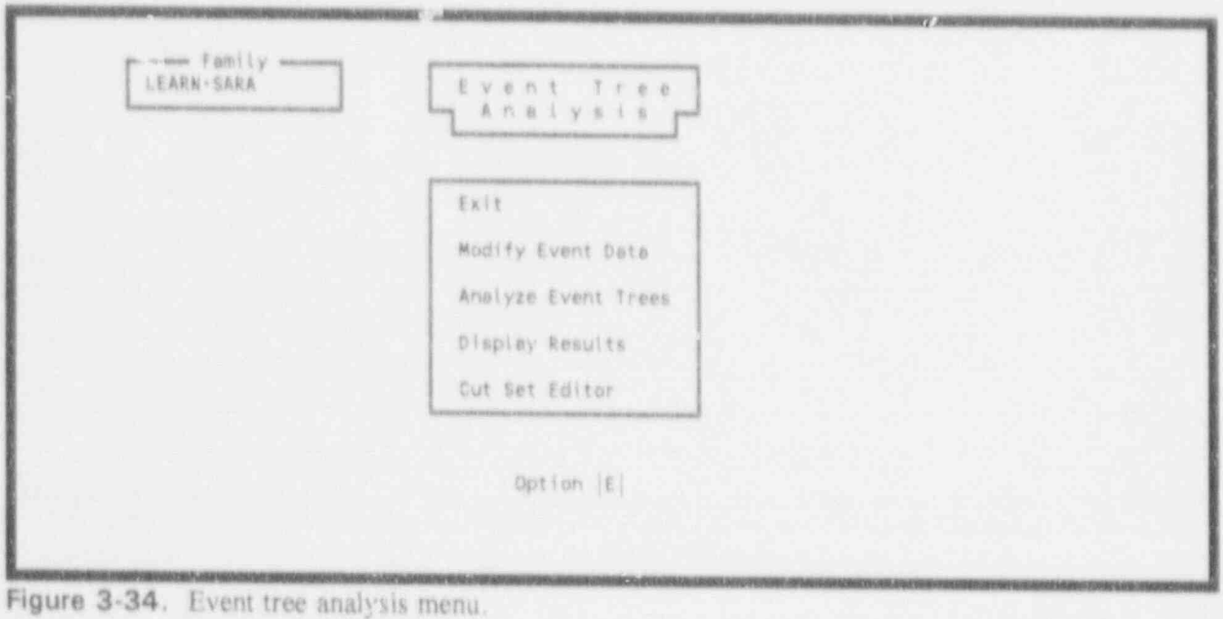


Figure 3-34. Event tree analysis menu.

2. Select Analyze Event Trees by highlighting that option and pressing **<Enter>**. The Analyze Sequence screen shown in Figure 3-35 will be displayed. Invoke the Quantification option by typing **<Q> <Enter>**. The message "Process all entries? (Y/N)" will appear at the bottom of the screen. Press **<Y>**. The message "Quantification in progress..." will appear at the bottom of the screen. When the quantification process is complete, the cursor will be returned to the option field. Type an **<E>** and press <Enter> to return to the Event Tree Analysis menu.

3. From the Event Tree Analysis screen, select the Display Results option, by typing **<D> <Enter>**. The sequence display shown in Figure 3-36 will appear. Press **<F6>** to view the base case and current frequencies for the sequences (see Figure 3-37).

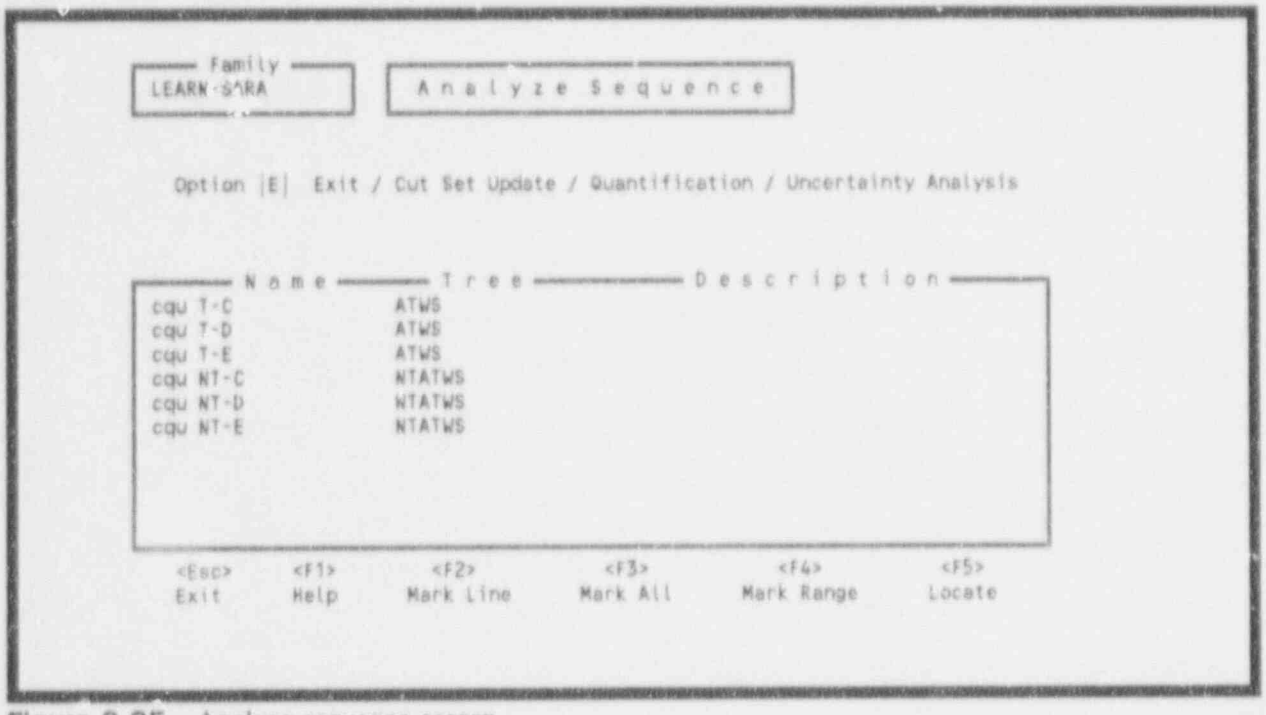


Figure 3-35. Analyze sequence screen.

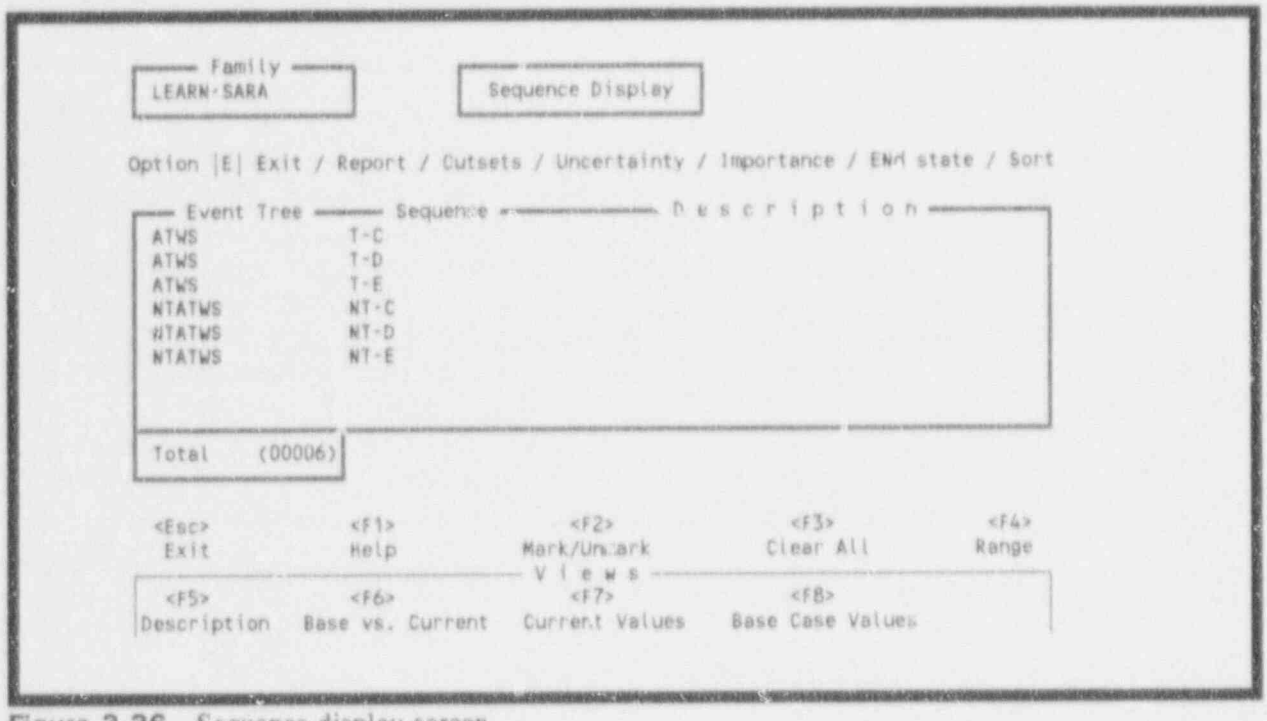


Figure 3-36. Sequence display screen.

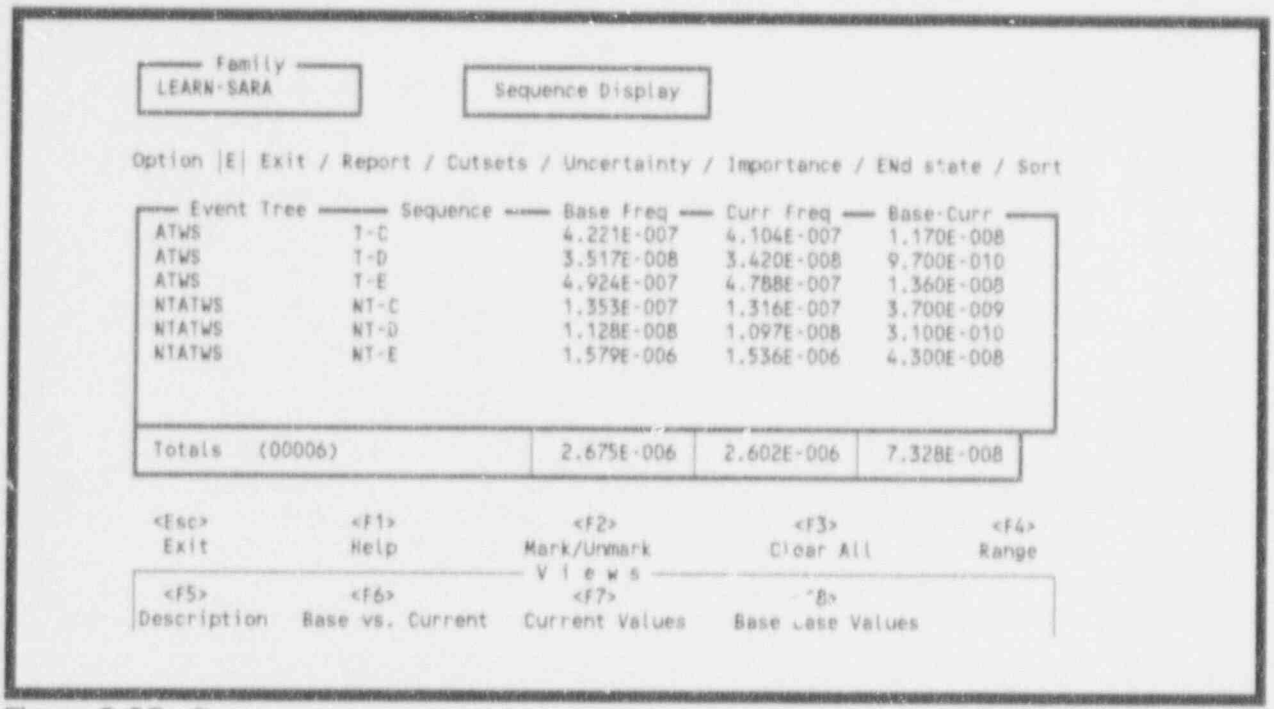


Figure 3-37. Base case versus current frequencies.

3.5.4 Generate Reports

1. Next, invoke the Report option by typing **<R> <Enter>**. The Report Options screen shown in Figure 3-38 will be displayed. From this screen you can send the report to the screen, the printer, or to a file on the disk. For this lesson we will send the report to the screen and to a file. CON (screen) is the default output file, and the report title is correct for our purposes, so press **<Enter>**. The report shows the sequence name, base frequency, current frequency, and the difference between the base and current frequencies. When finished viewing, press **<any key>** to terminate the reporting option and return to the Sequence Display screen.

2. Invoke the Report option again, by typing **<R> <Enter>**. Press **<Tab>** once to position the cursor at the Output File Name prompt. Type **OPTION1.RPT** and press <Enter>. The report will be displayed on the screen, but will also be written to a file called OPTION1.RPT in the PRADATA.B1\LEARN-SA directory (the current directory).

3. Press **<Esc>** three times to return to the SARA 4.0 Main Menu.

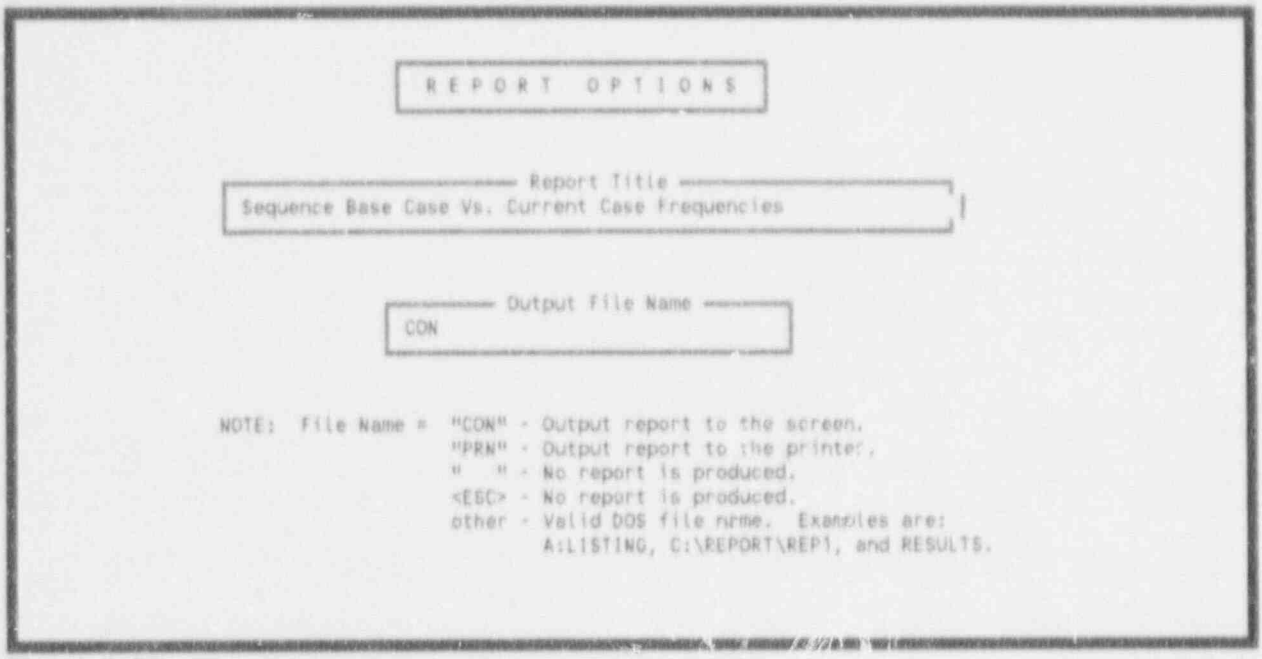


Figure 3-38 The report options screen.

3.6 Lesson 6. Using the Cut Set Editor

This lesson shows you how to use the cut set editor to model minor changes to the logic of a system. You will learn how to perform the following functions:

A. Make logic changes to the cut sets.

B. Perform cut set update for system changes.

C. Perform cut set update for sequence changes.

3.6.1 Make Changes to the Cut Sets

1. From the SARA 4.0 Main Menu, select the SYstems Analysis option. Invoke the SYstems Analysis by highlighting that option and pressing **<Enter>**. The System Analysis menu will appear (see Figure 3-39).

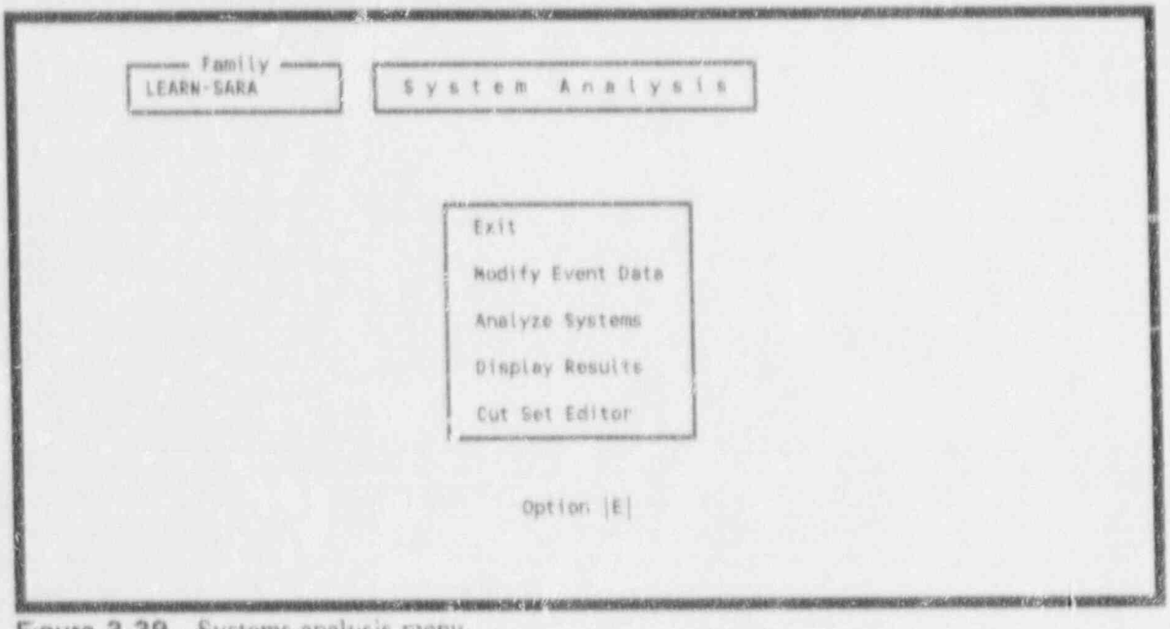


Figure 3-39. Systems analysis menu.

2. Select the Cut Set Editor option (**<C>** **<Enter>**). This brings up the Cutset Editor screen as shown in Figure 3-40. On this menu, you may use the base case or alternate cut sets. Base case cut sets are generally the cut sets that represent the data in its original form. Alternate cut sets represent data that were modified during previous cut set editor sessions. For this lesson, we will use the base case values.

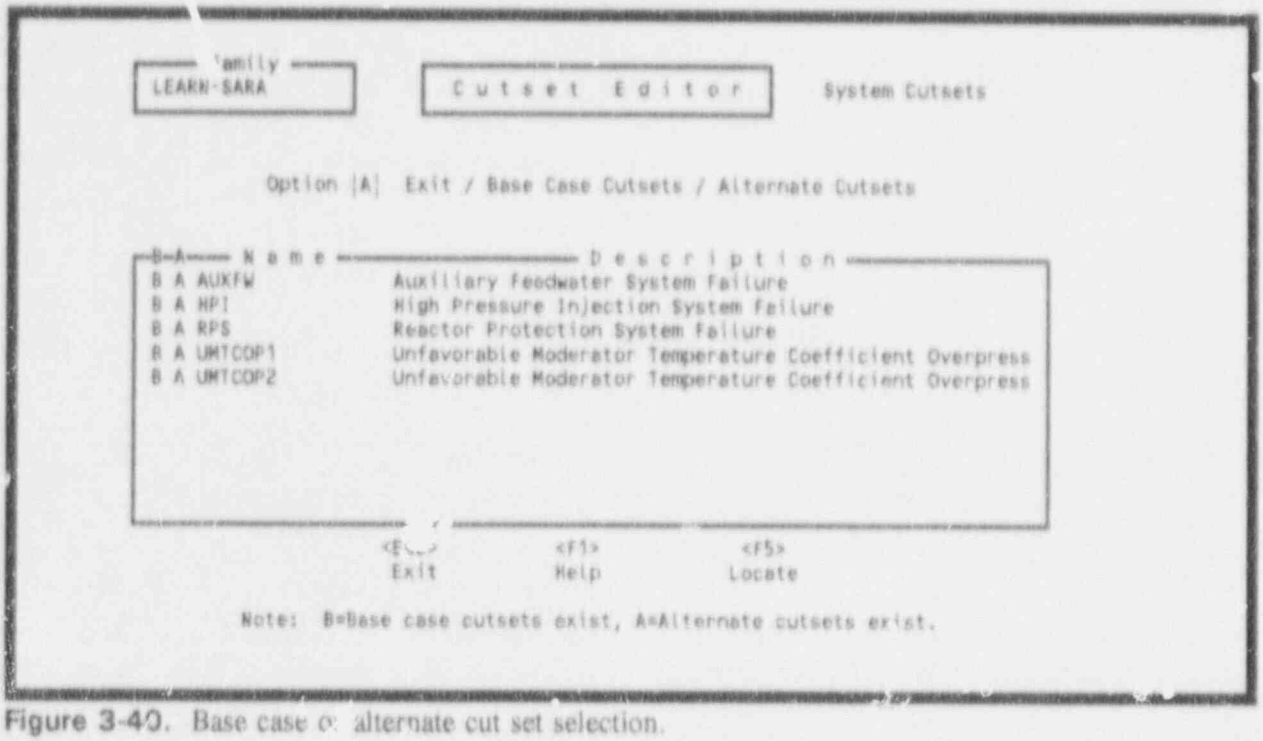


Figure 3-40. Base case or alternate cut set selection.

Type the letter **<B>**, use the **<down arrow>** key to highlight **RPS**, and press **<Enter>**. The message "Loading the Cut Sets" will be displayed at the bottom of the screen and the Cut Set Editor shown in Figure 3-41 will appear.

3. Invoke the Find and Delete Cutset option to remove all cut sets containing the basic events UVA, UVB, or UVCCF.

   Type the letter **<F>** to display the Find and Delete window (see Figure 3-42). This window provides the user with an "AND-ing" capability. If we wanted to delete all cut sets containing the basic events UVA, UVB, and UVCCF, we could type all three events in this window and press <Enter>. However, here we are performing an "OR" operation. We wish to delete cut sets that contain UVA, UVB, or UVCCF. Therefore, we must invoke the Find and Delete command, three separate times.

   A. Type **UVA**, and press **<Enter>**. The message "13 cut set(s) deleted" will be displayed at the bottom of the screen.

   B. Type a **<F> UVB**, and press **<Enter>**. The message "12 cut set(s) deleted" will be displayed at the bottom of the screen.

   C. Type **<F> UVCCF**, and press **<Enter>**. The message "1 cut set(s) deleted" will be displayed at the bottom of the screen.

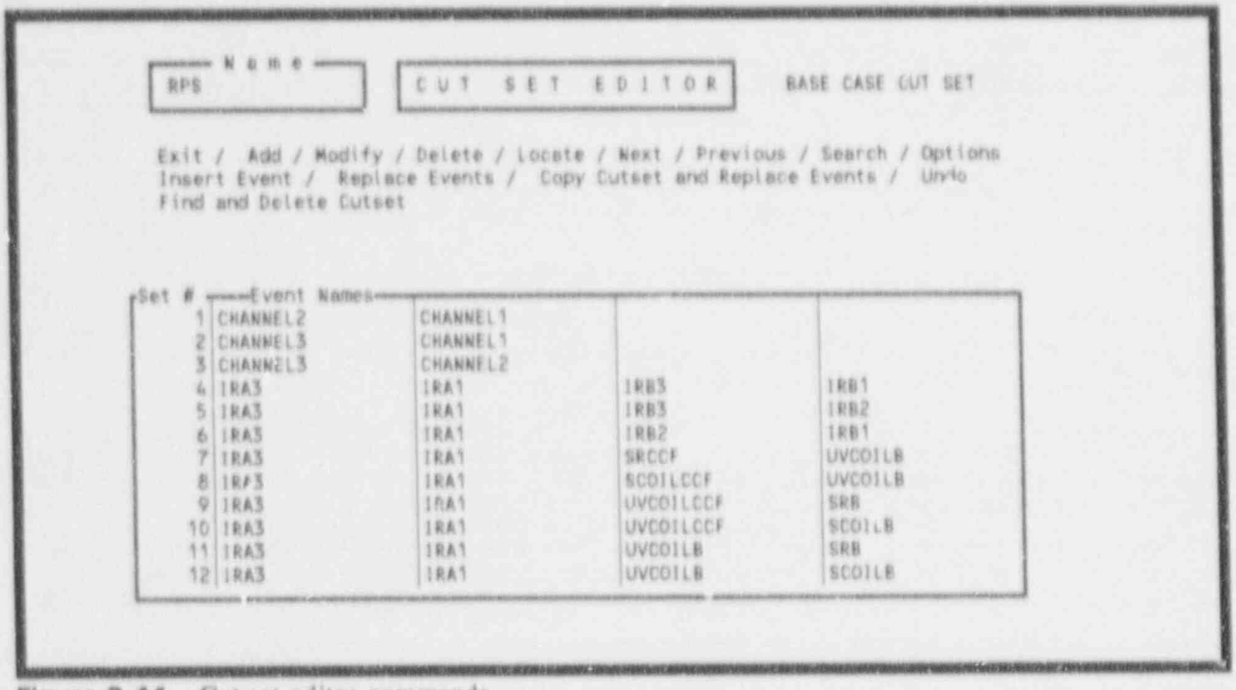


Figure 3-41. Cut set editor commands.

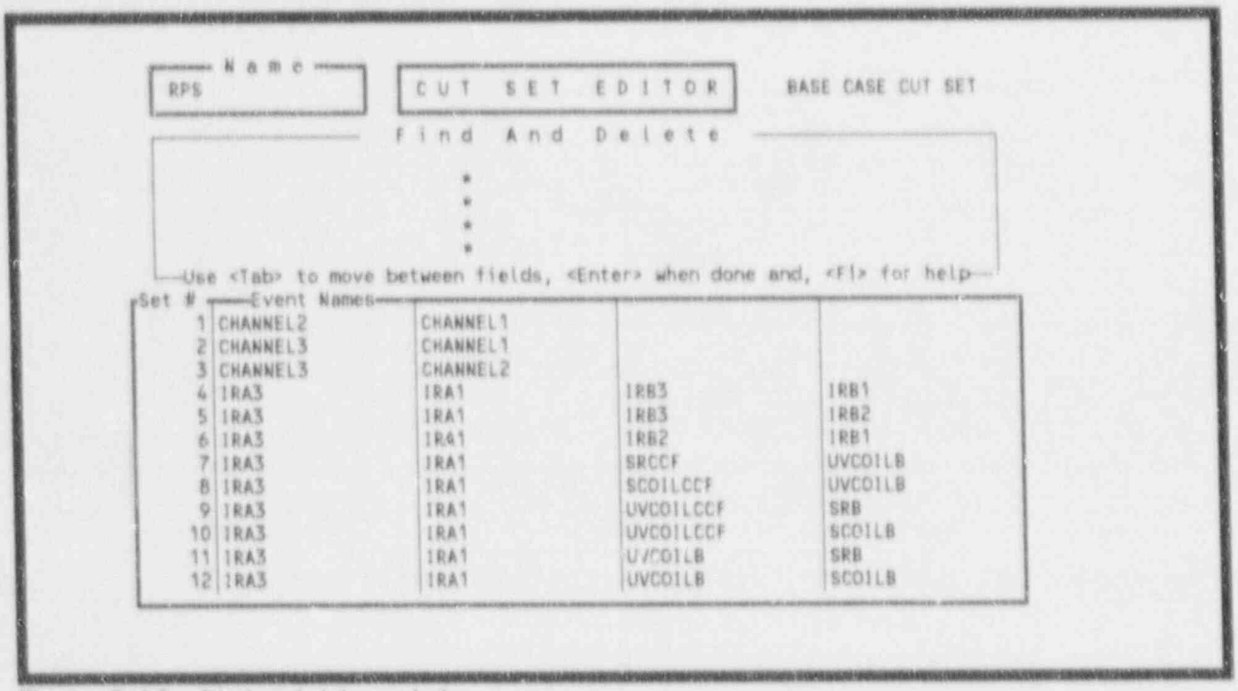


Figure 3-42. Find and delete window.

Press <**Esc**> to exit. A window will be displayed asking if you wish to save the changes made to the cut sets. Enter <**Y**> and press <**Enter**>. The message "Saving Cut Set Data to the Alternate Cut Sets" is displayed at the bottom of the screen. You will be returned to the Cutset Editor screen (Figure 3-40).

4. Now, we will go into the Alternate cut sets to show you that the changes were applied. Type an <**A**>, use the <**down arrow**> key to highlight RPS, and press <**Enter**>. Use the <**PgUp**>, <**PgDn**>, **and** <**arrow keys**> to scroll through the list of cut sets. Note that no cut sets exists that contain UVA, UVB, or UVCCF.

3.6.2 Perform Cut Set Generation for a System

1. Press <**Esc**> twice to return to the System Analysis menu. From this menu, invoke the Analyze Systems module by typing an <**A**> <**Enter**>. The Analyze Systems screen shown in Figure 3-43 will be displayed.

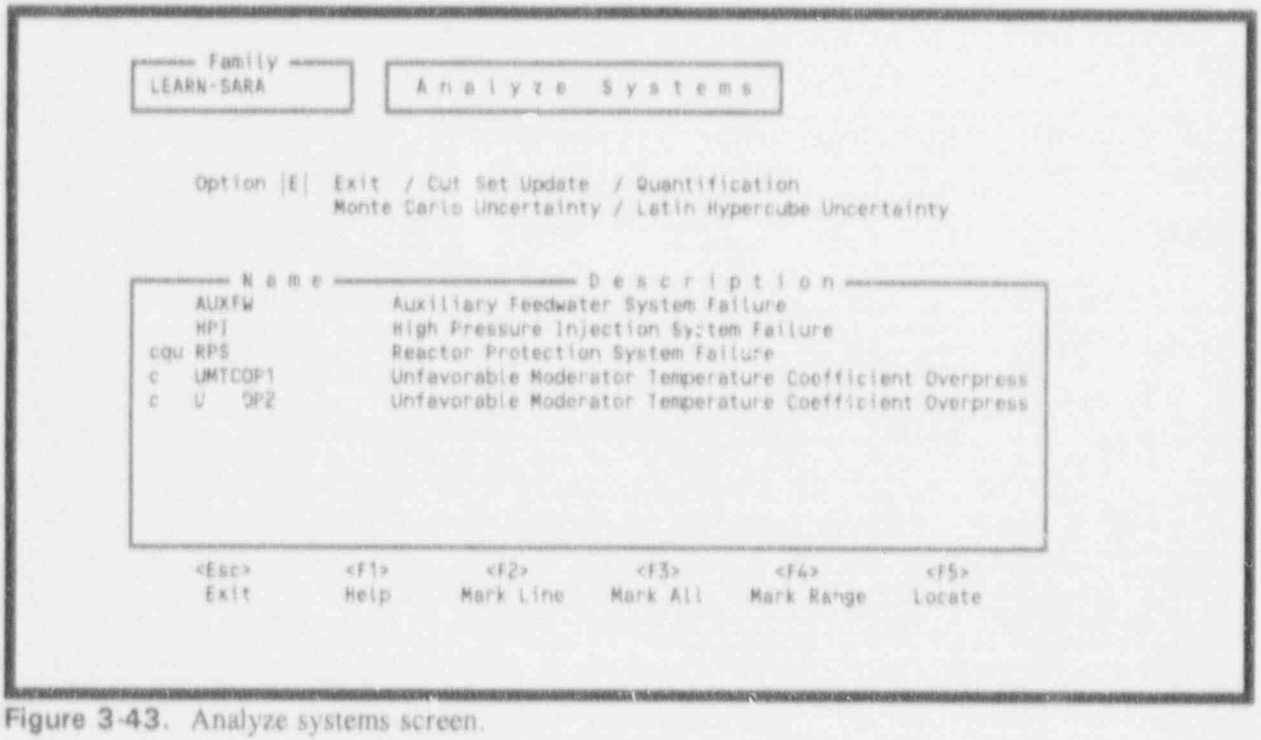


Figure 3-43. Analyze systems screen.

This display shows the list of systems in the data base for which cut set updating, quantification, and uncertainty analysis can be performed. The c, q, and u flags in front of a system name reflect the current status of the system analysis:

c - flags the system(s) as having cut sets that must be recalculated
q - flags the system(s) as having cut sets that must be requantified
u - flags the system as needing uncertainty distributions recalculated.

2. From the Analyze Systems screen we will perform a cut set update to process changes (deletions) made in the previous step. Type a **<C>**, use the **<down arrow>** key to highlight **RPS**, and press **<Enter>**. The Cut Set Generation Cutoff values screen shown in Figure 3-44 will be displayed. This option will update the alternate cut sets for the selected system (RPS) based on cut set generation cutoff values. Enter the following:

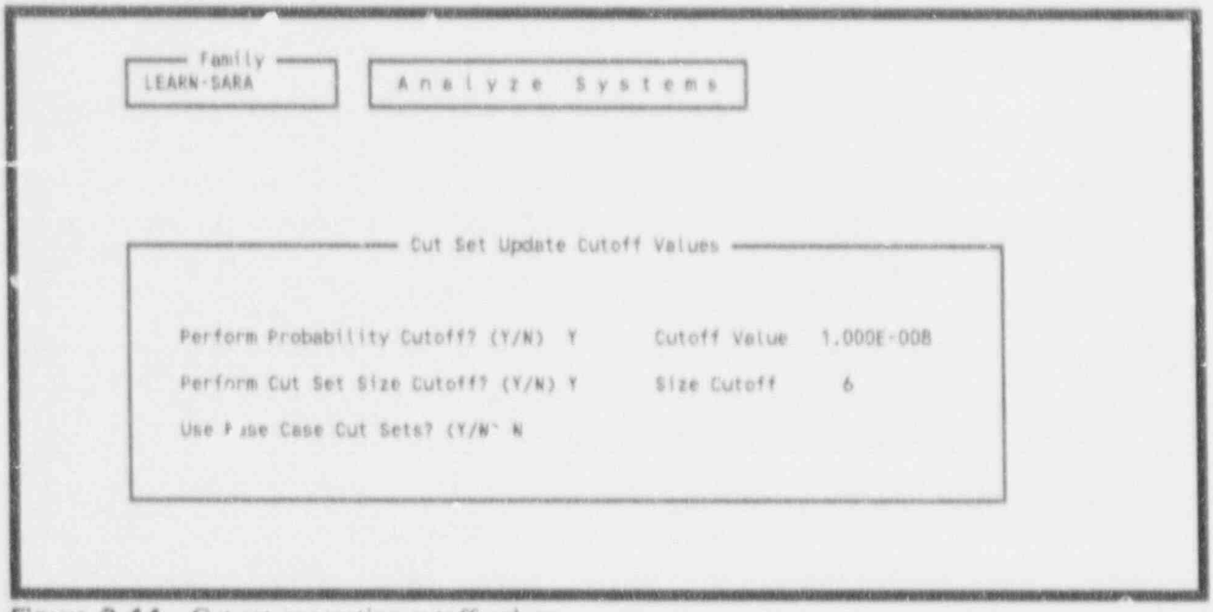


Figure 3-44. Cut set generation cutoff values.

Perform Probability Cutoff? (Y/N) - If you respond <Y> then only those cut sets whose product for all of its event probabilities is greater than or equal to the value in the Cutoff Value field will be kept. All other cut sets will be removed from the alternate case cut sets for that system. If you respond <N>, then the probability for the cut set will not be relevant for determining if the cut set should be retained or discarded.

Type a **<Y>**.

Perform Cut Set Size Cutoff? (Y/N) - If you enter a "Y", then only those cut sets whose number of events is less than or equal to the value in the Size Cutoff field will be kept in the alternate case cut sets for the system. All other cut sets will be removed. If you enter an "N" in this field, then the number of events in a cut set is irrelevant for determining if the cut set should be retained or discarded.

Type **<Y>**.

Use Base Case Cut Sets? (Y/N) - If you enter a "Y" in this field, then the base case cut sets will be used as the cut sets to be updated and then stored in the alternate case cut sets. However, if you respond <N>, the alternate cut sets will be used as the cut sets to be updated and then resaved in the alternate case cut sets.

Type **<N>**.

Cutoff Value - Enter the value to use as the probability cutoff value for cut set generation.

Type **1.0E-8 <Tab>**.

Size Cutoff - Enter the value to use as the cut set size cutoff value for cut set generation.

Enter a **6**.

When all fields have been input, press **<Enter>** to perform the cut set generation. During processing, the screen shown in Figure 3-45 is displayed and updated as the calculations proceed. Upon completion of the cut set update, the results are displayed as shown in Figure 3-46. Review the results. When complete, press **<Enter>**.

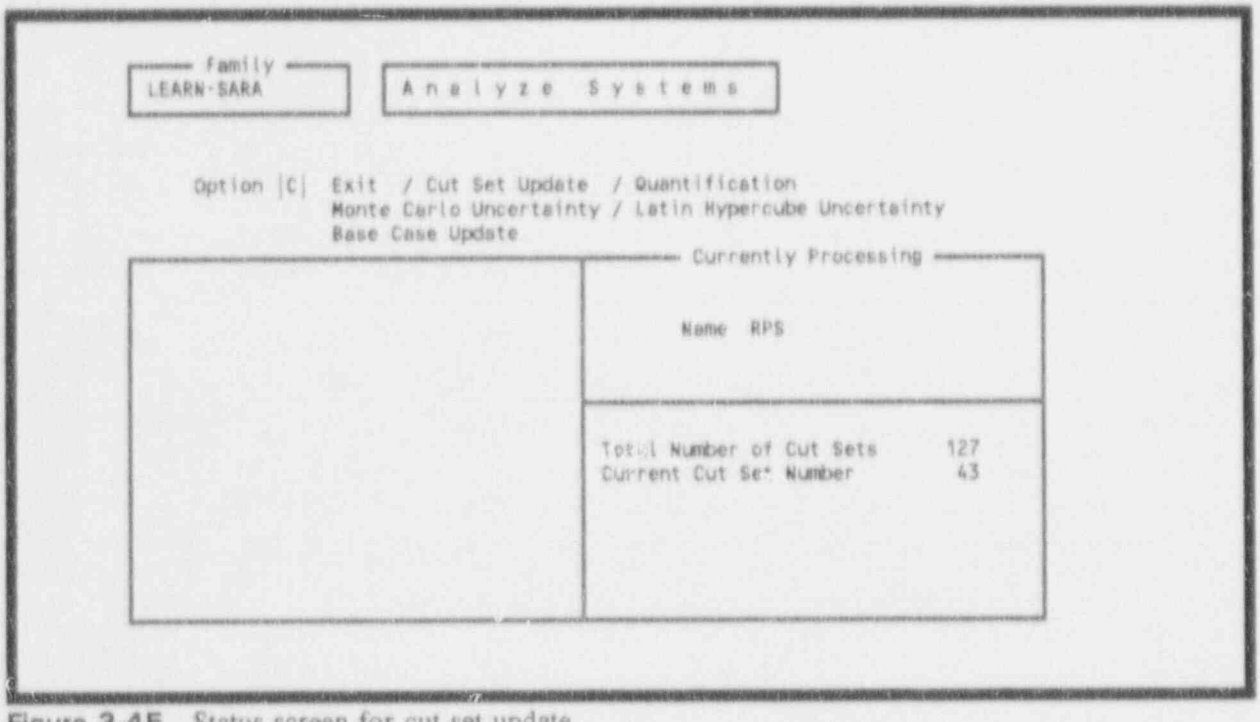


Figure 3-45. Status screen for cut set update.

Note, when you return to Figure 3-43, the cut set update flag "c" will be removed.

Press **<Esc>** twice to return to the Main Menu.

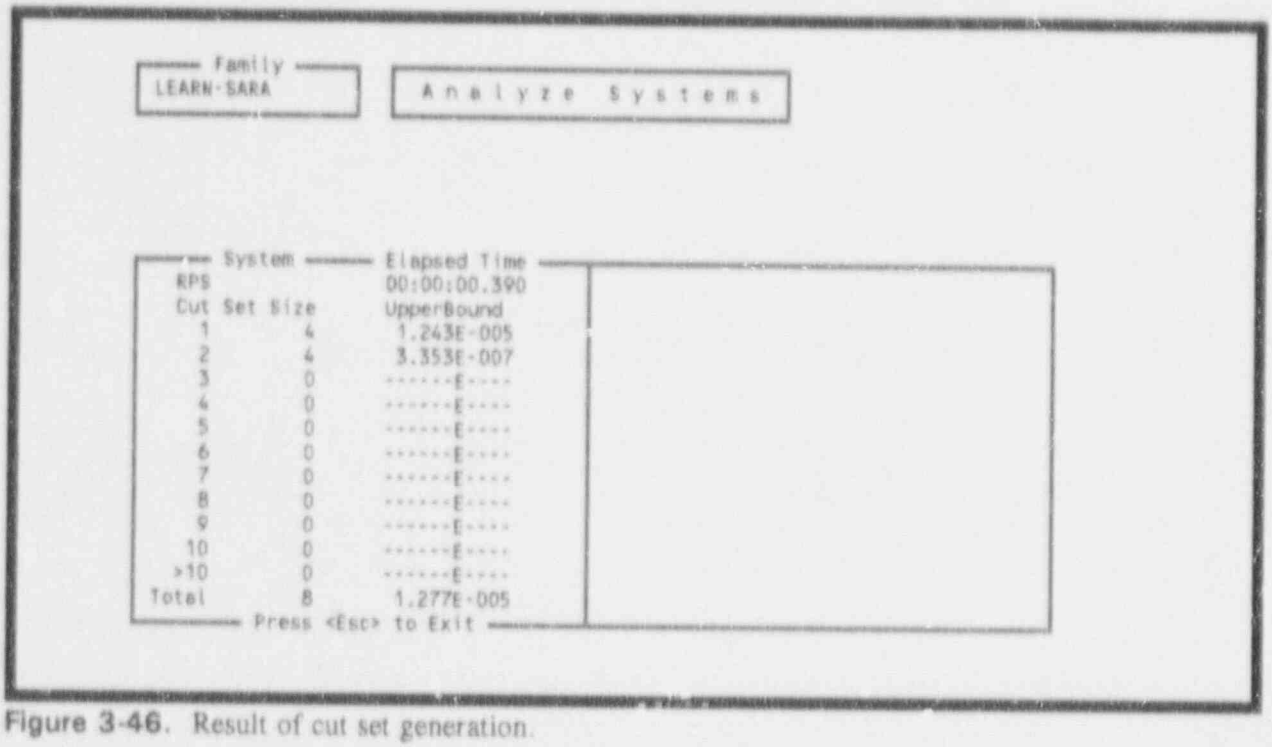


Figure 3-46. Result of cut set generation.

3.6.3 Perform Cut Set Generation for Sequences

1. Select the EVent Trees Analysis option by highlighting that option and pressing **<Enter>**. From the Event Tree Analysis screen, invoke the Analyze Event Trees option by typing **<A> <Enter>**.

2. Next, you need to mark all sequences for updating. To mark all sequences, press **<F3>**. An asterisk (*) appears in the first column of all sequences.

   Select the cut set update option by typing the letter **<C>** and pressing **<Enter>**. The Cut Set Generation Cutoff Values screen discussed in Paragraph 3.6.2, Step 2 appears. However, for this process you must turn off the size cutoff and use alternate cut sets.

   To select the proper probability cutoff value, place the cursor in the "Perform Probability Cutoff?" field and type a **<Y>**, press **<Tab>**, type **1E-8** and press **<Tab>**.

   Enter an **<N> <Tab>** at the Perform Cut Set Size Cutoff prompt. Because you have turned off size cutoff, the size cutoff value is meaningless.

   Finally, enter an **<N>** at the last prompt to use alternate values and press **<Enter>**. Screens similar to the ones shown in Figure 3-47 and Figure 3-48 will be displayed for each sequence. When the analysis is completed, you will be returned to the Analyze Sequence screen.

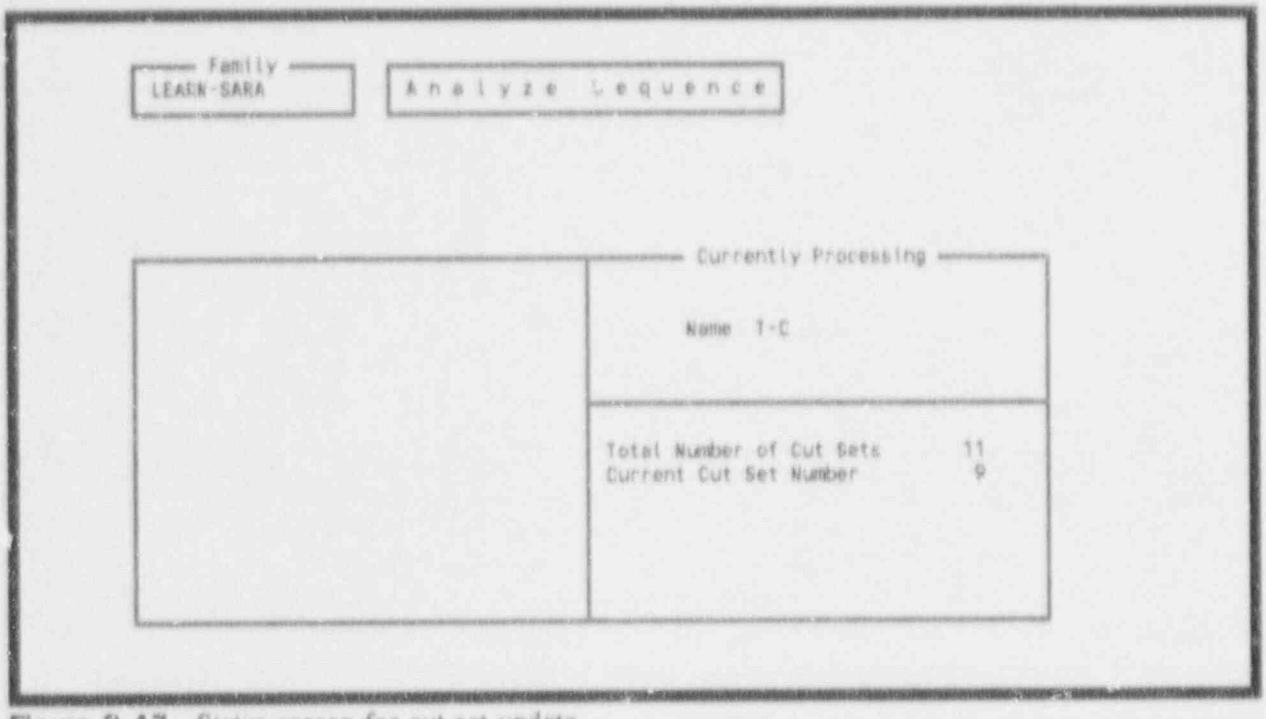


Figure 3-47. Status screen for cut set update.

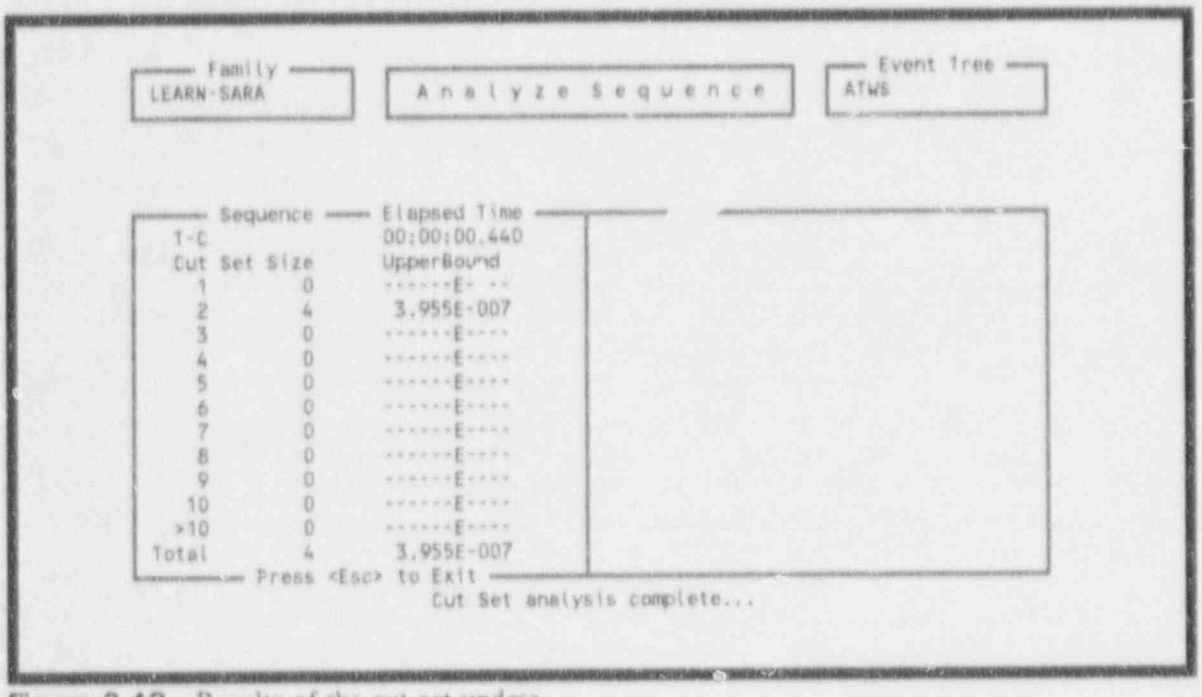


Figure 3-48. Results of the cut set update.

For each sequence processed, a number of status messages appear at the bottom of the screen. These messages tell when the cut sets are being generated, when the cut sets are being pruned based on house events, when minimal cut sets are being created by eliminating super sets, when the minimal cut sets are being saved, and when the cut set analysis for a given sequence is completed. Depending on the speed of your computer and the size and complexity of the sequence models, these messages may flash by too fast to read. If a fatal error or a need for further operator input is encountered, the system will display a permanent message or prompt for a response.
Press **<Esc>** to return to the Event Tree Analysis menu.

3. Select Display Results by highlighting that option and pressing **<Enter>**. The Sequence Display shown in Figure 3-49 will be displayed.

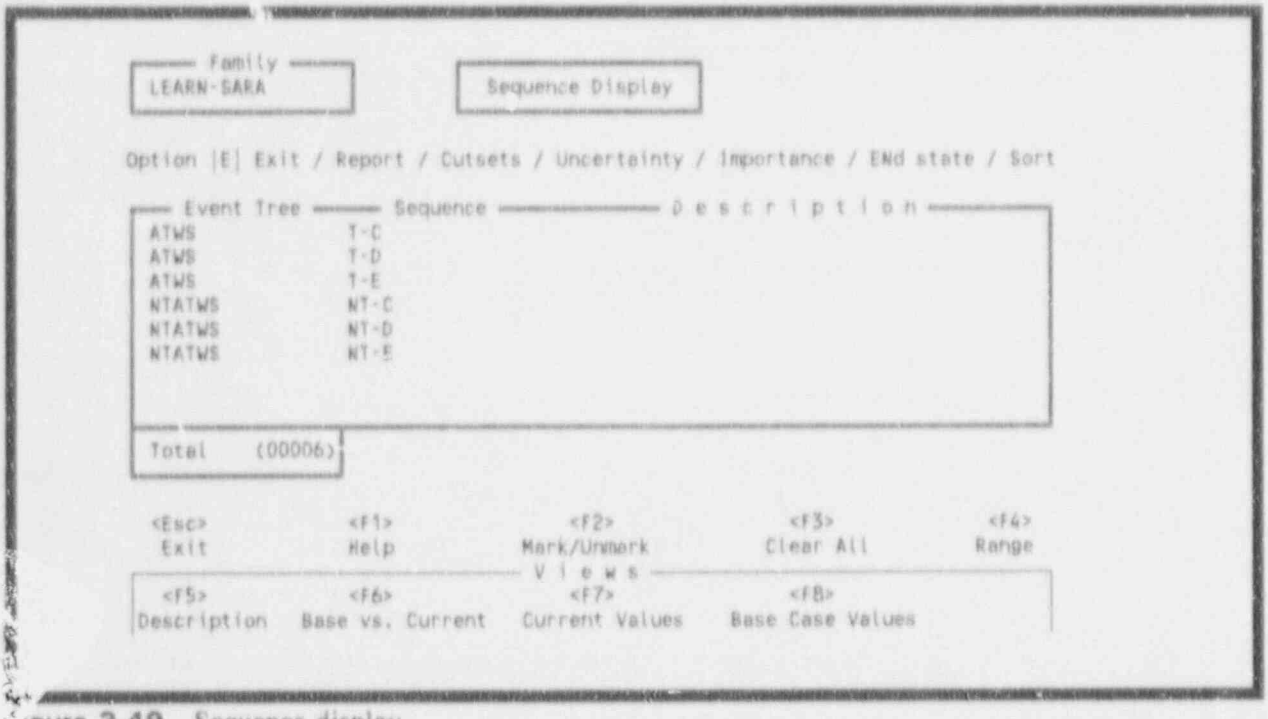


Figure 3-49. Sequence display.

Press **<F6>** to display the base case and current frequencies. Invoke the reports option by typing **<R> <Enter>**.

<Tab> to the Output File Name, and type **OPTION2.RPT**. The report showing the sequence name, base frequency, current frequency, and difference between the base and current frequency will be displayed on the screen. This report will also be written to a file called OPTION2.RPT on disk located in the PRADATA.B1\LEARN-SA directory.

Press **<Esc>** three times to return to the Main Menu.

3.7 Lesson 7. Displaying Results and Calculating Importance Measures

This lesson shows the user how to display the results of a sensitivity analysis and calculate importance measures based on those results. The importance measures calculated include the Fussell-Vesely importance, the risk reduction ratio, and the risk increase ratio.

1. From the Main Menu, select the SYstem Analysis module. Highlight that option and press **<Enter>**. The System Analysis menu will be displayed.

2. From the System Analysis menu, invoke the Display Results option by typing a **<D>** **<Enter>**. Figure 3-50 will be displayed.

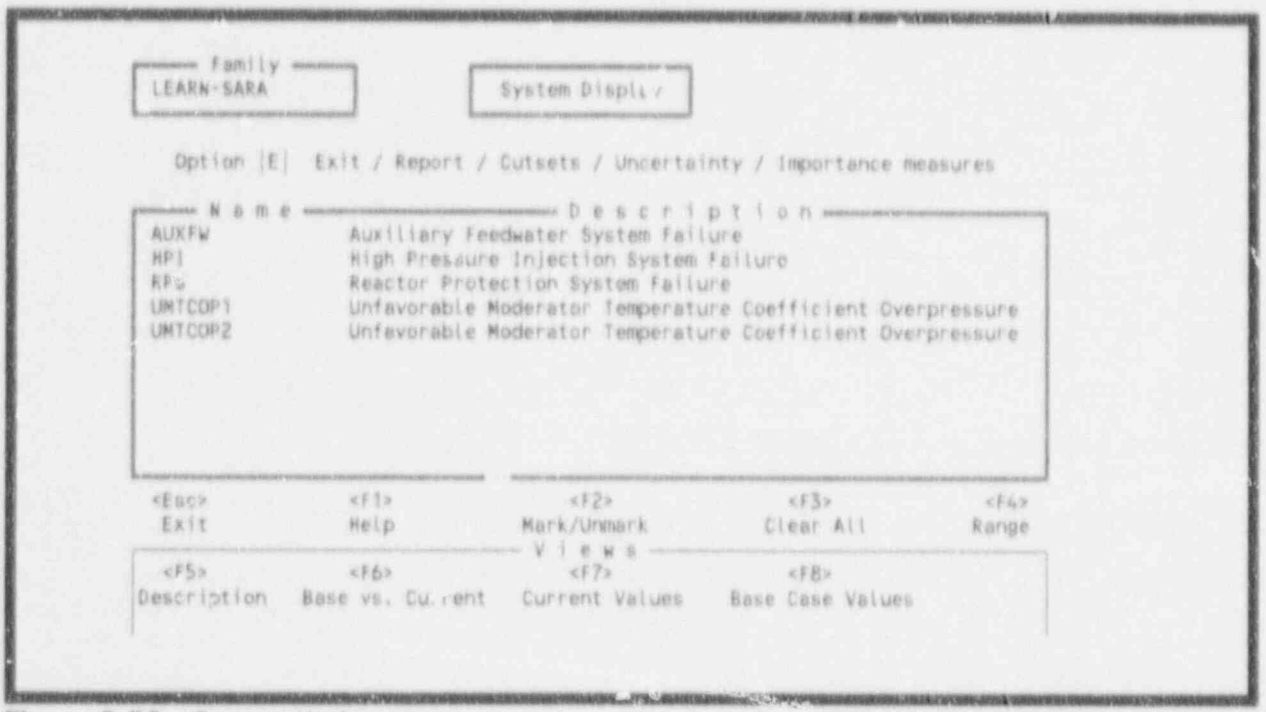


Figure 3-50. System display screen.

3. Type **<C>**, use the **<down arrow>** key to highlight RPS, and press **<Enter>**. The message "sorting cut sets" will be displayed at the bottom of the screen. Then, the Cut Sets screen shown in Figure 3-51 will be displayed.

   This Cut Sets screen shows the system cut sets, their corresponding percent of contribution to the system, frequency, and the event names that make up the cut sets. The system minimum cut set upper bound, the number of cut sets that make up the system, the current partition upper bound, the percentage that the partition contributes to the system, and the number of cut sets in the partition are displayed at the bottom of the screen.

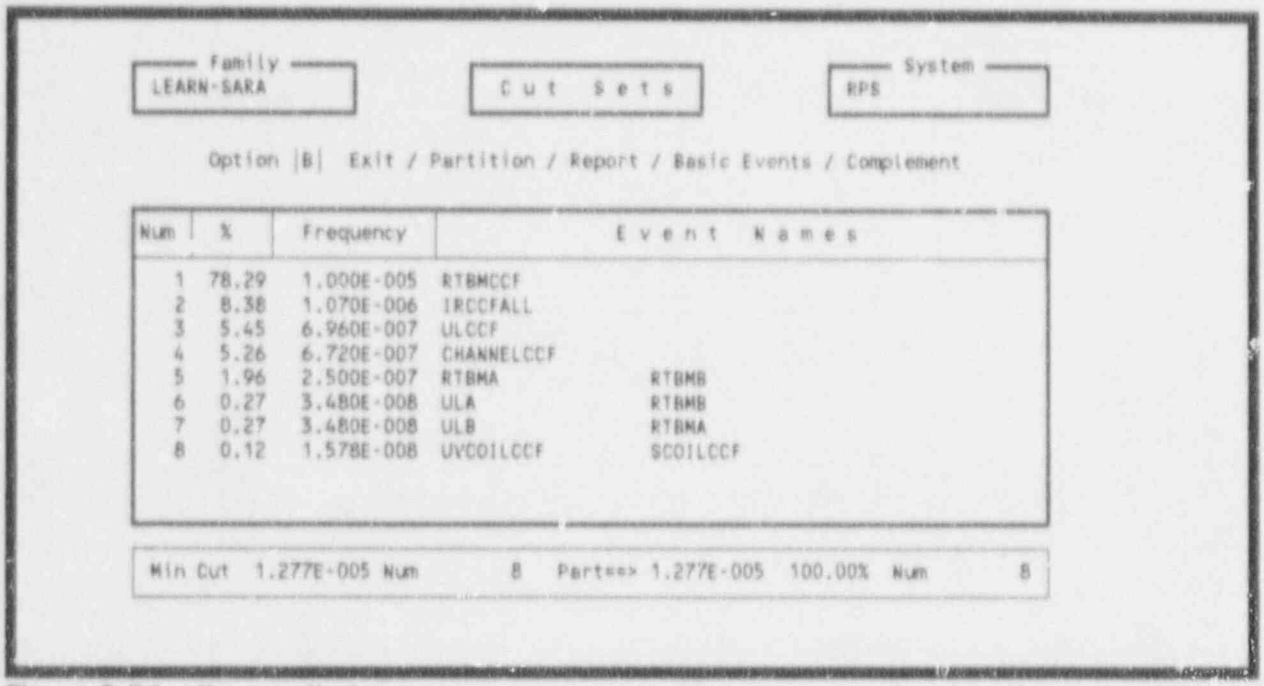


Figure 3-51. Cut sets display.

The minimal cut sets are displayed in ranked order based on frequency or probability of occurrence, with the most likely minimal cut set at the top. The basic events making up each cut set are listed on the right side of the screen. The order of a cut set tells the number of basic events making up the cut set. The display shows first, second, third order cut sets each on a single line. Fourth and higher order cut sets require multiple lines to be displayed. In Figure 3-51, the first four cut sets are all single-order and the rest are second order.

The frequency of each cut set is calculated by multiplying the failure probabilities for the basic events in the cut set. The percent contribution is determined by dividing the cut set frequency by the sum of all cut sets. Because the minimal cut set upper bound calculation used to determine the system failure probability is not the same as summing all cut sets, the total of the percentages will not be 100.00%.

4. Press **<B>**, highlight a cut set with two events in it (i.e., a second order cut set) and press **<Enter>**. The screen shown in Figure 3-52 will be displayed.

This display provides a more detailed look at the basic events making up the cut set. In Figure 3-52, a second order cut set in the RPS system is shown. For each basic event in the cut set, the following information is shown: event description, failure probability, component identification, system identification, component type, component failure mode, and component location. If any of this information has not been entered into the data base, the corresponding data field(s) will be empty.

Press **<Enter>** to return to the Cut Sets display (Figure 3-51).

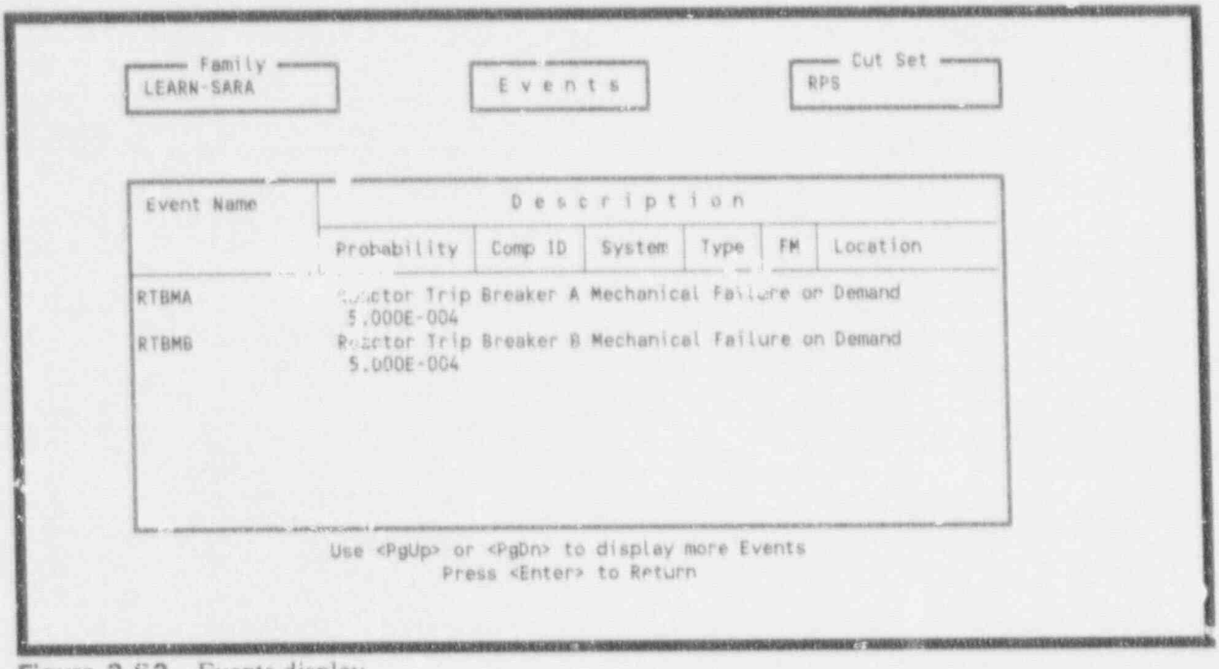


Figure 3-52. Events display.

5. Type a **<P>** **<Enter>** to invoke the partition option. The screen shown in Figure 3-53 will be displayed. The partition option allows you to redefine a system as a subset of the original cut sets. This is done by defining a set of events to be used to determine whether a cut set belongs to a partition.

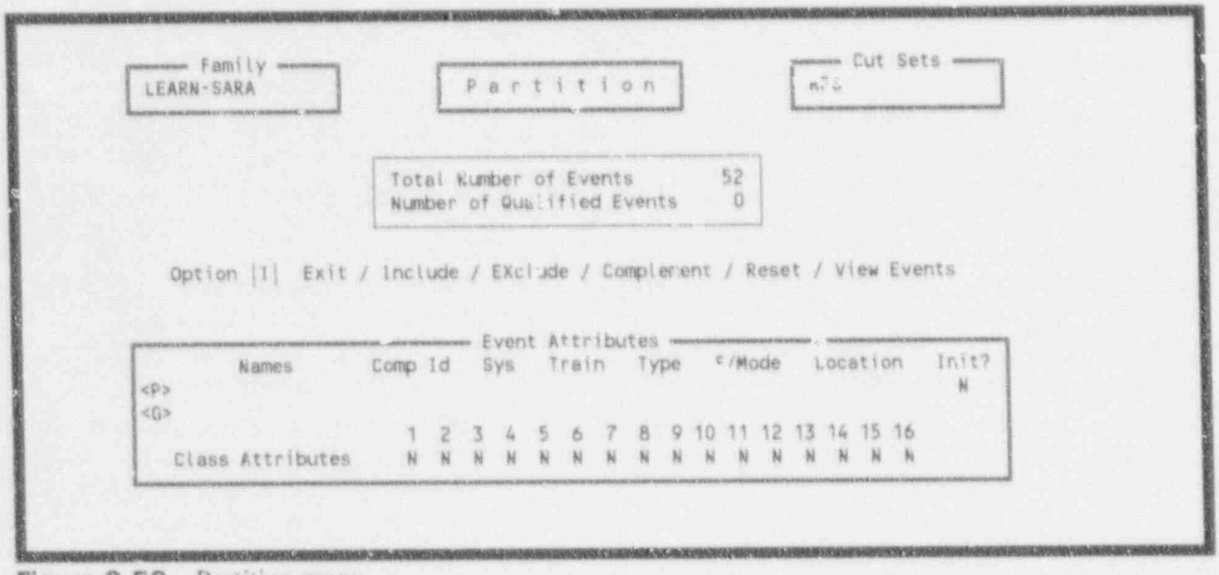


Figure 3-53. Partition menu.

Next, invoke the include command. To establish a partition via this option, we will invoke the option and then fill in the entry fields on the screen that are to be used to qualify the events that may be used in the new partition and press **<Enter>**. The application then proceeds to qualify the events and when complete will update the Number of Qualified Events field that appears at the top of the screen. In this case, qualified events will be those events that contain "CCF".

The Include option **<I>** should be selected. Type in ***CCF*** in the primary name field (labelled <P>) and press **<Enter>**. The system will be searched for all events that include the qualified attribute (CCF).

The message "10 basic events affected" will be displayed at the bottom of the screen, identifying that 10 events met the search criterion (i.e., contains "CCF"). The top window will be updated to reflect the counts (see Figure 3-54). Type an **<E> <Enter>**.

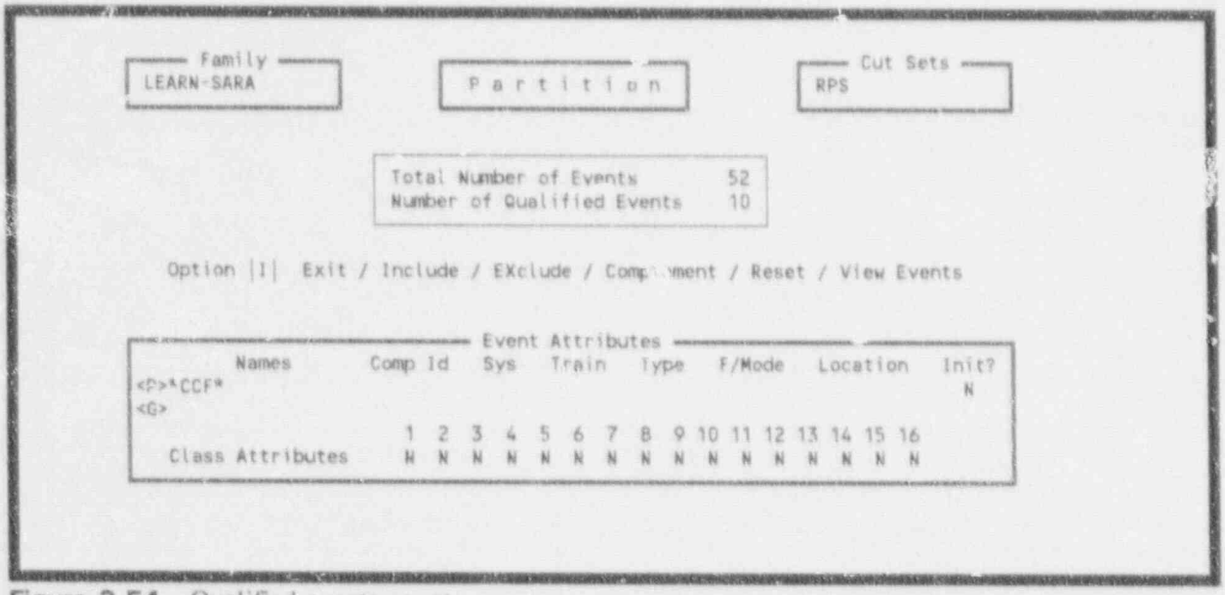


Figure 3-54. Qualified events count.

7. Type an **<E> <Enter>** to return to the Cut Sets screen (see Figure 3-55). The system cut set list contains only those cut sets that contain at least one of the qualified events. Figure 3-55 shows the result of specifying "CCF".

   The cut set list will show only those cut sets containing one or more of the qualified events. The main display area shows the same information for this partial cut set list as for the entire cut set list originally viewed. Note, however, that at the bottom of the display, the number of cut sets in this partition is 5 out of the 8 total cut sets. The probability total for these cut sets is 1.245E-005, or 97.49% of the original system failure probability. This means that over 97% of the system failure probability involves some sort of common cause failure.

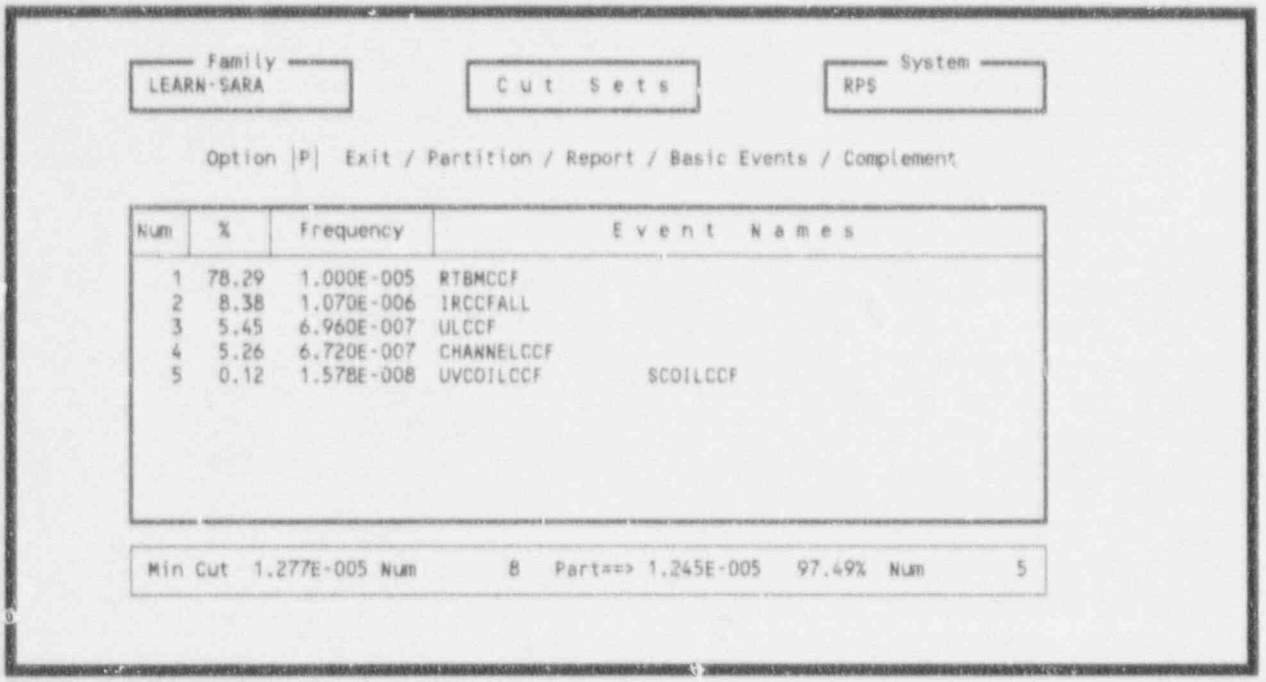


Figure 3-55. Partitioned cut sets listing.

8. Next, we will invoke the complement option. The complement option causes all currently qualified events to be disqualified, and all unqualified events to become the set of qualified events. The screen will change accordingly.

   Type a **<C> <Enter>**. The system cut set list contains only those cut sets that are made up of events that do not contain any "CCF" events (see Figure 3-56).

   Next, we will investigate the Importance measures. Type an **<E> <Enter>** to return to Figure 3-50.

3.7.1 Importance Measures

The Importance option calculates and displays the following three importance measures for each event in the system:

Fussell-Vesely importance - an indication of the percentage of the minimal cut set upper bound contributed by the basic event.

Risk Reduction Ratio - an indication of how much the minimal cut set upper bound would decrease if the basic event was made perfect (never fail).

Risk Increase Ratio - an indication of how much the minimal cut set upper bound would increase if the basic event was always failed.

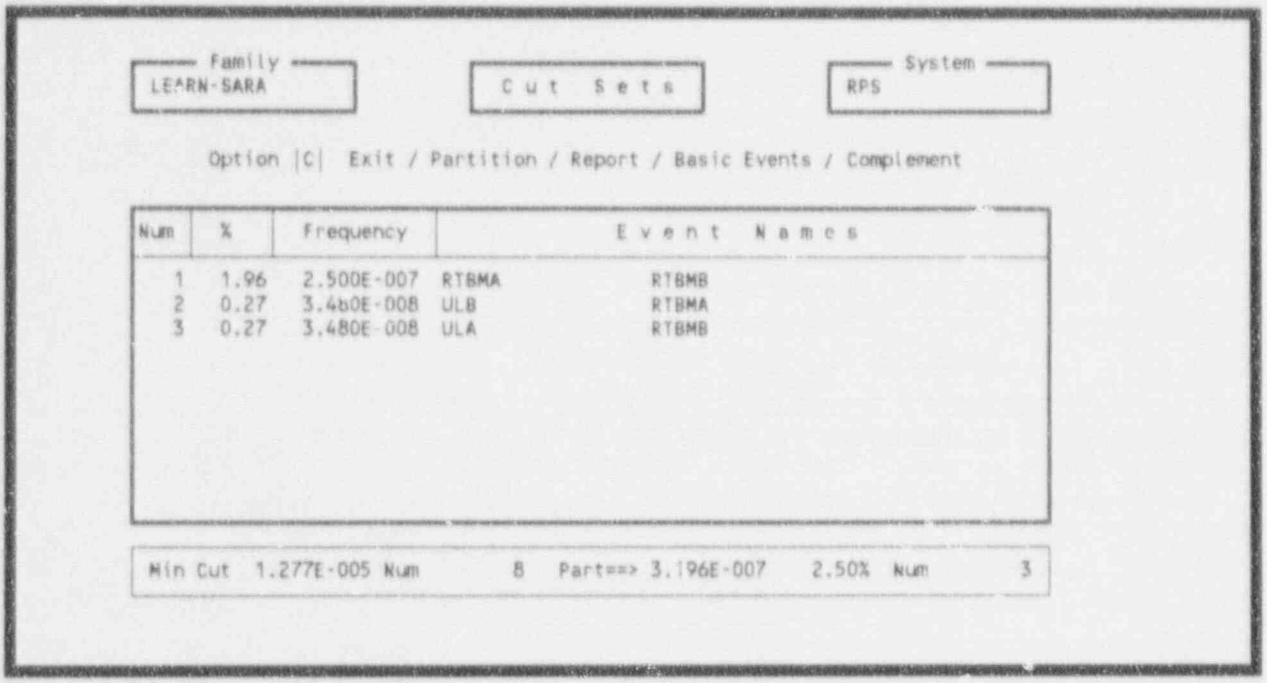


Figure 3-56. Cut set display after invoking complement option.

NOTE: If the Intervals flag is set in the Constants menu, the Birnbaum importance (the partial derivative), the Risk Reduction Interval, and the Risk Increase Interval will be displayed.

1. Type **<I>**, use the **<down arrow>** key to highlight **RPS** and press **<Enter>**. The message "Calculating importance measures" will be displayed, followed by Figure 3-57 and the message "Sorted by F-V."

2. Next, you will invoke the sort selection to reorder the display. The data can be sorted by the following: name, occurrence, probability, F-V, reduction, and increase.

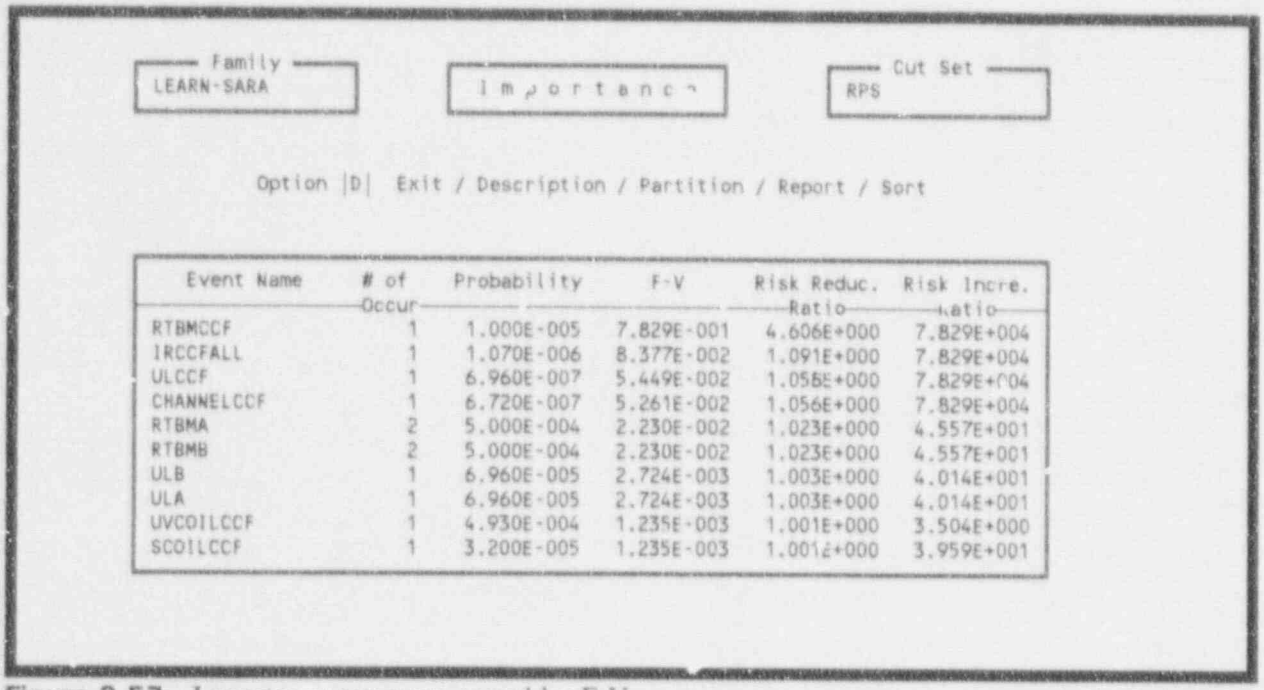
   Type **<S>**. The sort options (name, occurrence, probability, F-V, reduction, and increase) will appear. Type an **<I>**. The display is immediately reordered and displayed in risk increase ratio order (highest to lowest - see Figure 3-58).

   When finished viewing the display, type an **<E> <Enter>** to return to the System Display shown in Figure 3-50.

3.7.2 Uncertainty Measures

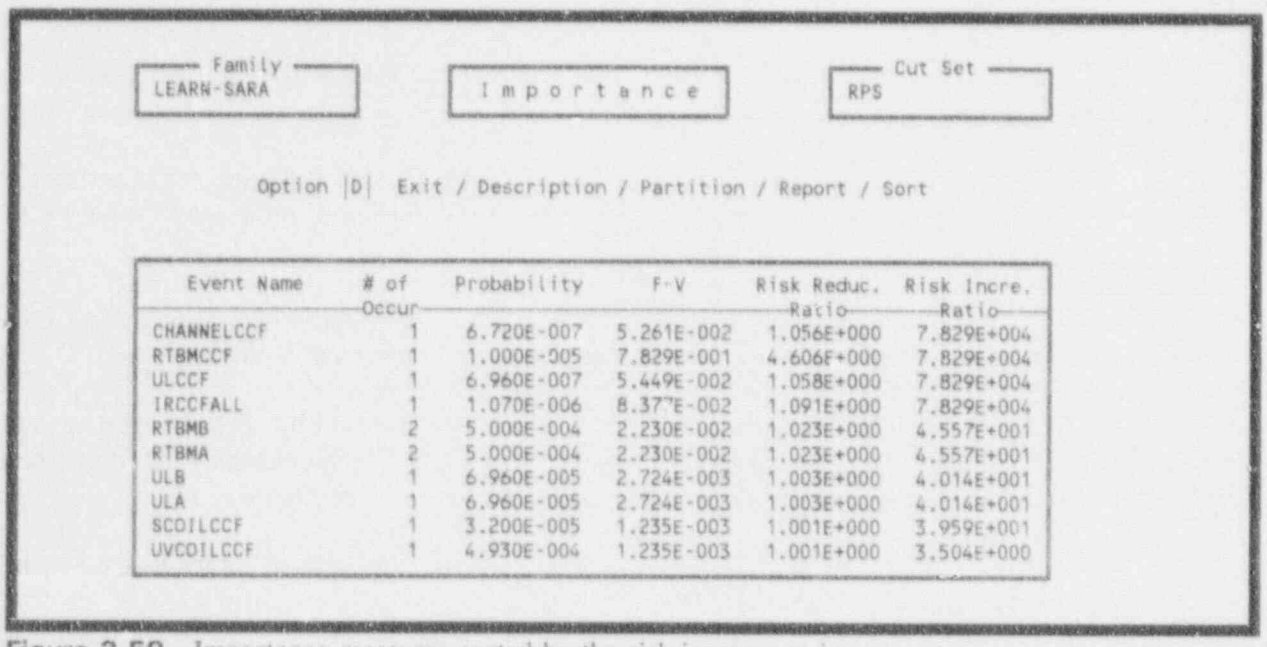
The Uncertainty option displays the distribution and confidence limits of a system for both base and current data values.

1. Type **<U>**, use the **<down arrow>** key to highlight **RPS** and press **<Enter>**.



Event Name	# of Occur	Probability	F-V	Risk Reduc. Ratio	Risk Incre. Ratio
RTBMCCF	1	1.000E-005	7.829E-001	4.606E+000	7.829E+004
IRCCFALL	1	1.070E-006	8.377E-002	1.091E+000	7.829E+004
ULCCF	1	6.960E-007	5.449E-002	1.058E+000	7.829E+004
CHANNELCCF	1	6.720E-007	5.261E-002	1.056E+000	7.829E+004
RTBMA	2	5.000E-004	2.230E-002	1.023E+000	4.557E+001
RTBMB	2	5.000E-004	2.230E-002	1.023E+000	4.557E+001
ULB	1	6.960E-005	2.724E-003	1.003E+000	4.014E+001
ULA	1	6.960E-005	2.724E-003	1.003E+000	4.014E+001
UVCOILCCF	1	4.930E-004	1.235E-003	1.001E+000	3.504E+000
SCOILCCF	1	3.200E-005	1.235E-003	1.001E+000	3.959E+001

Figure 3-57. Importance measures sorted by F-V.



Event Name	# of Occur	Probability	F-V	Risk Reduc. Ratio	Risk Incre. Ratio
CHANNELCCF	1	6.720E-007	5.261E-002	1.056E+000	7.829E+004
RTBMCCF	1	1.000E-005	7.829E-001	4.606E+000	7.829E+004
ULCCF	1	6.960E-007	5.449E-002	1.058E+000	7.829E+004
IRCCFALL	1	1.070E-006	8.377E-002	1.091E+000	7.829E+004
RTBMB	2	5.000E-004	2.230E-002	1.023E+000	4.557E+001
RTBMA	2	5.000E-004	2.230E-002	1.023E+000	4.557E+001
ULB	1	6.960E-005	2.724E-003	1.003E+000	4.014E+001
ULA	1	6.960E-005	2.724E-003	1.003E+000	4.014E+001
SCOILCCF	1	3.200E-005	1.235E-003	1.001E+000	3.959E+001
UVCOILCCF	1	4.930E-004	1.235E-003	1.001E+000	3.504E+000

Figure 3-58. Importance measures sorted by the risk increase ratio.

This brings up the Uncertainty Data display screen shown in Figure 3-59. This screen shows a summary of the base case and current case uncertainty analysis results. These values were calculated by performing an uncertainty analysis using Monte Carlo or Latin Hypercube sampling techniques. Lesson 8 will teach how to perform these calculations.

From this screen (Figure 3-59) you may return to the System Display or view the quantile values associated with the current case data or the base case data.

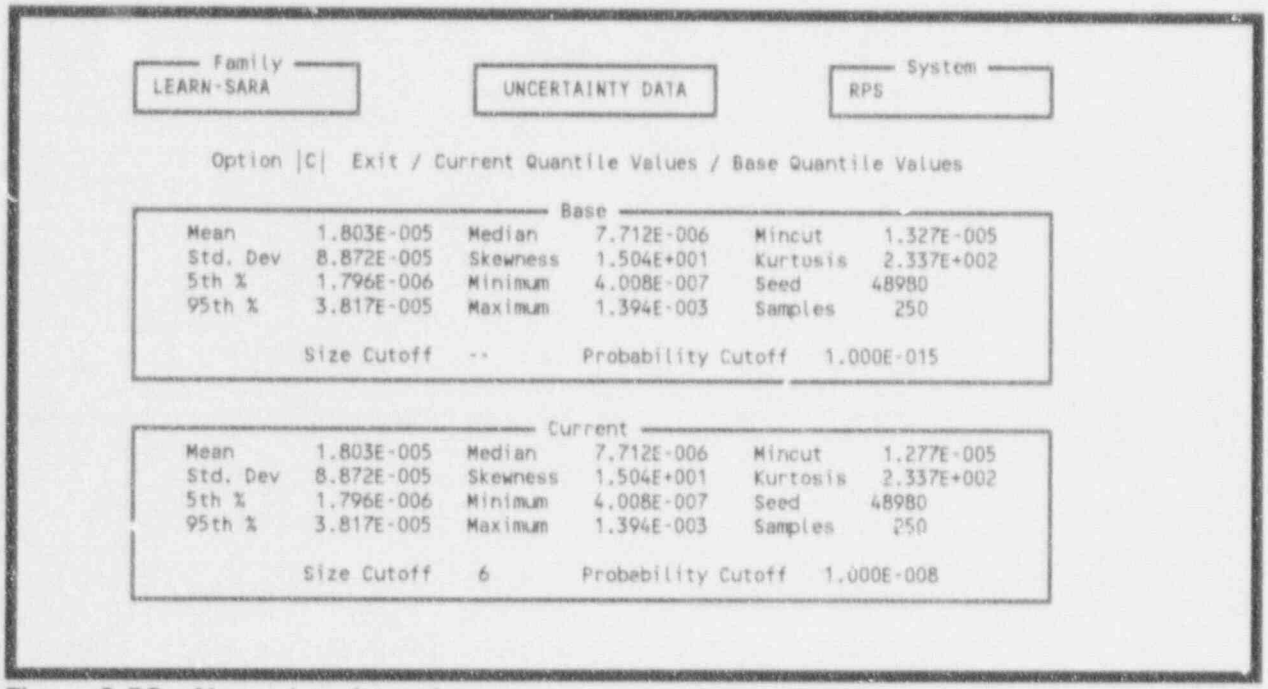


Figure 3-59. Uncertainty data values.

2. The <C> option to view current quantile values is the default option. Press **<Enter>** to view these values (see Figure 3-60).

   This display provides a breakdown of the system failure probability uncertainty distribution for the current case. The first column shows the various quantile level percentages. The third column is the failure probability value for the quantile level. For example, the 5% quantile level has a value of 1.7961E-6. This means that there is a 5% likelihood that the actual failure probability is less than 1.7961E-6.

   The second column indicates the uncertainty about the quantile level given the associated quantile value. The last two columns show the uncertainty bounds for the probability at the stated quantile level. Thus, the 5% quantile value (system failure probability) will fall between 1.4265E-6 and 2.1571E-6 95% of the time.

   Press **<Esc>** four times to return to the SARA 4.0 Main Menu.

Distribution Quantile Level (in per cent)	95% Confidence Interval On Quantile Level in % (+/-)	Quantile Value	CURRENT CASE 95% Confidence Interval on Quantile Lower Bound	Upper Bound
0.5	1.1	7.8065E-007	4.0081E-007	1.1281E-006
1.0	1.4	1.0840E-006	4.0081E-007	1.4265E-006
2.5	2.1	1.4768E-006	7.8065E-007	1.7770E-006
5.0	2.9	1.7961E-006	1.4265E-006	2.1571E-006
10.0	3.9	2.8255E-006	2.0389E-006	3.1773E-006
20.0	5.2	3.9973E-006	3.3809E-006	4.4312E-006
25.0	5.6	4.4312E-006	3.9905E-006	5.0093E-006
30.0	5.9	5.0093E-006	4.3481E-006	5.4352E-006
40.0	6.3	5.9902E-006	5.1703E-006	6.9902E-006
50.0	6.4	7.7120E-006	6.5945E-006	8.6011E-006
60.0	6.3	9.4029E-006	8.3061E-006	1.1326E-005
70.0	5.9	1.2375E-005	1.0958E-005	1.4086E-005
75.0	5.6	1.4023E-005	1.1996E-005	1.7303E-005
80.0	5.2	1.7303E-005	1.4023E-005	2.1763E-005
90.0	3.9	2.7889E-005	2.3301E-005	3.5034E-005
95.0	2.9	3.8177E-005	3.2340E-005	7.1203E-005
97.5	2.1	6.7871E-005	4.3747E-005	1.1895E-004
99.0	1.4	9.2685E-005	7.1203E-005	1.3947E-003
99.5	1.1	1.1895E-004	8.6831E-005	1.3947E-003

Figure 3-60. Current quantile values.

3.7.3 Sequence Displays

1. From the Main Menu, select Event Tree Analysis by highlighting that option and pressing **<Enter>**. From the Event Tree Analysis menu, select Display Results, by typing a **<D> <Enter>**.

   The screen shown in Figure 3-61 will be displayed. This menu lists all the event tree sequences retained in the data base. The cut set and uncertainty displays for sequences are manipulated and perform the same as those for systems. Importance measures can be calculated for a single sequence (this works as it did for systems). However, importance measures can also be calculated for a group of sequences or for the entire set of sequences. To calculate importance measures with respect to all sequences, perform the following steps.

2. Press **<I> <Enter>**. Because we did not highlight any sequences, the computer asks,

   "Show importance to family? (Y/N)"

3. Press **<Y>**. The messages, "Calculating importance measures" and "Sorted by F-V..." will appear at the bottom of the screen. Then, the screen shown in Figure 3-62 will be displayed. This shows each basic event that appears in any cut set from any sequence in the data base. The importances shown are with respect to the entire set of sequences in the family. Thus, if the data base contains all the core damage sequences for a plant,

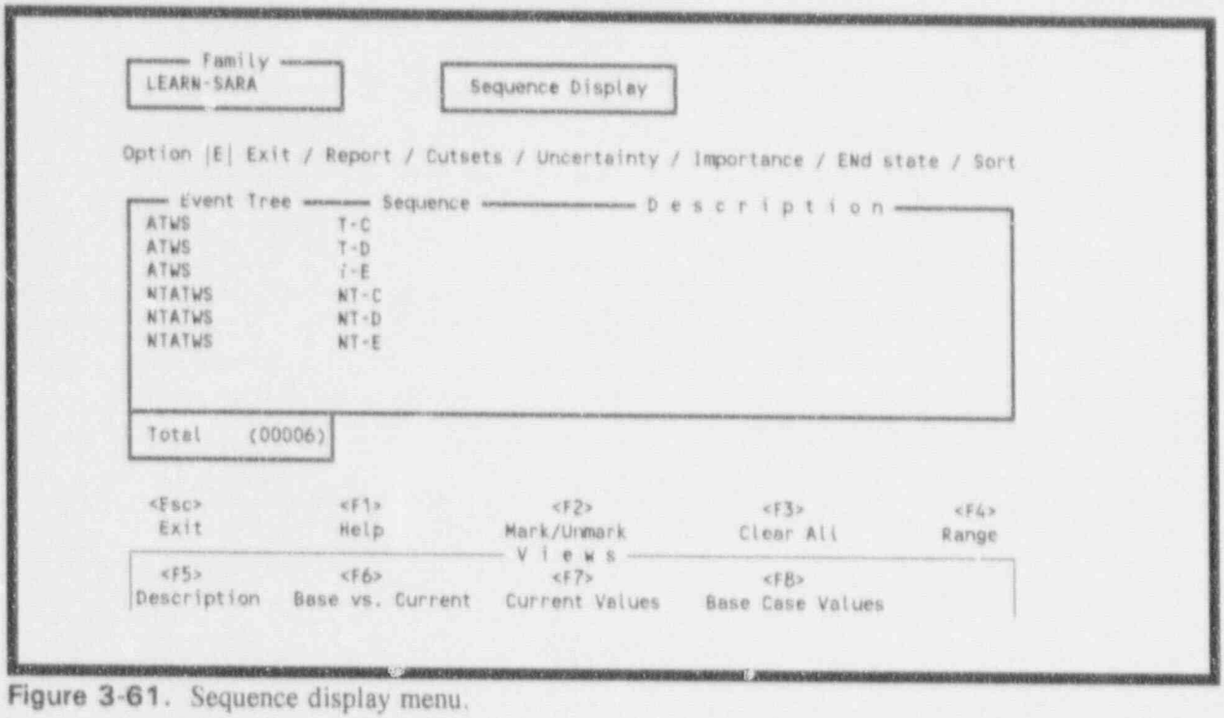
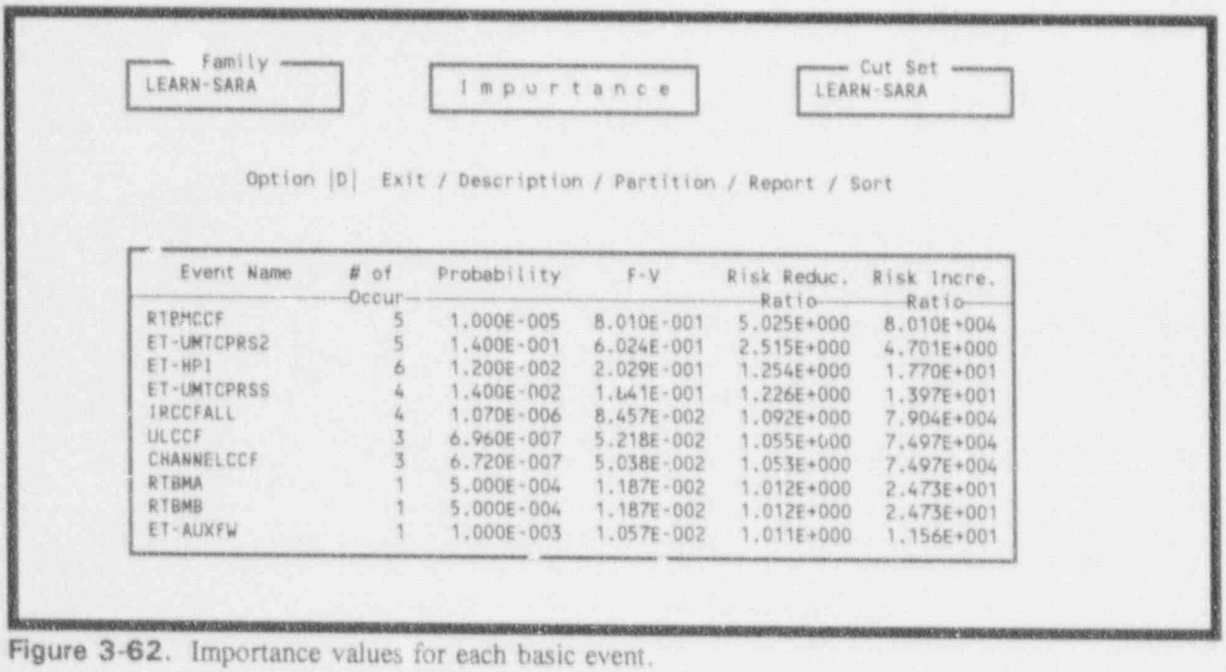


Figure 3-61. Sequence display menu.



Event Name	# of Occur	Probability	F-V	Risk Reduc. Ratio	Risk Incre. Ratio
RTBMCCF	5	1.000E-005	8.010E-001	5.025E+000	8.010E+004
ET-UMTCPRS2	5	1.400E-001	6.024E-001	2.515E+000	4.701E+000
ET-HPI	6	1.200E-002	2.029E-001	1.254E+000	1.770E+001
ET-UMTCPRSS	4	1.400E-002	1.641E-001	1.226E+000	1.397E+001
IRCCFALL	4	1.070E-006	8.457E-002	1.092E+000	7.904E+004
ULCCF	3	6.960E-007	5.218E-002	1.055E+000	7.497E+004
CHANNELCCF	3	6.720E-007	5.038E-002	1.053E+000	7.497E+004
RTBMA	1	5.000E-004	1.187E-002	1.012E+000	2.473E+001
RTBMB	1	5.000E-004	1.187E-002	1.012E+000	2.473E+001
ET-AUXFW	1	1.000E-003	1.057E-002	1.011E+000	1.156E+001

Figure 3-62. Importance values for each basic event.

these importance measures would indicate the basic events most important to core damage.

4. Press **<Esc>** to return to the sequence display screen of Figure 3-61.

   It may be desirable to know the importances of basic events to specific groups of sequences, such as those in a common end state or with a common initiating event. Previously defined end states can be accessed and used for various displays by using the ENd state option on the menu of Figure 3-61.

   Special groupings can be created by using the function keys. The following steps calculate the importance measures with respect to all ATWS sequences.

5. Using the **<down arrow>**, highlight the first ATWS sequence, **T-C**.

6. Press the **<F2>** function key to mark this sequence with an asterisk (*).

7. Repeat steps 5 and 6 to mark sequences **T-D** and **T-E**. These are all the ATWS sequences in the data base.

8. Press **<Esc>** twice to return to the SARA 4.0 Main Menu.

3.8 Lesson 8. Conducting Uncertainty Analysis

This lesson shows the user how to assign uncertainty distribution data to basic events and initiating events and how to perform uncertainty analysis on the sensitivity models.

There are two sampling techniques provided to allow you to run an uncertainty analysis: Monte Carlo simulation technique and the Latin Hypercube simulation technique. You are given the option of running an uncertainty analysis on the alternate cut sets for either a single system or sequence, for a group of systems or sequences, or for all systems or sequences within the current family. The sampling techniques are executed in the same fashion.

For our lesson, we will use the Latin Hypercube technique.

3.8.1 Perform Uncertainty Analysis for a System

1. From the Main Menu, invoke the SYstems Analysis option by highlighting that option and pressing **<Enter>**. From the Systems Analysis menu, invoke the Analyze Systems option high pressing **<A> <Enter>**.

2. Type **<L>**, use the **<down arrow>** key to highlight **RPS**, and press **<Enter>**. The screen shown in Figure 3-63 will be displayed. This screen prompts the user to enter the number of samples to be generated during the simulation and the initial value of the seed for the random generator. Default values for both fields are provided.

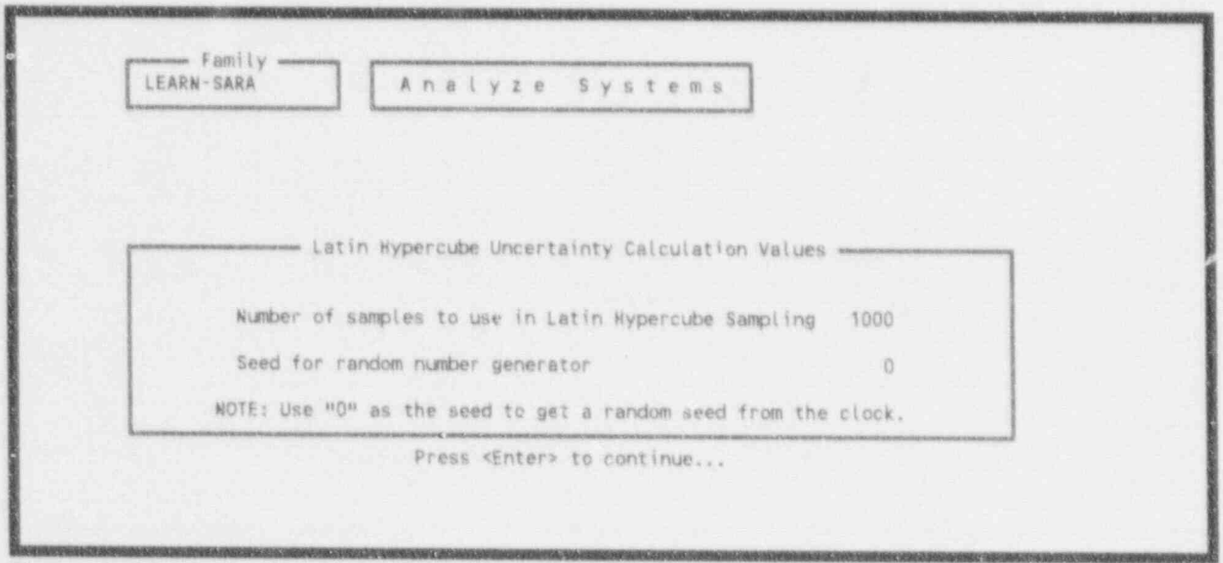


Figure 3-63. Latin Hypercube Uncertainty calculation values.

When using the Latin Hypercube Sampling technique, if the number of samples entered is less than twice the total number of unique events in the system or sequence, then the number of samples will be increased to two times the total number of unique events

before the analysis will continue. This technique gives its best results if the number of samples is at least twice the total number of unique events. For this lesson, we have used 250 for the number of samples.

3. Use your **<up arrow>** key to move to the number of samples field. Enter **250** then use the **<Del>** key to remove the remaining default number, and press **<Tab>**.

   This places the cursor in the "Seed for random number generator" field. The random number generator is used in the selection of sample values from the uncertainty distributions for the basic events and initiating events in the cut sets. The seed establishes the starting point for the sequence of random numbers generated. Knowing and using a consistent seed allows for repeatability and comparison of results. In this lesson, we have selected a seed of 3571.

4. Enter **3571**, press **<Del>** once to delete the remaining "0", and press **<Enter>**.

   The message "Calculating uncertainty for RPS" will be displayed at the bottom of the screen. Also, a screen similar to the one shown in Figure 3-64 will be displayed. This screen will be constantly updated to reflect the samples being processed.

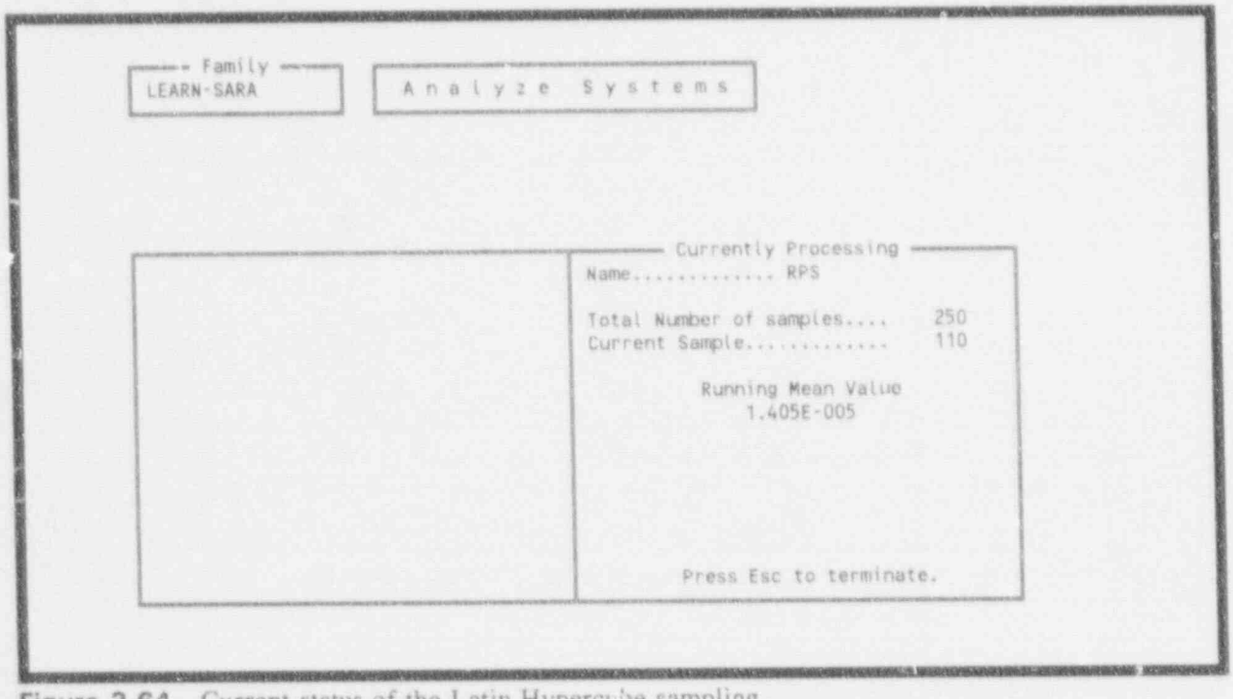


Figure 3-64. Current status of the Latin Hypercube sampling.

When complete, the screen shown in Figure 3-65 will be displayed. This display shows a summary of the uncertainty analysis just completed for the RPS system. The first three lines show some general information: system name, the random seed used, the number of samples used, the number of unique events in the cut sets, and the number of cut sets

for the system. The next line shows the point estimate result for the minimal cut set upper bound using the mean values for the basic events. The next four lines show the mean, 5th, median, and 95th percentile values for the resulting system failure probability distribution. The last six lines show some other statistics for the output distribution.

Next, we will look at a more comprehensive display of results.

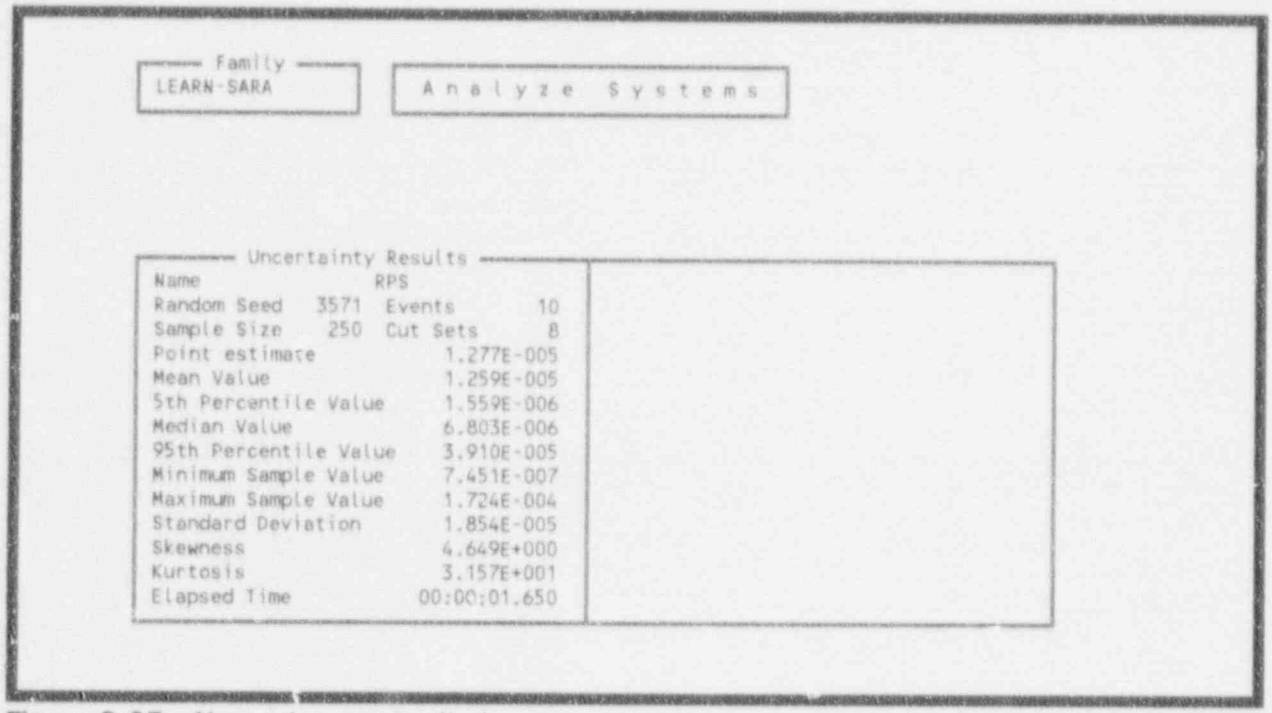


Figure 3-65. Uncertainty results display.

5. Press **<Esc>** twice to return to the System Analysis menu. Highlight **Display Results** and press **<Enter>**. The screen shown in Figure 3-66 will be displayed.

6. From the System Display, type **<U>**, use the **<down arrow>** key to highlight **RPS**, and press **<Enter>**. The Uncertainty option displays the distribution and confidence limits for RPS for both the base and current data values. These values were derived by using the Latin Hypercube Sampling technique performed in the previous and are similar to those discussed in Step 4.

   From Figure 3-67 you may return to the System Display or view the quan alues associated with the current case data or the base case data.

7. The "C" (current quantile values) is the default option, so press **<Enter>**. Figure 3-68 will be displayed. This display was explained in Lesson 7.

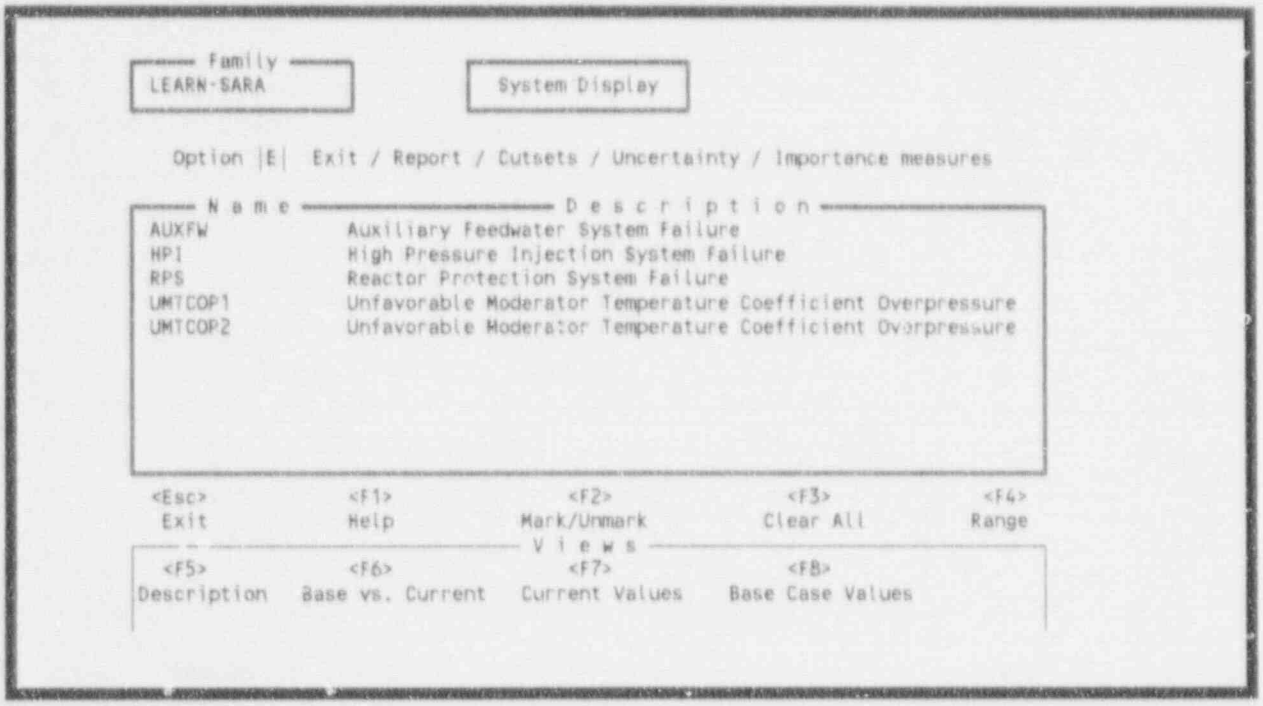


Figure 3-66. Systems display.

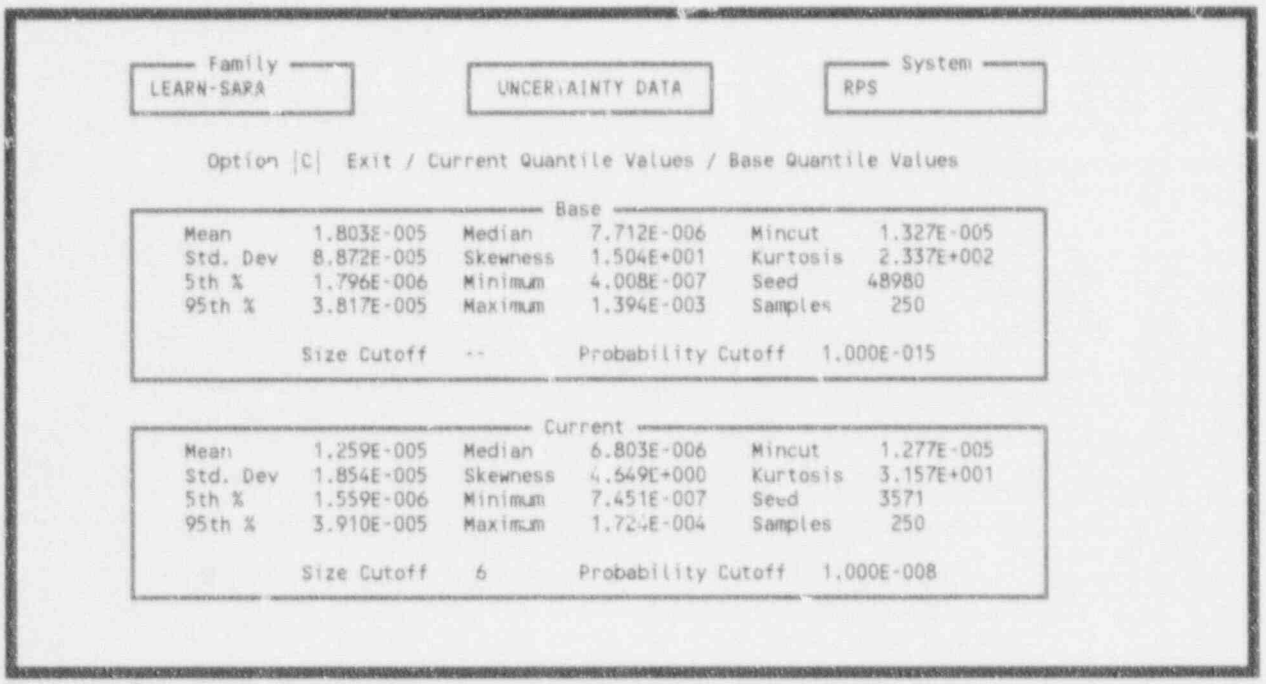


Figure 3-67. Uncertainty data values.

Distribution Quantile Level (in per cent)	95% Confidence Interval On Quantile Level in % (+/-)	Quantile Value	CURRENT CASE 95% Confidence Interval on Quantile Lower Bound	Upper Bound
0.5	1.1	8.5255E-007	7.4516E-007	1.0511E-006
1.0	1.4	9.0143E-007	7.4516E-007	1.2130E-006
2.5	2.1	1.2701E-006	8.5255E-007	1.5099E-006
5.0	2.9	1.5595E-006	1.2130E-006	1.8843E-006
10.0	3.9	2.0100E-006	1.6011E-006	2.7038E-006
20.0	5.2	3.4814E-006	2.8097E-006	3.7551E-006
25.0	5.6	3.7551E-006	3.4407E-006	4.4184E-006
30.0	5.9	4.4184E-006	3.7496E-006	5.1770E-006
40.0	6.3	5.6330E-006	4.9252E-006	6.5039E-006
50.0	6.4	6.8037E-006	6.3151E-006	7.7233E-006
60.0	6.3	8.7869E-006	7.5627E-006	1.0586E-005
70.0	5.9	1.2193E-005	1.0120E-005	1.4059E-005
75.0	5.6	1.4019E-005	1.2187E-005	1.5279E-005
80.0	5.2	1.5279E-005	1.4019E-005	2.0201E-005
90.0	3.9	2.6994E-005	2.1357E-005	3.2715E-005
95.0	2.9	3.9103E-005	3.0960E-005	7.0886E-005
97.5	2.1	6.5445E-005	4.1234E-005	1.1745E-004
99.0	1.4	9.7654E-005	7.0886E-005	1.7243E-004
99.5	1.1	1.1745E-004	8.9058E-005	1.7243E-004

Figure 3-68. Current quantile values display.

When finished viewing the current quantile values, press **<Esc>** four times.

3.8.2 Perform Uncertainty Analysis for Sequences

1. From the Main Menu, select the EVent Trees Analysis by highlighting that option and pressing **<Enter>**. The Event Tree Analysis menu will appear. Select Analyze Event Trees by typing **<A> <Enter>**. The Analyze Sequence screen shown in Figure 3-69 will be displayed.

2. Next, invoke the uncertainty analysis option by typing **<U> <Enter>**. This option allows you to run a single uncertainty analysis for a single sequence or an overall uncertainty analysis for a group of sequences.

   When you invoke this option, Figure 3-70 will be displayed. As shown, the four types of uncertainty analysis are:

   Single - This option allows the user to run an uncertainty analysis for either a single highlighted sequence, or batch process a number of individual sequences up to and including all sequences in the family.

   After you invoke this option, you must select the Monte Carlo Uncertainty or Latin Hypercube Uncertainty.

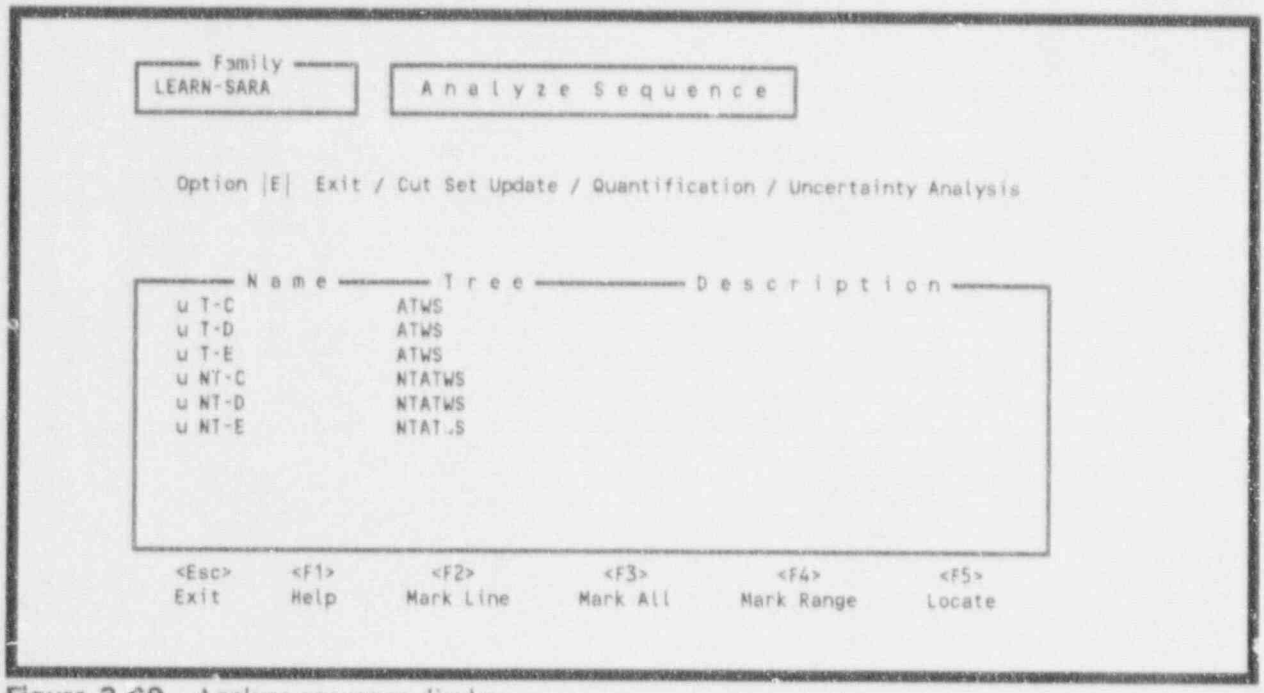


Figure 3-69. Analyze sequence display.

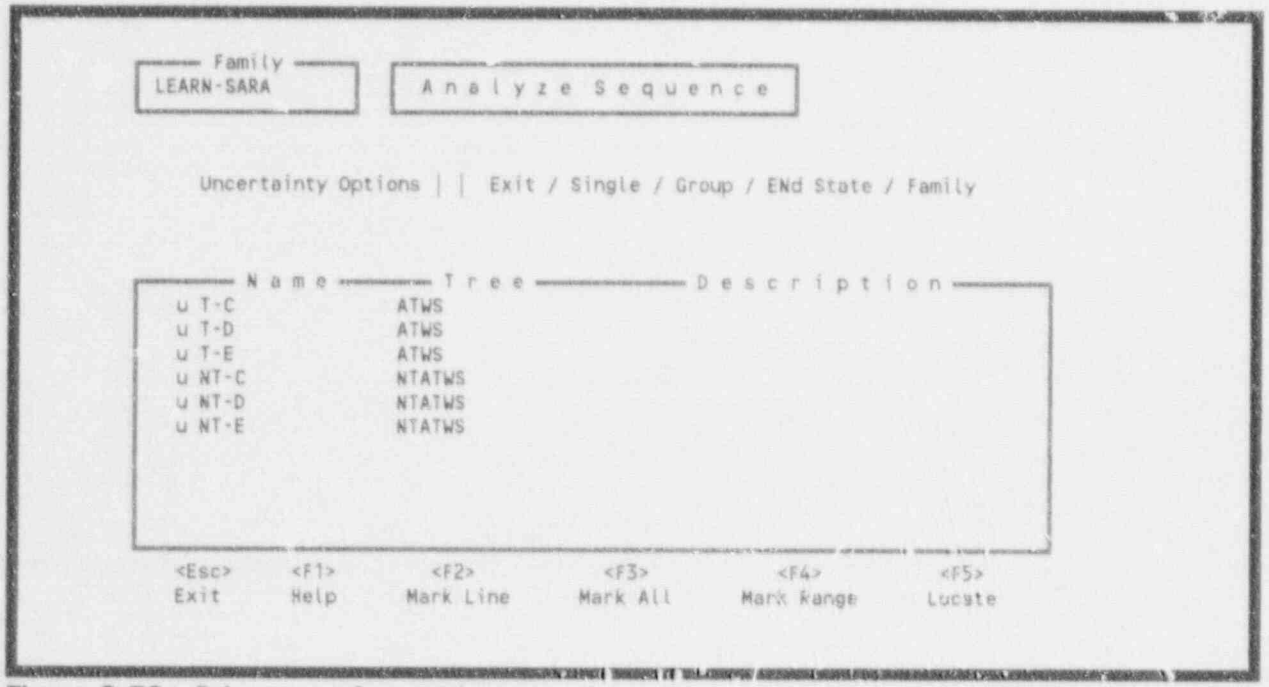


Figure 3-70. Select type of uncertainty analysis.

Group - This option allows you to generate an overall uncertainty analysis for a group of sequences. This option will be discussed further in Step 3.

ENd Sate - This option allows you to generate an overall uncertainty analysis for all sequences within a selected end state.

Family - This option allows you to generate an overall uncertainty analysis for all of the sequences within the current family.

3. For this lesson, we will invoke the Group option to perform an uncertainty analysis on the group of sequences with ATWS as the initiating event.

   Type a **<G>** to initiate the Group option. Figure 3-71 will be displayed. We wish to include all ATWS sequences in our uncertainty analysis. Type an **<L>** (Latin Hypercube Uncertainty), use the **<down arrow>** key to highlight the first ATWS sequence and press **<F2>**. An asterisk (*) will appear in the first column, indicating that this sequence is marked for further processing. Repeat these steps for the next two sequences. When complete, press **<Enter>**.

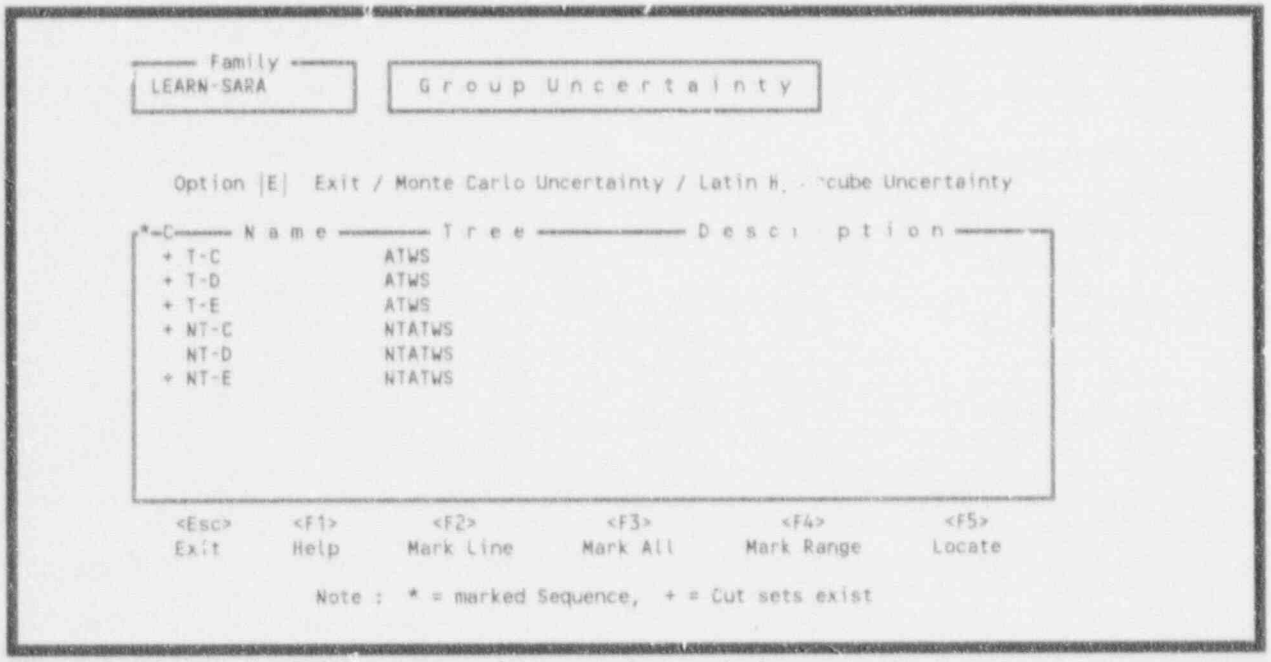


Figure 3-71. Mark ATWS sequences for uncertainty analysis.

4. Upon pressing **<Enter>**, Figure 3-72 will be displayed. On this screen, you must supply the number of samples to be used in the analysis and the seed number. Enter **250** as the sample size, and **3571** as the seed, and press **<Enter>**.

   During processing, the current group status screen (Figure 3-73) will be displayed and updated as the samples are generated, Twenty-five samples will be generated at a time, before the status screen will be updated with a new calculated mean value.

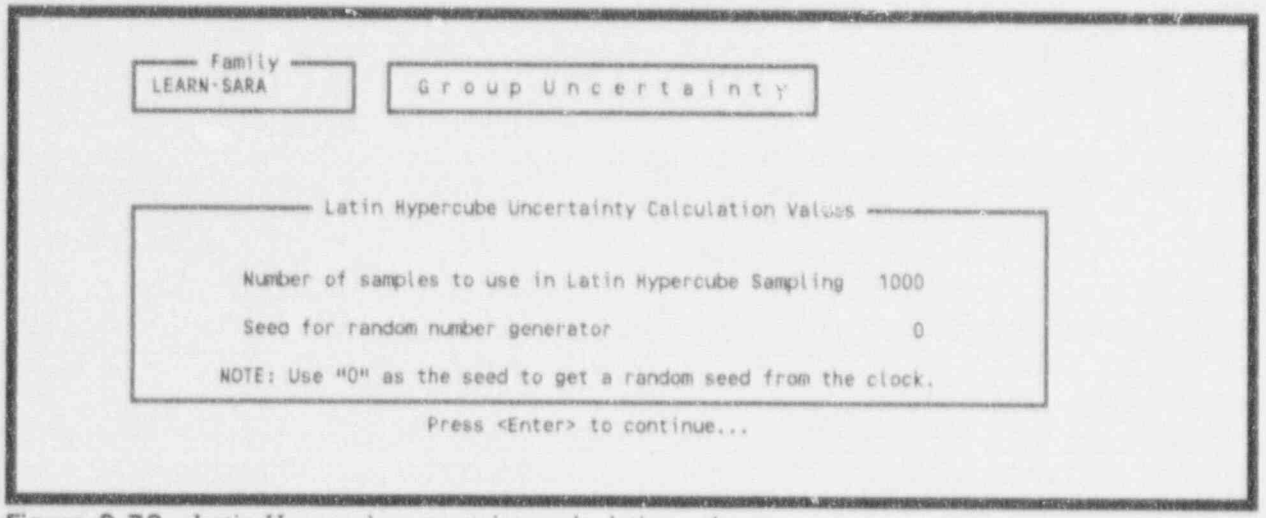


Figure 3-72. Latin Hypercube uncertainty calculation values.

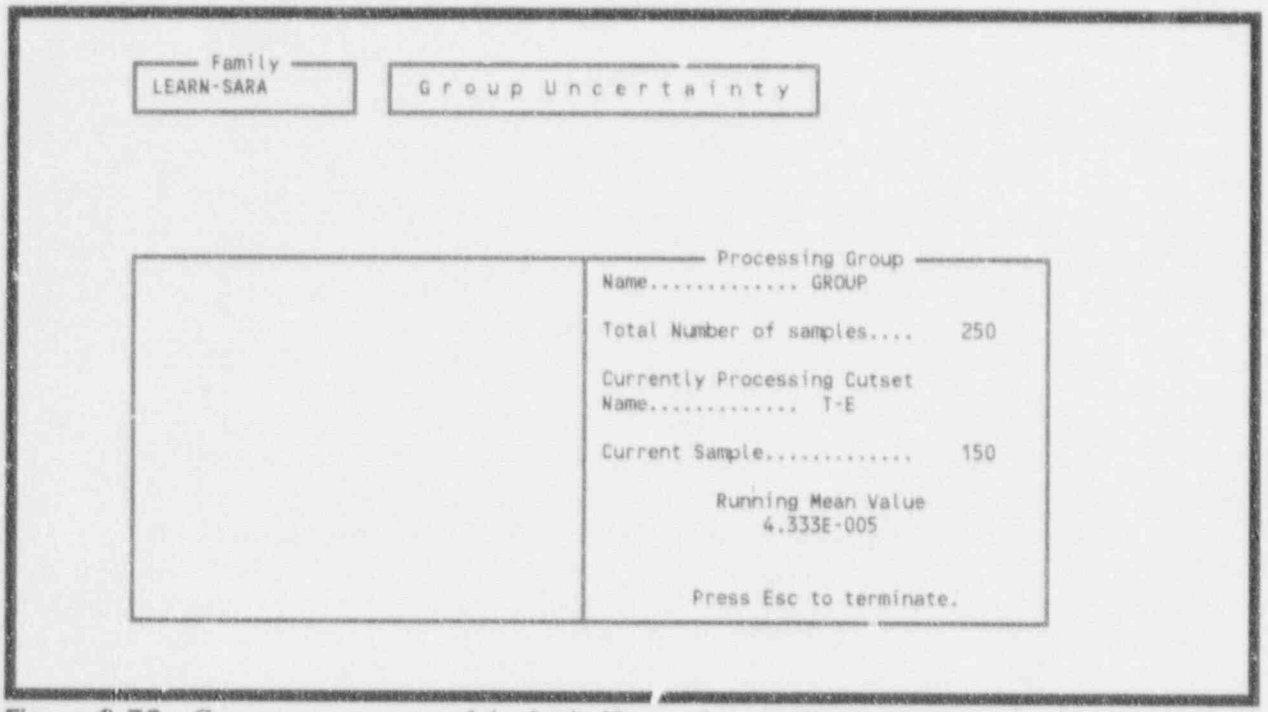


Figure 3-73. Current group status of the Latin Hypercube sampling.

Upon completion of these calculations, Figure 3-74 will be displayed. This display is identical to that described in Step 4 of Section 3.8.1, except the results pertain to the defined group of sequences instead of a system.

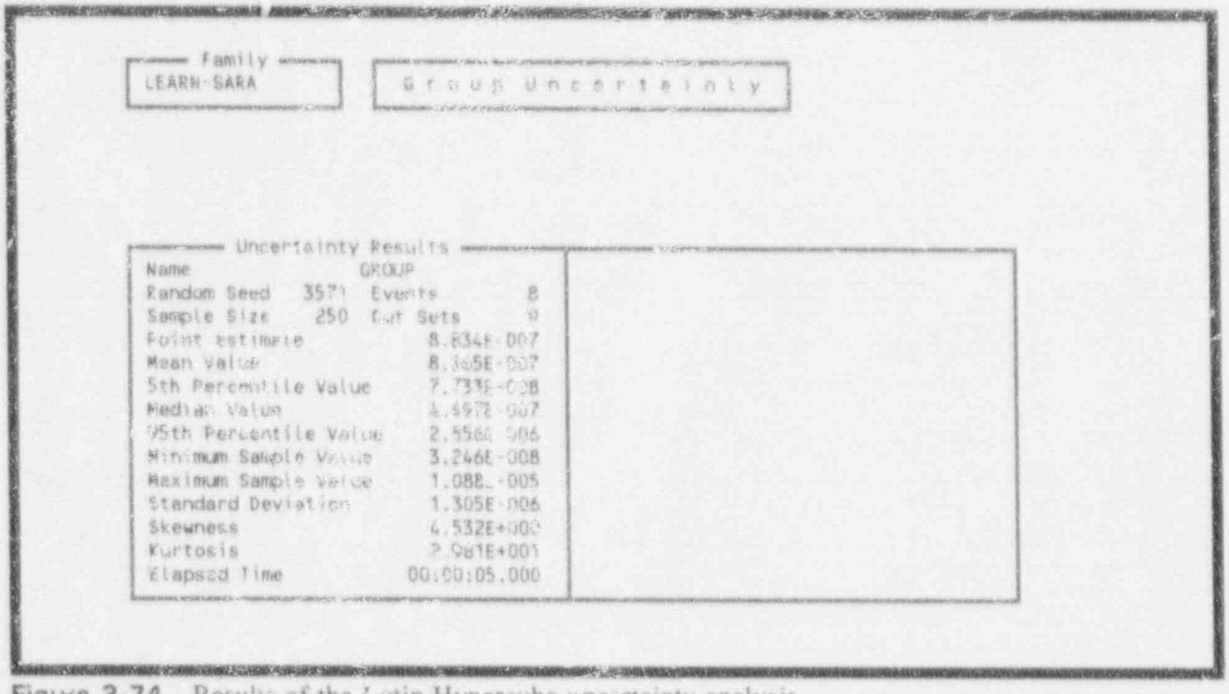


Figure 3-74. Results of the Latin Hypercube uncertainty analysis.

5. Press <Esc> four times to return to the SARA 4.0 Main Menu.

4.0 SUMMARY

This concludes the tutorial for SARA 4.0. After completing the eight lessons, we believe you will have a more general understanding of how SARA operates and the capabilities it has to offer. If questions arise, the user should refer to the *SARA Version 4.0, Volume 1 - Reference Manual*.

5.0 REFERENCES

1. K. D. Russell et al., *Integrated Reliability and Risk Analysis System (IRRAS), Version 4.0, Volume 1 - Reference Manual,* NUREG/CR-5813, EGG-2664, January 1992.

2. U.S. Nuclear Regulatory Commission, *Amendments to 10 CFR 50 Related to Anticipated Transient Without Scram (ATWS) Events*, SECY-83-293, July 19, 1983.

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

This NUREG is the tutorial for the System Analysis and Risk Assessment System (SARA) Version 4.0, a microcomputer–based system used to analyze the safety issues of a family [i.e., a power plant, a manufacturing facility, any facility on which a probabilistic risk assessment (PRA) might be performed]. A series of lessons are provided that walk the user through some basic steps common to most analyses performed with SARA. The example problems presented in the lessons build on one another, and in combination, lead the user through all aspects of SARA sensitivity analysis.

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