MEADEP

A SOFTWARE TOOL FOR SYSTEM DEPENDABILITY MEASUREMENT, MODELING AND EVALUATION

User's Manual

Version 1.2

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1. Introduction

MEADEP (MEAsure DEPendability) is a data based dependability analysis and modeling tool. The development of MEADEP integrates techniques in graphical user interface (GUI) programming, database engineering, dependability modeling, and statistical/numerical analysis. Section 1.1 gives a brief overview of MEADEP. Section 1.2 describes MEADEP's file types in tabular form. Section 1.3 discusses the contents of this manual, and Section 1.4 describes the background of MEADEP.

1.1 Overview

MEADEP consists of four modules. These modules are:

1. The Data Pre-Processor (DPP)
2. The Data Editor and Analyzer (DEA)
3. The Model Generator (MG)
4. The Model Evaluator (ME)

Figure 1 below shows the overview of the data flow of the program and how each of MEADEP's modules interact with each other.

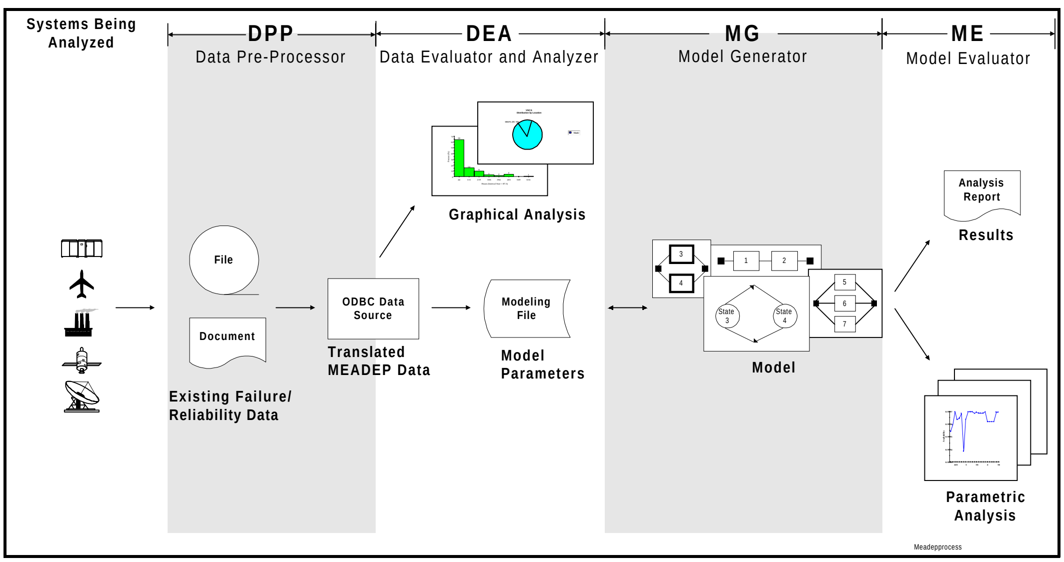

Figure 1 Overview of MEADEP

Results generated by MEADEP are either directly obtained from data or evaluated from dependability models. Thus, the two basic types of input to MEADEP are:

- Data — structured reports containing information on event time, location, impact and other event characteristics, and

- Models — graphical specifications of dependability models consisting of reliability blocks and Markov chains

In order for MEADEP to work on data, the data must be in the MEADEP required format. Therefore, MEADEP includes the Data Pre-Processor (DPP) module which enables you to convert already existing databases (which can be in a variety of formats such as ASCII Delimited Text, Access, dBASE, Paradox, etc.) into the MEADEP data format.

However, if the data is not contained in a file, and you need to input data manually, then the Data Editor and Analyzer (DEA) module can be used. This module allows you to create MEADEP formatted databases and to input data directly into it without any conversion necessary.

After completing the data entry, DEA can use the data to graphically display dependability characteristics and perform parameter estimation. The following is a list of DEA's graphing and parameter estimation capabilities:

- Pie charts for event distribution
- Progressive curves over time for Mean Time Between Events (MTBE) and its confidence interval
- Histograms for Time Between Events (TBE) and for Time To Recovery/Repair (TTR), with the option to superimpose typical analytical functions accompanied by the results of their goodness-of-fit tests
- The mean, lower and upper bounds for failure rate, recovery time, and coverage
- Clustering analysis statistics

As mentioned above, another way to input data is by building dependability models. The Model Generator (MG) module can be used to do this. MG is a graphical "drag and drop" interface which allows you to create models hierarchically. The models are made up of reliability block diagrams (including the k-out-of-n block) and/or Markov chains. A library of dependability models, including primitive models for typical fault-tolerant architectures and complex models for real critical systems, are included in MEADEP for reuse by users. From these models, MG can generate text modeling files which contain model descriptions and parameters. These text modeling files can then be used by the Model Evaluator (ME) module to generate desired results.

Results evaluated from models include:

- Mean Time Between Failures (MTBF)
- Reliability at a time point
- Interval-reliability (average reliability) for a time interval
- Steady-state availability
- Yearly downtime

Furthermore, ME also enables you to generate and graph these results using a user-specified range of values for a selected parameter.

For all of its functions, MEADEP provides you with a graphical user interface (GUI) on Windows 95 or NT featuring menus, dialogs, pictures, printing previews, and extensive on-line help information.

1.2 File Types

MEADEP has six file types. The table below lists these file types with their descriptions.

Type	Used By	Produced By	Contents
Graphical Modeling File (*.mdg)	MG	MG	This file contains the graphical models and parameters created in the MG module.
Library File (*.mdl)	MG	MG	This is a pre-defined graphical modeling file that defines the structure of a model but does not contain parameter values.
Text Modeling File (*.mdt)	ME, DEA	MG	This file contains parameters and models that ME uses to generate results. Parameters generated in DEA can also be bounded to parameters in this file.
Parameter File (*.txt)	ME	ME or any text editor	This file contains a list of parameters and their initial values. It can be included in model evaluations performed by the ME module.
Query File (*.bch)	DEA	Any text editor	This file contains a specification of one or more queries that DEA uses in its analyses.
Windows Metafile (*.wmf)	Other Windows Apps.	DEA, MG, ME	This file contains pie charts, histograms and line graphs produced in DEA, models produced in MG and results produced in ME.

1.3 Contents of Manual

This user's manual contains information about MEADEP. It discusses MEADEP's functions and capabilities and gives step-by-step instructions on how to use the program's modules. Chapter 1 introduces you to MEADEP and contains information on its background. This chapter also includes a brief overview of the program and lists all the file types that can be used and created in it. Chapter 2 describes how to install MEADEP and includes a section that runs through some quick and helpful examples. Chapters 3 discusses the Data Editor and Analyzer (DEA) module. Chapters 4 discusses the Data Pre-Processor (DPP) module. Chapters 5 discusses the Model Generator (MG) module. Chapters 6 discusses the Model Evaluator (ME) module. This manual also includes an appendix that contains a listing and description of the library files that are included with the MEADEP package.

1.4 Background of MEADEP

MEADEP was developed to provide a means of quantitatively assessing the availability, reliability and probability of failure on demand for computer-based safety systems in nuclear power plants (referred to as “digital systems”). Existing instrumentation and control (I&C) systems are obsolete or obsolescent. However, upgrading these safety grade (Class 1E) systems to digital technology currently poses a technological and regulatory risk. This risk is not so much due to the technology, which is mature and proven, as to limitations of methods used for verifying compliance with system safety and reliability requirements. While methods for predicting analog hardware reliability are widely accepted by the nuclear power community, this does not hold for similar methods for Class 1E digital systems.

There are two conventional approaches to reliability and availability prediction: 1) modeling of a system in the design phase, or 2) assessment of the system in a later phase, typically by test. The first approach relies on probabilistic models that use component level failure rates published in handbooks or supplied by the manufacturers. This approach provides an early indication of system dependability, but the model as well as the underlying data later need to be validated by actual measurements. The second approach typically uses test data and reliability growth models. It involves fewer assumptions than the first, but it can be very costly. The higher the reliability specified for a system, the longer the required test. A further difficulty arises in the translation of reliability data obtained by test into those applicable to the operational environment.

MEADEP is intended for use in the third approach: measurement-based dependability evaluation. This approach is well suited to the operational environment, but it can also be applied during test. The primary advance over the conventional methods lies in the use of models for interpretation of the measurements. This methodology extracts much more information from available data than conventional approaches. In turn, it permits creditable assessment of the probability of rare events from measurement of (more frequent) predecessor events and without the need of observing the actual event. Based on measurements of operational systems, MEADEP can provide objective dependability assessments with stated confidence levels. This is like proof of the pudding by eating, rather than by analyzing the ingredients. A further benefit for regulatory agencies is that the use of standardized failure rate data for digital systems provides an overview of the performance of these systems. Measurements can be performed on commercial grade components without requiring the vendor to reveal proprietary information or to modify an established development process.

Critical digital systems are found in a broad spectrum of applications, and the goals of dependability assessment vary widely among these. It is instructive to consider the following two extremes in order to understand where the methodology and the tool discussed in this manual are most applicable:

1. Networked systems, such as air traffic control, telephone switching, and funds transfer
2. Stand-alone protection systems for nuclear or chemical plants

Networked systems are characterized by:

- Continuous input, although the workload may fluctuate, making a "usage profile" and Mean Time Between Failures (MTBF) relevant.
- Ability to tolerate occasional outages because alternate routines or similar work-arounds can be used.
- Users that are highly motivated to keep downtime statistics and assess causes of failures.

An earlier study found downtimes of between 30 and 35 hours per year per installation for these systems, with between 30 and 50 percent of the downtime being due to identified software problems[1]. This environment permits systematic studies of failure mechanisms and occurrence rates that can be used to build and validate software reliability models. Models that assume an initial fault density and an increase in the MTBF proportional to the faults removed are appropriate for this application area[2].

In contrast, in stand-alone protection systems, the performance under routine workload is largely irrelevant to the safety actions expected of the system in response to malfunctions; the most important dependability criterion is probability of failure on demand rather than mean time between failures; alternate means for accomplishing the intended actions are not always available (human intervention or defense-in-depth of automatic systems); and, most significant in the context of this investigation, the user (utility, chemical plant) has no clear motivation and very little ability to keep statistics of non-catastrophic system failures and to investigate and correct the causes of these failures.

MEADEP has capabilities relevant to this last point by providing users of digital protection systems with an easy means of keeping track of non-catastrophic failures and of propagating the resulting statistics to system failure probabilities. Furthermore, by making it easy to collect relevant statistics and identify the potential contribution to catastrophic events of non-catastrophic conditions, it will motivate users to investigate and correct the causes of failures or exception conditions as they are encountered.

Of course, many applications fall between the two extremes discussed above, and the tool will be valuable to these as well as for the specialized needs of stand-alone protection systems. For example, Air Traffic Control (ATC) systems which have many characteristics of a networked system. The example shows how the tool can furnish MTBF predictions, and also how it can estimate the fault tolerance coverage, a capability not provided in any of the published reliability models and the tools that support them.

The importance of the methodology and the associated tool rests partly on the assumption that catastrophic failures in well-tested systems usually result from the

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[1]H. Hecht and M. Hecht, *Reliability, Testability and Design of Fault Tolerant Systems*, RADC-TR-84-57, Rome Air Development Center, April 1984.

[2]J.D. Musa, A. Iannino, and K. Okumoto, *Software Reliability: Measurement, Prediction, Application*, McGraw-Hill Book Company, 1987.

coincidence of a number of conditions that are individually tolerable, or at least, non-catastrophic. A number of examples of such occurrences are documented in NUREG/CR-6293[3]. That catastrophic failures result from a combination of failures and mistakes that individually have much lesser consequences is not restricted to digital systems. This process is very much at work in many major industrial, transportation, and energy generation accidents.

Potentially the greatest benefit of MEADEP is when it is used during concept development and early design because deficiencies identified at that time can be corrected at relatively low cost and with few side-effects. The difficulty is that no direct measurements from the system will be available at that time. Even in these circumstances, the tool can be used for sensitivity studies, for "what if?" investigations, and for comparison of alternatives under a given set of parameters. As operational data acquired by use of the tool are made available for dependability assessment during earlier phases, these benefits will be considerably increased.

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[3]*Verification and Validation Guidelines for High Integrity Systems*, U.S. Nuclear Regulatory Commission Contractor Report NUREG/CR-6293, March, 1995, available from the National Technical Information Service, Springfield, VA.

2. Getting Started with MEADEP

This chapter contains information on how to get started using MEADEP. Section 2.1 describes the installation process and Section 2.2 runs through some examples which will help you get familiar with MEADEP's modules.

2.1 Installing MEADEP

Before you install MEADEP, you should be sure that your computer meets the following requirements.

MEADEP SYSTEM REQUIREMENTS:

- IBM PC® version or fully compatible personal computer with a 486 or later processor
- At least 20 megabytes (MB) of hard disk space
- At least 16 MB of memory (RAM)
- Microsoft Windows 95 or NT

MEADEP's performance on your system is affected primarily by the size of your data and models.

The following section will guide you through the MEADEP installation process.

Note for Novell networks, the network client program should be halted prior to installing MEADEP.

To install MEADEP:

1. If you are installing from a CD, insert the CD into the CD drive. If you are installing from floppy disks, insert disk 1 into its appropriate drive.
2. In the Windows Startup menu, choose Run. The Run dialog box should appear on the screen.
3. Select the appropriate drive. If you are installing from floppy disks, choose setup.exe. If you are installing from CD, choose "setup.bat".
4. Follow the instructions on the screen to install MEADEP.

The MEADEP installation program will guide you through the process and at the end of the installation, the following dialog box will appear.

Figure 2 Last Message Box in MEADEP Installation

After clicking “OK”, the MEADEP installation is completed. If this is your first time installing MEADEP (version 1.1 or higher), run the “DATAACC.EXE” program found under the MEADEP program directory. When you run this program it will first ask you if you want to install the Microsoft Data Access Pack, click “YES”. This will initiate the installation process and will guide you through the procedures. When you get to the dialog shown below, choose “Select All” and click “Continue”. This will complete the installation process.

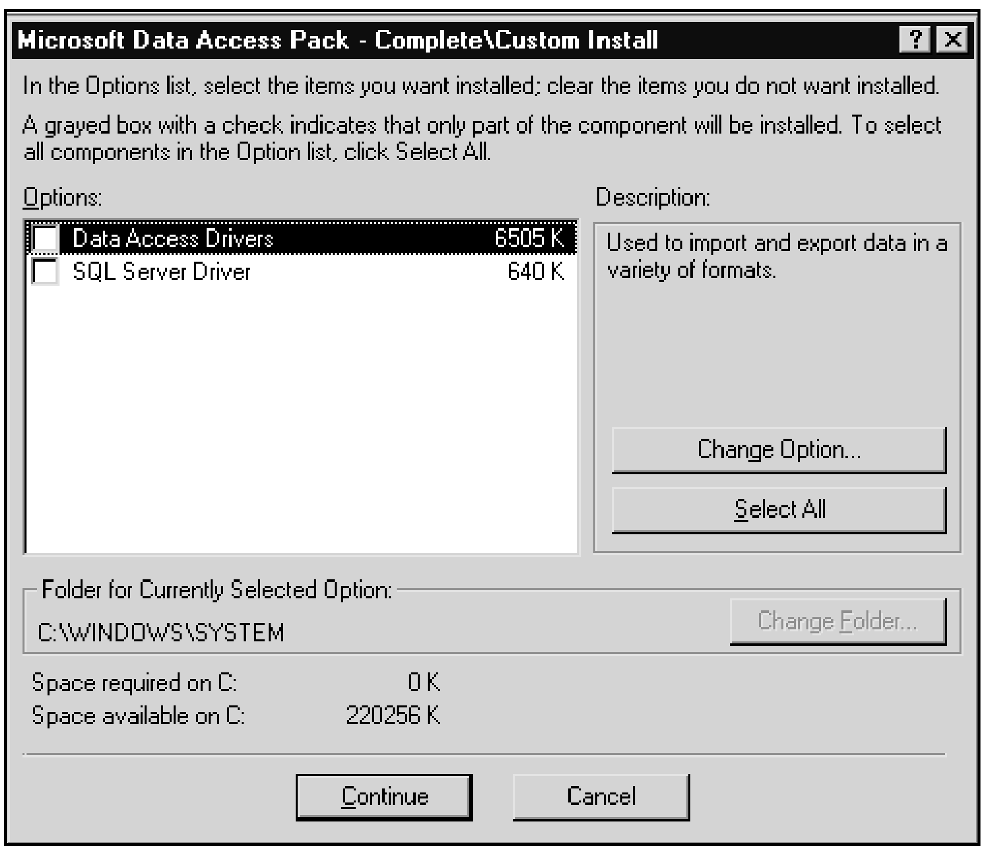

Figure 3 A Dialog Box in ODBC Installation

If this is not your first time installing MEADEP, make sure you have the most recent version of ODBC. To do this, click the ODBC icon in your Window's Control Panel and under the "ODBC Drivers" tab, check to see if you have at least the Microsoft Access Driver 3.50 or later. If you do not have this driver or you cannot find the ODBC icon or the ODBC Driver tab, run the "DATAACC.EXE" program found under the MEADEP program directory and follow the instructions given above.

When the installation is completed, you should restart your computer to ensure that new settings take effect. After you restart your system, you should find the following programs under your MEADEP menu.

- Data Editor & Analyzer
- Data Pre-Processor
- Model Evaluator
- Model Generator

2.2 Examples

This section runs through some examples that will help you get familiar with MEADEP's modules. The "Example" directory included in the MEADEP package contains example files that you can use to help you learn about MEADEP.

2.2.1 Data Editor and Analyzer (DEA) Examples

First, run the Data Editor & Analyzer (DEA) module found under the MEADEP menu. After the DEA main form appears, choose the "Open" command under the File menu. If this is your first time opening the "Plant" example database, follow these instructions:

1. In the "Select Data Source" box, under the "Machine Data Source" tab, click "New".
2. In the "Create New Data Source" box, select either the "User Data Source" or the "System Data Source" option and click Next. If you are running Windows NT, and you choose the "User Data Source" option, then other users must use the same logon as you to see this data. However, if you choose the "System Data Source" option, than other users can also access the data even if they use a different logon.
3. Then, select the "Microsoft Access Driver" and click Next and then Finish.
4. In the "ODBC Microsoft Access 97 Setup" box, enter the name of the data source. For clarity, we suggest you use "MEADEP Example Database" as the data source name. Click "Select".
5. Go to the \MEADEP\Example directory (unless you specify otherwise) and pick the database called "Plant.mdb" and click "OK" twice.
6. Select the new data source you just created ("MEADEP Example Database") in the "Machine Data Source" tab and press "OK".
7. In the "Choose Table Name" box, choose the "Channel" table and click "OK".

If you have already created a data source by following the above steps, to re-open it, just do steps 6 and 7 after choosing "Open" under the File menu.

This database is in the MEADEP data format and contains information on component failures in an assumed digital safety system in a plant for a period of two years (1995/1/1 to 1996/12/31).

When you open this database in DEA, the DEA main form will display the first record of the database. The database contains 12 records (shown on bottom of form), each record corresponding to a single failure. A record has fields which contain information about the failure. For example, the first failure (i.e. record 1) was a hardware failure. The component that failed was the Central Processing Unit (CPU). It occurred once (Count field) on February 1, 1995 and lasted for 1 hour. A coverage value of “1” means that the failure was compensated by switching to another standby component. Now, let us run through some of DEA’s graphical and analytical capabilities.

Event Pie Chart

First, we’ll generate an event pie chart (Section 3.3.1 in this manual) for the 4 top items in the Component field. This means that the 4 items that occur the most times in the component field will be graphed. To do this, follow these instructions:

1. Select the “Event Pie Chart” option in the Graphical-Analysis menu
2. Under “Select a field by which to draw chart” choose “Component” and click “OK”.
3. Specify “4” for the number of top items and click “OK”.

The event pie chart as shown in Figure 4 will appear displaying the four top items in the Component field and what percentage of times they appear. The figure shows that number of events for IO, CPU, Power and OS is 4, 4, 2 and 2, respectively.

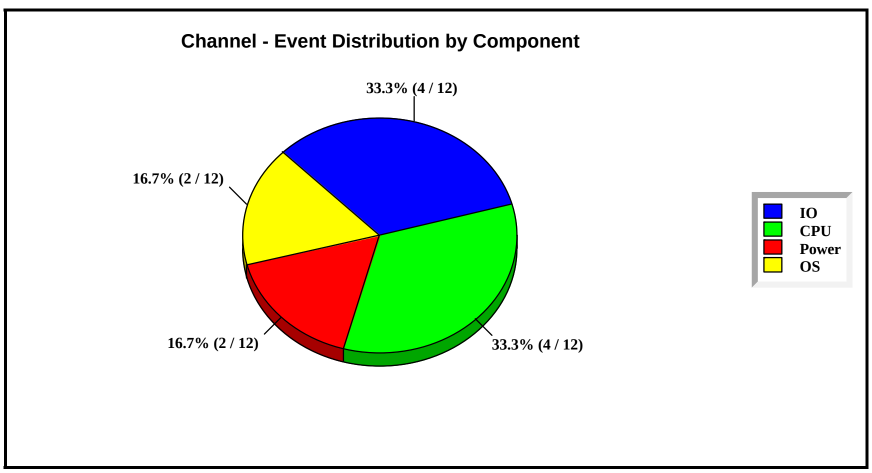

Figure 4 Example of Event Pie Chart

Duration Pie Chart

Similar to the above example, we can generate an duration pie chart (Section 3.3.2 in this manual) for the items in the Component field. This means that the outage time for each item in the component field will be graphed. To do this, follow these instructions:

1. Select the “Duration Pie Chart” option in the Graphical-Analysis menu
2. Under “Select a field by which to draw chart” choose “Component” and click “OK”.
3. In the next dialog box, click “OK”.

The duration pie chart as shown in Figure 5 will appear displaying the outage times and their percentage for the four items in the Component field. The figure shows that the outage time for Power, IO, CPU and OS is 8, 6, 4 and 2 hours, respectively.

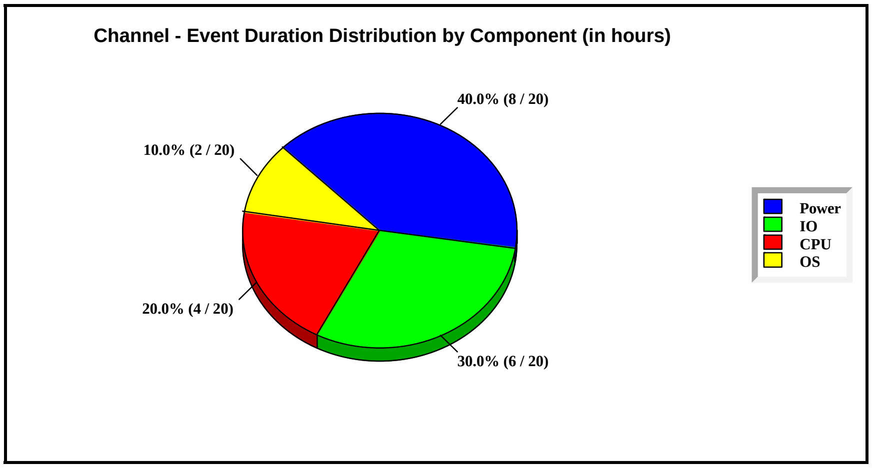

Figure 5 Example of Duration Pie Chart

MTBE Line Graph

For the last graphical analysis example, let us graph a Mean Time Between Events (MTBE) Line Graph.

1. Select the “MTBE Line Graph” option in the Graphical-Analysis menu.

2. Choose a value of 0.8 for the confidence level (for information on “confidence level, see Section 3.3.5 in this manual). Also, enter the amount of time to be considered in the calculation. For this example, let us pick a time interval from January 1, 1995 to December 31, 1996. Finally, enter “3 months” for the time between plotted points and click “OK”.

The line graph with it’s upper and lower bounds will be displayed as shown in Figure 6. For more information on MTBE line graphs, see Section 3.3.5 in this manual.

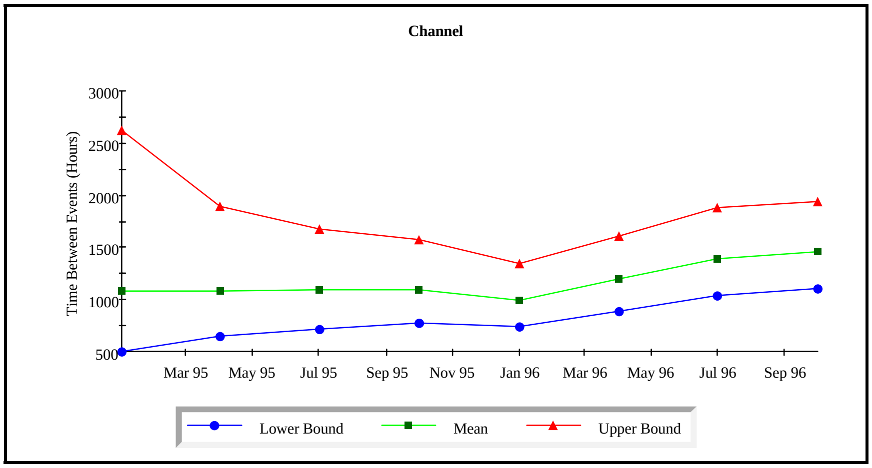

Figure 6 Example of MTBE Line Graph

Failure Rate

Now we'll move on to a parameter analysis example. First, let us calculate the failure rate for the CPU component and its upper and lower bound values. Choose the "Failure Rate" option under the Statistics-Estimation menu (Section 3.4.3 in this manual). Specify a confidence level of 0.8 and click "OK". Then, in the "Specification of Criteria in Selecting Records" box, enter "CPU" in the "Component" field. This selection will only include those failures that occurred in the CPU in the calculation. After clicking "OK", the "Iteration Specification" box will appear with some resulting calculations. The number of events selected should be 4 and the total elapsed time should be 8352 hours. This means that 4 out of the 12 failures occurred in the CPU component and that from the first CPU failure to the last CPU failure, there were 8352 hours.

Where MEADEP asks you to add additional records to be included in the statistic, choose "No" (unless you are interested in adding more records) and the failure rate with its upper and lower bound values will be displayed. You can bind these results to parameters in a text modeling file by choosing the "Insert into Modeling File" option. When you choose this option, you will be asked to open the desired modeling file (*.mdt) and you will be given detailed instructions on how to bind these results to parameters in the file. See Section 6.1 in this manual for information on text modeling files.

Multiple Statistics

Now we show how to obtain multiple statistics for multiple queries by running a query file. For more information on multiple statistics and query files, see Sections 3.4.6 and 3.4.7 in this manual. First choose "Multiple Statistics" option under "Batch-Processing" menu. Then specify a confidence level of 0.8 and click "OK". In the "Open" box, select file "Plant.bch" under the "Example" subdirectory in your MEADEP program directory and open it. Multiple statistics results for failures of two types - Software and Hardware - and of four components - OS, CPU, IO, and Power - will be displayed on the screen as shown in Figure 7 below. You can click the scroll bar on the screen to view these six groups of statistics.

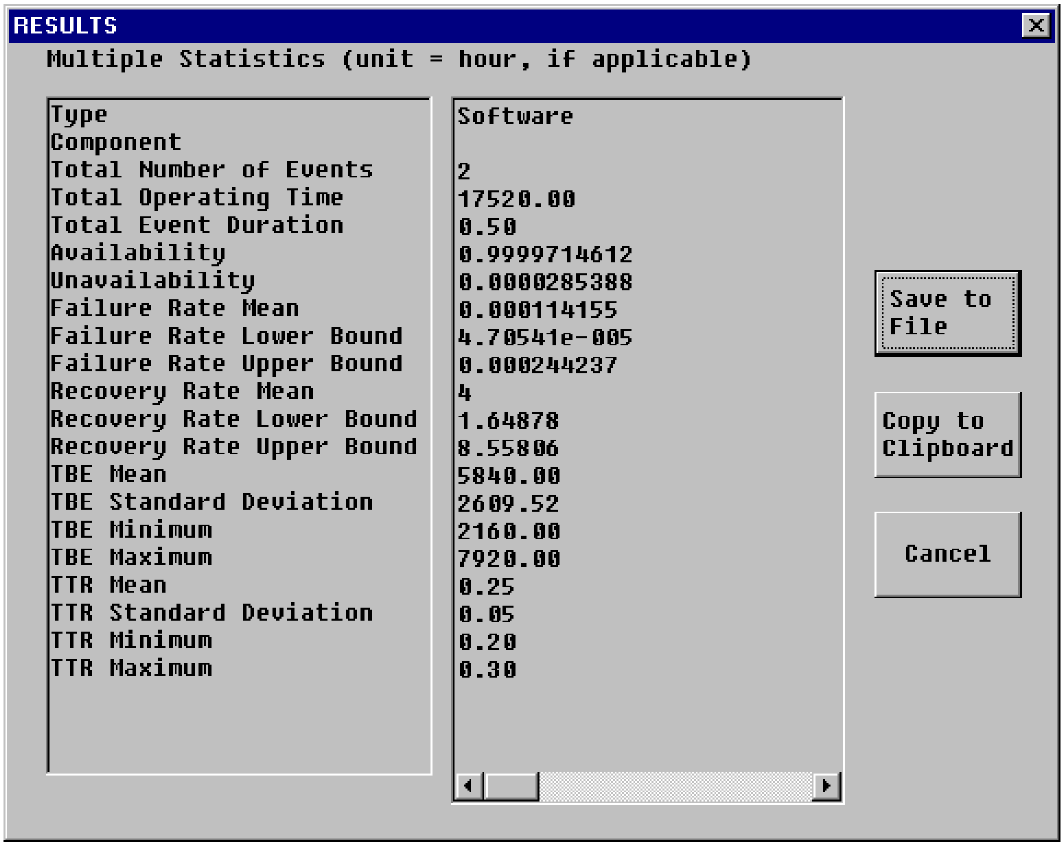

Figure 7 Example of Multiple Statistics Results

The “Plant.bch” you just used is a simple text file. It contains the following query specifications (Section 3.4.7 discusses the format and keywords that can be used in a query file):

```
StartDate   1995/01/01
EndDate     1996/12/31
Type        Software

StartDate   1995/01/01
EndDate     1996/12/31
Type        Hardware

StartDate   1995/01/01
EndDate     1996/12/31
Type        Software
Component   OS

StartDate   1995/01/01
EndDate     1996/12/31
Type        Hardware
Component   CPU
```

```
StartDate   1995/01/01
EndDate     1996/12/31
Type        Hardware
Component   IO

StartDate   1995/01/01
EndDate     1996/12/31
Type        Hardware
Component   Power
```

TBE and TTR Distributions

A distinguished advantage of MEADEP is its ability to identify if an empirical Time Between Events (TBE) or Time To Repair (TTR) distribution statistically matches one of the five commonly used probability distribution functions: exponential, gamma, Weibull, normal, and lognormal. When DEA displays a histogram (for more information on the histogram see Sections 3.3.3 and 3.3.4 in this manual) for a TBE or TTR distribution, it allows the user to super-plot, over the histogram, the above five analytical functions determined by the sample mean and sample variance. Meanwhile, the estimated parameters for these functions as well as the results of the Chi-Square (Chi) and Kolmogorov-Smirnov (KS) goodness-of-fit tests are also provided on the screen and automatically copied to the clipboard.

To show this capability, we now close the “Channel” table by clicking the File/Close command. Then we choose the File/Open command. Select “MEADEP Example Database” (the data source you created in Sec. 2.1.1) in the “Machine Data Source” tab and press “OK”. In the “Choose Table Name” box, choose the “Facility” table and click OK. You’ll see “Number of records in current selection: 1067" at the bottom of the DEA main window. This table contains outage data for facilities A, B, ..., H for a period over five years.

Now choose the Database-Operation/Query Records command. In the “Type” box, type “A” and then click “OK” to select all records for facility type A. You’ll see that 146 records are selected.

To identify TBE distribution for this facility:

1. Choose Graphical-Analysis/TBE Distribution
2. Click “OK” in the “Interval Specification” screen
3. Click “Draw Histogram” in the “TBE Distribution Results” screen
4. Click the “Exponential” , “Gamma” and “Weibull” buttons in the “Histogram Display” screen

The resultant screen is shown in Figure 8. You can see the TBE distribution better matches the Weibull function because it passed both the Chi and KS tests (>0.05) while the other two functions only passed the KS test.

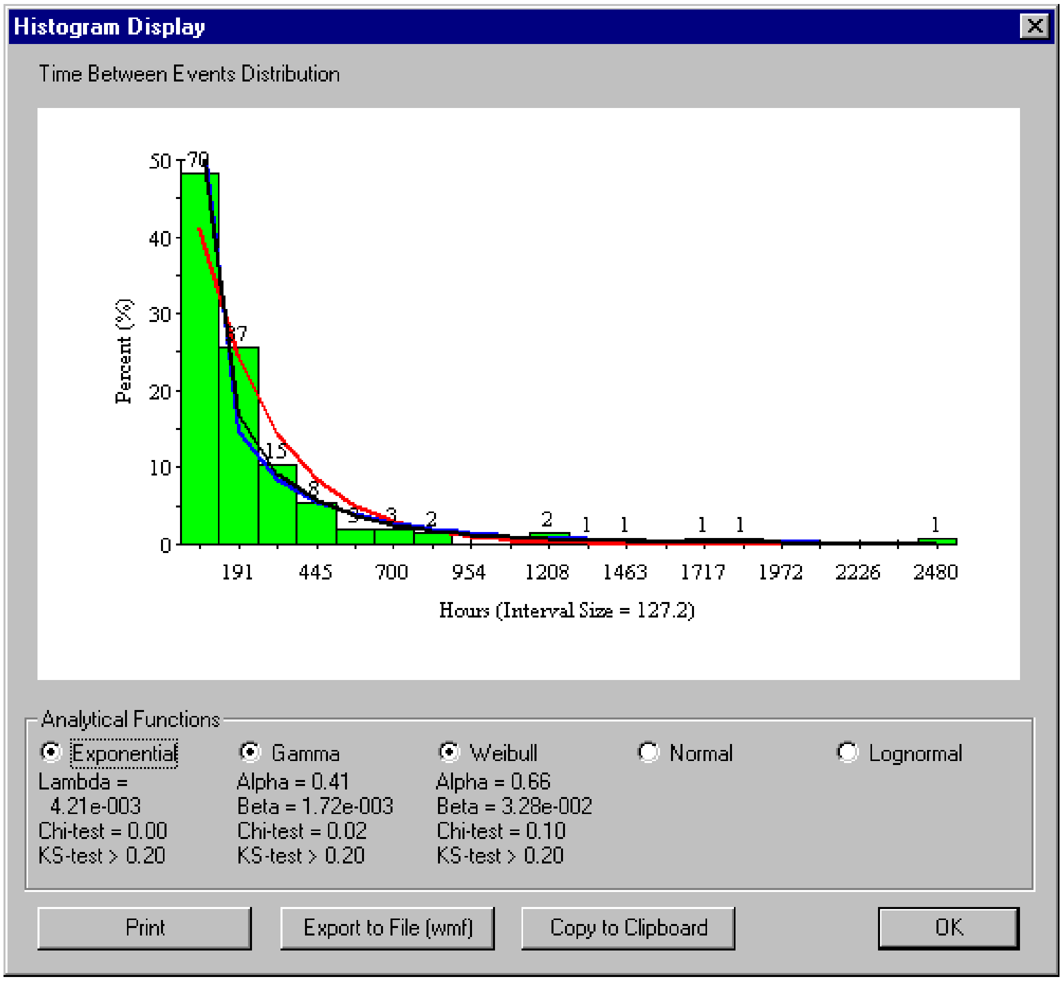

Figure 8 Identification of TBE Distribution

To identify TTR distribution for this facility:

1. Choose Graphical-Analysis/TTR Distribution
2. Click “OK” in the “Initial Value Specification” screen
3. Click “OK” in the “Interval Specification” screen
4. Click “Draw Histogram” in the “TBE Distribution Results” screen
5. Click the “Exponential” , “Gamma” and “Weibull” buttons in the “Histogram Display” screen

You can see the TTR distribution matches both the gamma and Weibull functions (both passed the Chi and KS tests) but does not matches the exponential function which failed to pass either Chi and KS tests.

2.2.2 Model Generator (MG) Examples

Text modeling files are generated from graphical models that are “designed” in the Model Generator (MG) module. Let us now run through a quick example on how to generate a text modeling file.

First, run MG from the MEADEP main menu. For our example, we will use an existing graphical modeling file named “Plant.mdg” found in the \MEADEP\Examples directory (for instructions on how to design graphical modeling files, see Section 5.1 in this manual). After you load up MG, open this file. The top level diagram (“Plant”) will appear on the screen. To expand to the lower level diagram (“SafSys”) choose “Expand” from the Diagram menu. The cursor will change to a magnifying glass with a “plus” sign inside it. Go to the frame (a box with the word “SafSys” inside it with a bunch of Greek fonts under it) and click inside it. This will take you to the lower level diagram called “SafSys”. Then, you can expand “SafSys” to see its lower level-diagram by expanding the “Channel” frame. The three diagrams are shown below. A detailed description of this model is given in Appendix A.

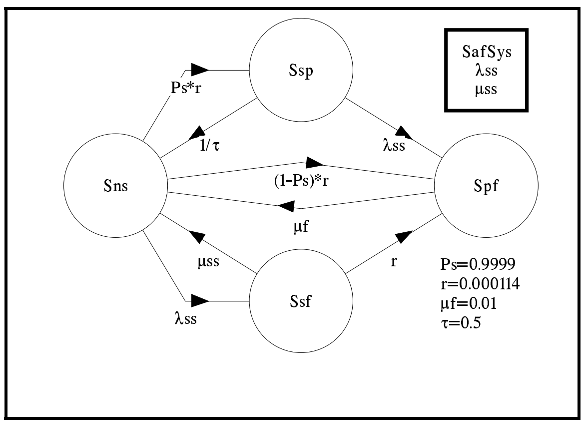

Figure 9 Diagram “Plant”

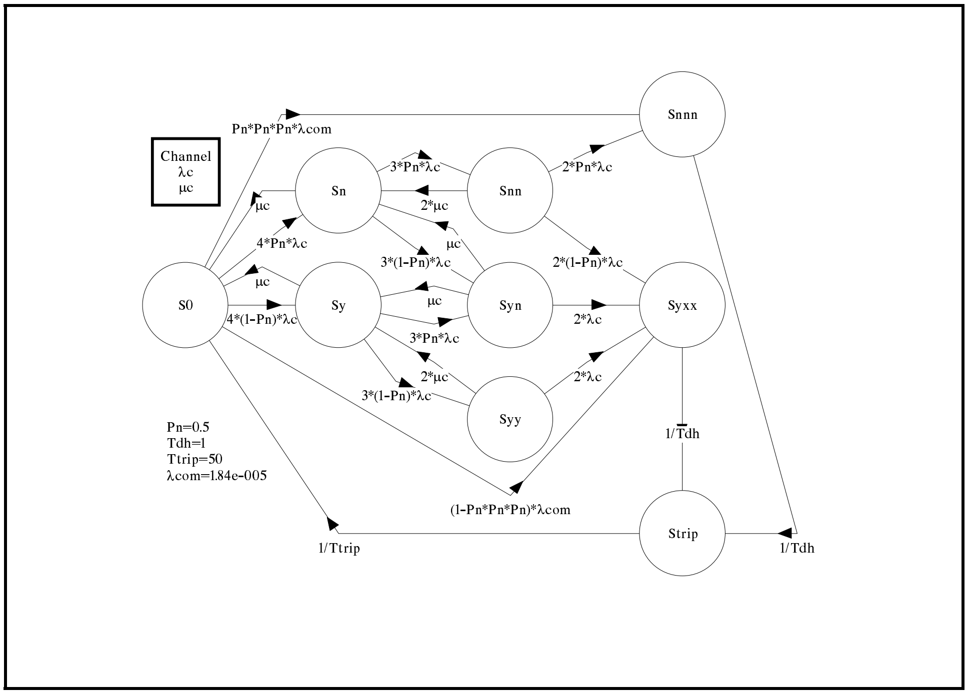

Figure 10 Diagram "SafSys"

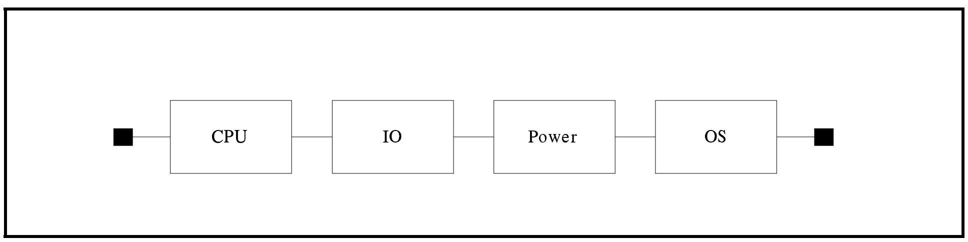

Figure 11 Diagram "Channel"

Now we'll generate the text modeling file. Choose the "Generate Text Modeling File" option in the File menu. A text modeling file for the "plant.mdg" model called "plant.mdt" is already included in the Example directory. You can overwrite this file or give the new generated file another name. After choosing the name and location of your text modeling file, click "Save". MG will validate the model and if it is valid you will be asked to:

- bind values to parameters in your model,
- enter the models/submodels you want to include in the output list of your text modeling file, and
- include any comments you want displayed before each model's/submodel's output results.

After completing the above procedures, MG will notify you that your new text file has been created.

2.2.3 Model Evaluator (ME) Examples

Now that we have a text modeling file, we'll generate some results using the Model Evaluator (ME) module. First, run ME from the MEADEP main menu and open the text modeling file you just created. It will appear on the screen. Let us first generate the Mean Time Between Failures (MTBF) results for the "Plant" submodel given a set of values for the "Ps" parameter. To do this, choose the "Loop by Value Set" command found in the Solution menu. When you run this command, you will be asked to specify a parameter and a set of values for the parameter. Specify "Ps" as your parameter and input a set of values as indicated. Because "Ps" is a probability, you can only choose values between 0 and 1. Let us choose:

- 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, and 0.7 as the set of values for "Ps",
- "Plant" for the model, and
- MTBF as your measure.

This selection will generate a box containing a set of values for the "Ps" parameter and their corresponding MTBF values. You will be able to graph the results and save the graph as a Windows Metafile (*.wmf) for inputting into other programs. The graph is shown in Figure 12.

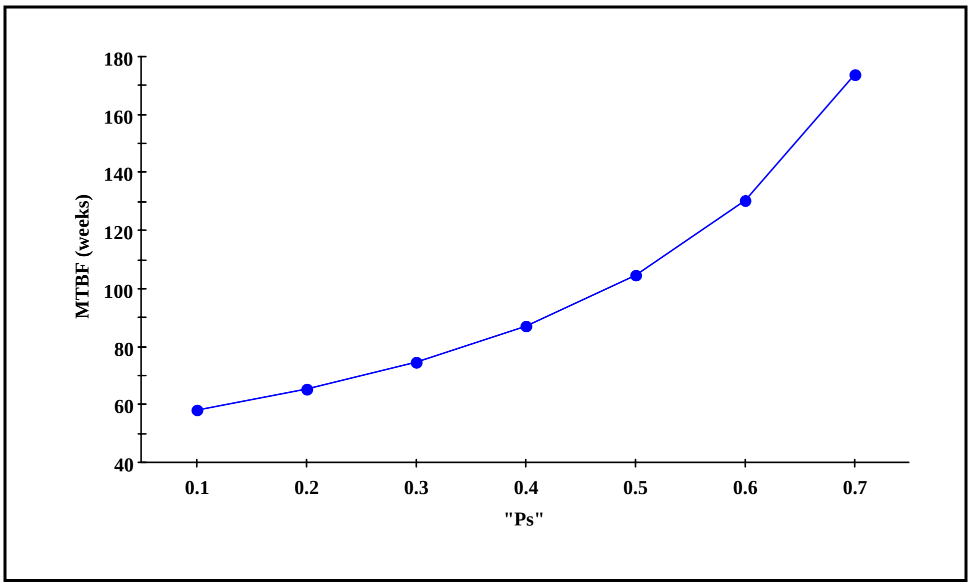

Figure 12 Example of "Loop By Value Set" Generated Graph

For the last example, let's generate the failure rate, restoration rate, availability, and unavailability results for our model. You can calculate **all** these measures with one simple command. This command is the "Regular Results" command found in the Solution menu. After you choose this command, *the above results will be displayed for only those submodels that are listed in the output specification section of the text modeling file.* You will be given a choice to copy these results to the clipboard and to save them as a text file.

3. Data Editor and Analyzer (DEA) Module

The Data Editor and Analyzer (DEA) module works on data and performs statistical analysis on it. The results of DEA's statistical analysis can be graphed or bound to parameters that are found in text modeling files (created in the Model Generator module). Figure 13 shows DEA's Main Menu commands. These commands will individually be explained in later sections.

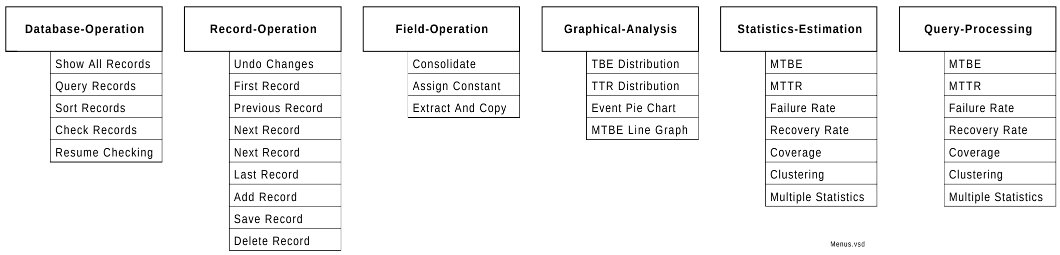

Figure 13 DEA's Main Menus

DEA has three major functions:

Data Editing- Data Editing includes correctness checking for data formatting, querying records, sorting records, adding records, deleting records, undo changes, consolidating fields, saving records, assigning a constant string to a field and more.

Graphical Analysis- Graphical Analysis can generate pie-charts for event distributions, histograms for Time Between Events (TBE) or Time To Recovery/Repair (TTR) distributions, and progressive curves for Mean Time Between Failures (MTBF) and its confidence interval over the time axis. Graphical analysis can be specified by the user through multiple window dialogs.

Parameter Estimation- Parameter Estimation provides the mean, upper and lower bounds at a specified confidence level for the following: Mean Time Between Failures (MTBF), Mean Time To Recovery/Repair (MTTR), failure rate, recovery/repair rate, and fault-tolerance coverage. Estimates are also given even if failures are rare. These estimates can then be inserted into a text modeling file for binding to model parameters. Parameter estimation can be specified by the user through multiple window dialogs and can also be specified by a predefined query command file (Section 3.4.7).

***Please note: Before doing any Graphical Analyses or Parameter Estimations for the first time, you should run the "Check Records" command (Section 3.2.3). This command will normalize the date field and avoid incorrect results.

3.1 Getting Started

In order for DEA to run successfully, MEADEP must be fully installed. To run the DEA module, go to the MEADEP program group in the Windows Program menu and select the DEA menu item. You can also create a DEA shortcut for quicker and easier accessability. See your Windows Manual on how to do this.

When you first run DEA, the main form used in DEA for viewing and editing database records appears. This form is shown below.

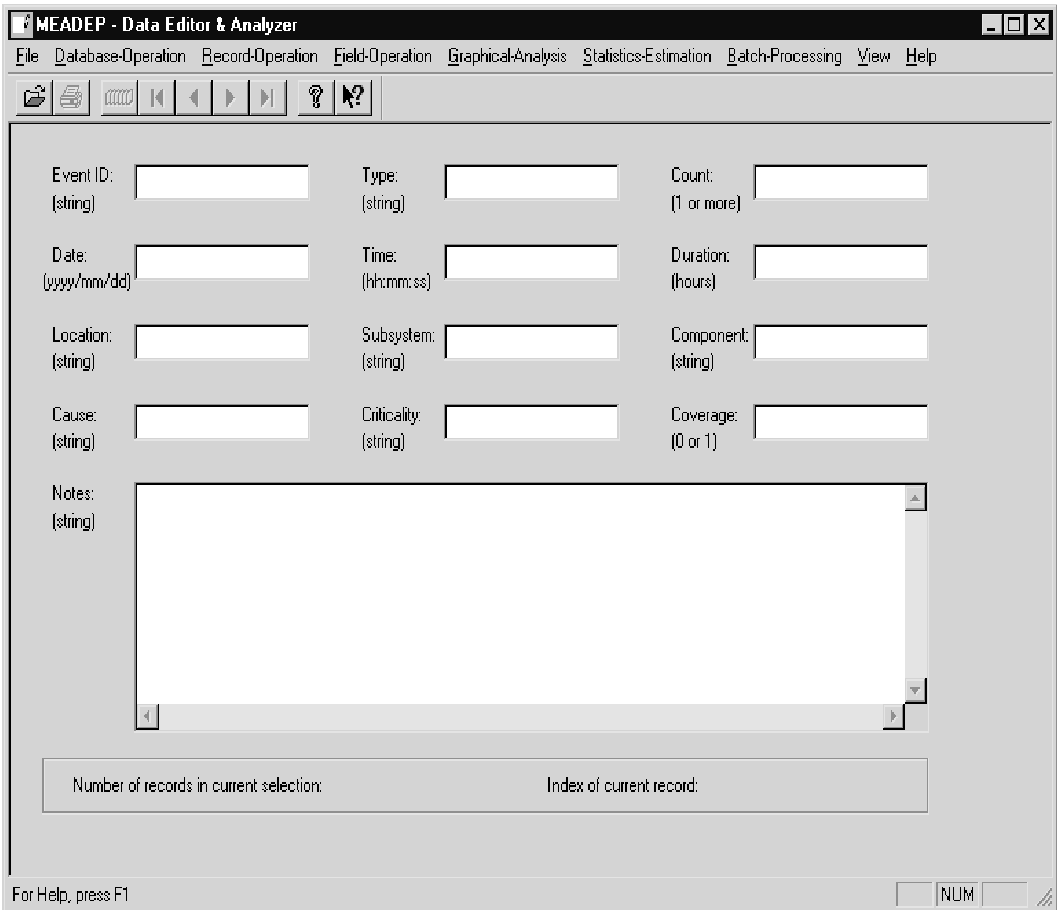

Figure 14 DEA's Main Form

The form remains blank until a database is opened or created. Afterward, the main form will display the data for all MEADEP-defined fields (listed in the table below) in the current record. You can scroll back and forth through records and edit records using the commands described in the Data Editing section of this report (Section 3.2). The total number of records in the database and the index of the record currently displayed are always shown at the bottom of this form.

The database fields displayed on DEA's main form are listed and described in the following table:

Field Name	Description	Format/Units	Comments
Event ID	Identification of the event	String	Limited to 512 characters
Date	Date on which the event occurred	yyyy/mm/dd	Stored as a string
Time	Time at which the event occurred	hh:mm:ss	Stored as a string
Duration	Duration of the event	Hours	Stored as a “double” number
Type	Type of the event	String	Limited to 512 characters
Location	Where the event occurred	String	Limited to 512 characters
Subsystem	Subsystem in which the event occurred	String	Limited to 512 characters
Component	Component in which the event occurred	String	Limited to 512 characters
Cause	Cause of the event	String	Limited to 512 characters
Criticality	Degree in which the event impacted the system	String	Limited to 512 characters
Coverage	Indication if the failure event has been covered by redundancy provisions	0 or 1	Stored as an integer
Count	Number of occurrences of the event	1 or more	Stored as an integer
Notes	Description for or comments on the event	String	Limited to 4096 characters

Creating MEADEP-formatted Databases in DEA and DPP

In order for DEA to analyze the data, the data must be in the MEADEP required format. You can generate a database with this required format in two ways.

1. If the data is already stored in an existing non MEADEP-formatted database then you should first run the MEADEP Data Pre-Processing (DPP) module which converts your database’s current data format into the MEADEP required format (see the DPP section in this user’s manual).

2. If you don’t have an existing database, you can create a MEADEP formatted database using DEA itself. This option is useful when your source data are hand-written event logs. Following these instructions will help you do that.

2. Choose File Open.
2. Choose New under the “Machine Data Source” tab.

3. In the “Create New Data Source” box, select either the “User Data Source” or the “System Data Source” option and click Next. If you are running Windows NT, and you choose the “User Data Source” option, then other users must use the same logon as you to see this data. However, if you choose the “System Data Source” option, than other users can also access the data even if they use a different logon.
4. Then, select the “Microsoft Access Driver” and click Next and then Finish.
5. In the “ODBC Microsoft Access 97 Setup” box, select “Create” and enter the database’s name and location.
6. Choose “OK”.
7. Enter information about the data source, such as its name and description.
8. Choose “OK”.
9. In the Select Data Source box, choose the data source you just created under the “Machine Data Source” tab and Choose “OK”.
10. Choose “Create New Table” and enter the table’s name.
11. Choose “OK” twice.

A blank form will be displayed and in order to enter data into your new database, you will have to add a new record and start inputting the data (see Section 3.2.6 for more information).

Opening MEADEP-formatted Databases in DEA

To open an existing database in DEA that is in the MEADEP required format and has a data source, do the following:

1. Choose “Open” under the File menu.
2. Select the data source in the “Machine Data Source” tab and press “OK”.
3. Then, in the “Choose Table Name” box, choose the table you wish to open and click “OK”.

The first record in the database should appear on the screen.

The following sections describe the data editing commands that DEA provides.

3.2 Data Editing Commands

DEA provides data editing and record manipulation commands for querying, sorting, checking, inserting, deleting, editing, and copying records. The following sections describe each of these commands and functions in further detail.

3.2.1 Querying Records

The “Query Records” command is used for selecting a set of records from the DEA database. The “Query Records” command can be found in the Database-Operation menu. Queries are performed from the dialog box shown in Figure 15. The keywords for specifying search criteria are explained below:

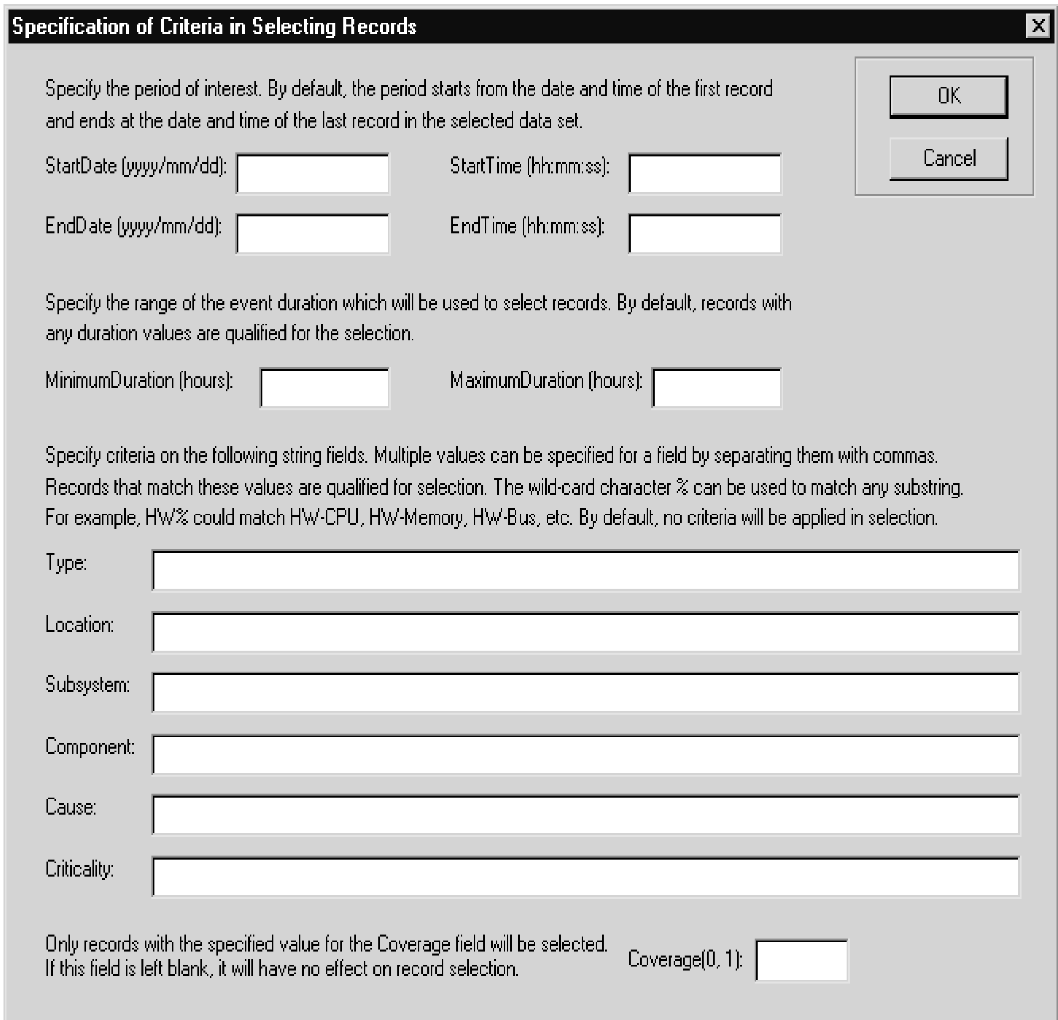

Figure 15 Query Form

StartDate, *StartTime*, *EndDate*, *EndTime*: Records whose Date and Time fall in the period between the time point determined by StartDate and StartTime and the time point determined by EndDate and EndTime meet these criteria. If no values are specified for these four keywords, no criteria will be applied to the *Date* and *Time* fields in selecting records. In this case, for the purpose of estimating statistics, the default StartDate and StartTime will be the Date and Time values of the first record in the selection, and the default EndDate and EndTime will be the Date and Time values of the last record in the selection.

MinimumDuration, *MaximumDuration*: Records whose Duration value is between MinimumDuration and MaximumDuration meet these criteria. If both MinimumDuration and MaximumDuration are zero (default value), no criteria will be applied to the Duration field in selecting records.

Type, Location, Subsystem, Component, Cause, Criticality, Coverage: These keywords are actual field names of the MEADEP data schema. If values are specified for a field, the selected records must match the specified values. If no value is specified for a field, no criteria will be applied to that field in selecting records. In the value specification, the wildcard % can be used. For example, ABC% will match any strings starting with ABC.

Copies: This keyword is meaningful only for commands in the Statistics-Estimation menu. The value of Copies represents the number of systems from which the data were collected (and thus the measurement time should be multiplied by this number).

3.2.2 Sorting Records

The "Sort Records" command can be found in the Database-Operation menu. Use this command to sort all records in the database. You will be asked to specify up to three fields as sort criteria. The sort command will sort the records in ascending order.

3.2.3 Checking Records

The "Check Records" command can be found in the Database-Operation menu. Use this command to check the correctness of the format for all records in the database. You should run this command immediately after converting a database to the MEADEP format with the DPP module (see Section 4). The command will normalize the "Date", "Time", and "Notes" fields and avoid incorrect results. This operation can be aborted at any point in the database and later continued with the "Resume Checking" command found in the same menu.

3.2.4 Resume Checking

The "Resume Checking" command can be found in the Database-Operation menu. Use this command to continue an aborted run of the "Check Records" command from the point of interruption.

3.2.5 Moving Through Your Database

In the Record-Operation menu, you are given the following four choices for moving through the database:

First Record —This command goes to the first record in the current database.

Last Record — This command goes to the last record in the current database.
Next Record — This command goes to the next record in the current selection. This command will be disabled if you are currently viewing the last record.
Previous Record — This command goes to the previous record in the current database. This command will be disabled if you are currently viewing the first record.

3.2.6 Adding Records

The “Add Record” command can be found in the Record-Operation menu. Use this command to add a new record to the currently opened or created database.

3.2.7 Deleting Records

The “Delete Record” command can be found in the Record-Operation menu. Use this command to delete the record currently displayed on the screen from the database.

3.2.8 Undo Changes

The “Undo Changes” command can be found in the Record-Operation menu. This command refreshes the screen and discards any changes made to the current record. It also cancels the “Add Record” command if the new record has not yet been saved.

3.2.9 Save Record

The “Save Record” command can be found in the Record-Operation menu. Use this command to save the newly created record to the database. To save any changes made to an already existing record, just move to the previous or next record.

3.2.10 Consolidate Command

The “Consolidate” command can be found in the Field-Operation menu. Consolidation means replacing a set of one or more distinct values with one single value. For example, if inconsistent nomenclature are used (“Black”,”Blk”,”B”) then these can be consolidated into a single category. Consolidation can also be used to aggregate more detailed information into higher level categories. For instance, if you want to consolidate the “Location” field by grouping the locations by region, this command could be used to replace California, Nevada, Arizona, and Oregon with the string West (see Figure 16 below). You will be asked to select a field, to choose a set of source values from among all existing values in that field, and to specify a destination value to substitute for the chosen set of source values.

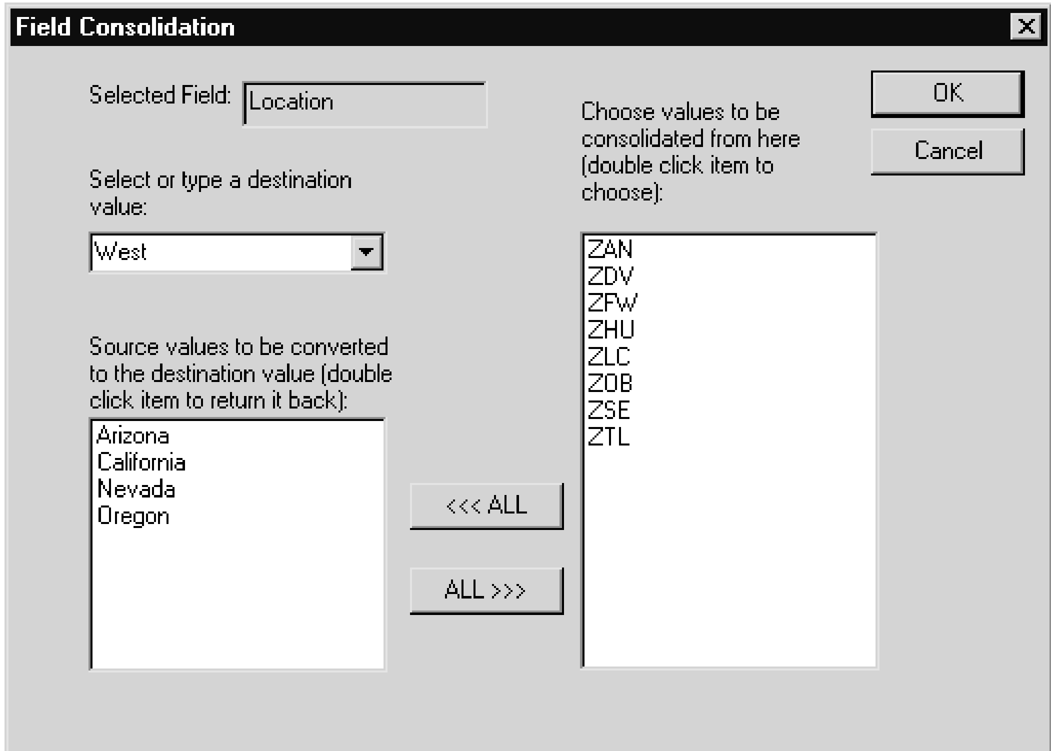

Figure 16 Consolidate Form

3.2.11 Assign Constant

The "Assign Constant" command can be found in the Field-Operation menu. Use this command to assign a constant string to a field. You will be asked to select a field and to specify a string to replace or to append to the current values in the selected field for every record. If you click the Replace button, then the string entered in the text box will replace the contents of the selected field **in every record of the current selection**. If you click the Append button, then the string entered will be appended to the contents of the selected field **in every record of the current selection**.

3.2.12 Extract and Copy Command

The "Extract and Copy" command can be found in the Field-Operation menu. Use this command to extract a substring (or the whole string) from a field and copy or append it to another field. You will be asked to:

- Select a source field and a destination field
- Specify the start position and length of the substring that will be extracted from the source data
- Click the Replace or Append button to perform the operation.

3.3 Graphical Analysis

The graphical analysis functions of DEA allow for the presentation of MEADEP data in any of the following formats:

- Pie-charts for event distributions
- Histograms for Time Between Events (TBE) and Time To Recovery/Repair (TTR) distributions
- Progressive curves for Mean Time Between Events (MTBE) and its confidence interval over the time axis.

Graphical analysis can be specified by the user through multiple window dialogs as described in the following sections.

3.3.1 Event Pie Chart

The “Event Pie Chart” Distribution command can be found in the Graphical-Analysis menu. This command generates a pie chart for the distribution of events according to the data contained in a particular database field. Events can be filtered by first invoking the Query command from the Database-Operation menu (Section 3.2.1). When the Event Pie Chart command is invoked, you will be asked to specify the database field for which the distribution is to be charted and to choose whether to chart the distribution of events relating to a ‘Single Item’ in the specified field or relating to ‘Top Items’ in this field. If ‘Single Item’ is chosen, you are then going to be asked to select the item from those items available in the specified field. If ‘Top Items’ is chosen, you will be asked (in the “Choose a Value” box) to select the number of high frequency items to distinguish in the distribution.

The Event Pie Chart command also enables you to:

- Print the pie chart directly to a printer
- Output the pie chart to a Windows metafile or
- Copy the pie chart to the clipboard for pasting into another application.

An example of event pie chart is shown in Figure 4.

3.3.2 Duration Pie Chart

The “Duration Pie Chart” Distribution command can be found in the Graphical-Analysis menu. This command generates a pie chart for the distribution of cumulative event duration according to the data contained in a particular database field. Events can be filtered by first invoking the Query command from the Database-Operation menu (Section 3.2.1). When the Event Pie Chart command is invoked, you will be asked to specify the database field for which the distribution is to be charted and to choose whether to chart the distribution of event duration relating to a ‘Single Item’ in the specified field or relating to ‘Top Items’ in this field. If ‘Single Item’ is chosen, you are then going to be asked to select the item from those items available in the specified field.

If ‘Top Items’ is chosen, you will be asked (in the “Choose a Value” box) to select the number of high duration items to distinguish in the distribution.

The Duration Pie Chart command also enables you to:

- Print the pie chart directly to a printer
- Output the pie chart to a Windows metafile or
- Copy the pie chart to the clipboard for pasting into another application.

An example of duration pie chart is shown in Figure 5.

3.3.3 Time Between Events (TBE) Distribution Histograms

The “Time Between Events” (TBE) Distribution command can be found in the Graphical-Analysis menu. This command generates a histogram for the Time Between Events distribution of events. Before using this command, you should select the appropriate record set. This set can be selected by invoking the Query command from the Database-Operation menu (Section 3.2.1). When the TBE Distribution command is invoked, a box will appear prompting you to specify the number of intervals and the interval size.

After you specify the above, click “OK”. The “TBE Distribution Results” box should appear, displaying the following parameter results:

- TBE Count — Number of TBEs.
- TBE Mean — Average TBE value (In Hours)
- TBE Maximum — Maximum TBE value (In Hours)
- TBE Minimum — Minimum TBE value (In Hours)
- TBE Variance — The formula for the TBE Variance (*S*) is shown below (In Hours)

$$S^2 = \frac{\sum_{i=1}^{N} (TBE_i - Mean)^2}{N}$$

- Histogram Data — Consisting of the number of TBEs and their corresponding interval midpoint values

If desired, you can edit these results and copy them to the clipboard for use in another application. Once you click “Draw Histogram”, a histogram graph similar to the one in Figure 17 below will appear.

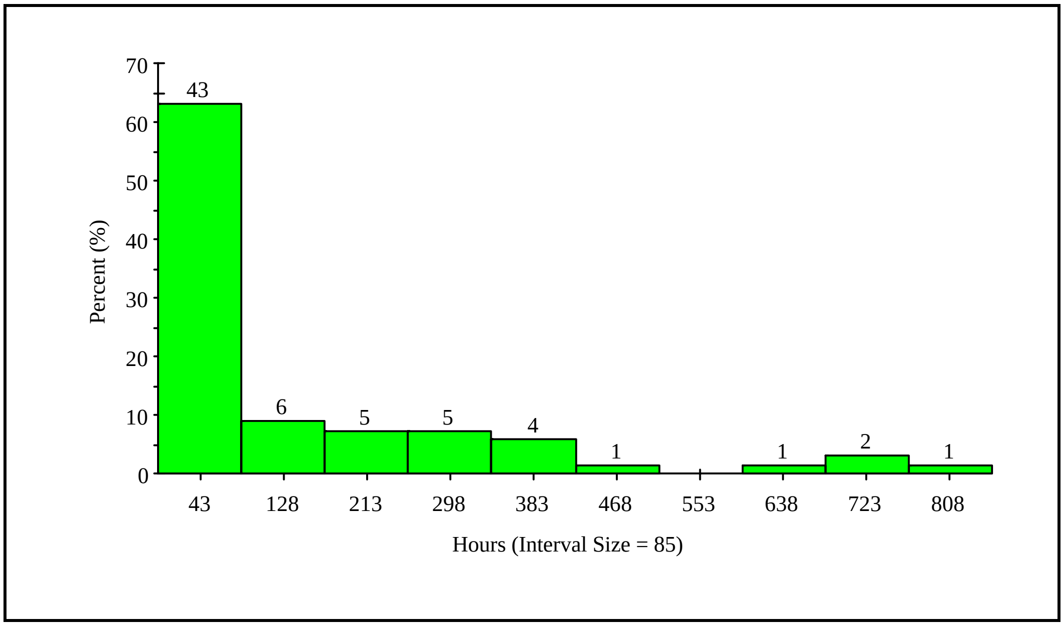

Figure 17 TBE Distribution Histogram

In this particular graph, you see that there are 43 TBE values in the range of 0 to 85 hours. These values constitute ~63% of the total number of TBE instances. Also, you can see that for the range of 85 to 170 hours, there are 6 TBE values which constitute ~9% of the total number of TBE instances. And so on.

Once the results have been graphically displayed on the screen, you can "superimpose" the exponential, gamma, Weibull, normal and lognormal PDF (Probability Density Function) curves on the screen. The display of each of these curves can be individually toggled on and off via independent radio buttons. The curves are determined by the sample mean and the sample variance. Superimposing these curves will allow you to see if the histogram is close to one of the five analytical functions.

In addition, the estimated parameters for these functions as well as the results of the Chi-Square and Kolmogorov-Smirnov goodness-of-fit tests are displayed. The Chi-Squared test and Kolmogorov-Smirnov goodness-of-fit test are two statistical methods which measure how well the analytical distribution calculated by MEADEP fits the empirical distribution estimated from the data. The results for each test provided by MEADEP is the significance level at which the assumption that the empirical distribution matches the analytical distribution cannot be rejected. A significance level of 0.05 is the minimum value typically used for acceptance.

3.3.4 Time To Recovery/Repair (TTR) Distribution Histogram

The "Time To Recovery/Repair" (TTR) Distribution command can be found in the Graphical-Analysis menu. This command generates a histogram for the Time To Recovery/Repair distribution of events. Events can be filtered by first invoking the Query command from the Database-Operation menu (Section 3.2.1). When the TTR

Distribution command is invoked, you will first be asked to specify a default recovery/repair time to be used for event records that lack this information. The default value as 0.5 hours is used if no input is provided. Once a default value is given and you click “OK”, a box will appear prompting you to specify the number of intervals and the interval size.

After you specify the above, click “OK”. The “TTR Distribution Results” box should appear, displaying the following parameter results:

- TTR Count — Number of TTRs.
- TTR Mean — Average TTR value (In Hours)
- TTR Maximum — Maximum TTR value (In Hours)
- TTR Minimum — Minimum TTR value (In Hours)
- TTR Variance — The formula for the TTR Variance (*S*) is shown below (In Hours)

$$S^2 = \frac{\sum_{i=1}^{N} (TTR_i - Mean)^2}{N}$$

- Histogram Data — Consisting of the number of TBEs and their corresponding interval midpoint values

If desired, you can edit these results and copy them to the clipboard for use in another application. Once you click “Draw Histogram”, a histogram graph similar to the one in Figure 14 will appear.

As was the case with the TBE Distribution, once the results have been graphically displayed on the screen, you will be given options to superimpose the exponential, gamma, Weibull, normal and lognormal PDF (Probability Density Function) curves on the screen. The display of each of these curves can be individually toggled on and off via independent radio buttons. The curves are determined by the sample mean and the sample variance. Superimposing these curves will allow you to see if the histogram is close to one of the five analytical functions.

In addition, the estimated parameters for these functions as well as the results of the Chi-Square and Kolmogorov-Smirnov goodness-of-fit tests are displayed. The Chi-Squared test and Kolmogorov-Smirnov goodness-of-fit tests are two statistical methods which measure how well the analytical distribution calculated by MEADEP fits the empirical distribution estimated from the data. The results for each test provided by MEADEP is the significance level at which the assumption that the empirical distribution matches the analytical distribution cannot be rejected. A significance level of 0.05 is the minimum value typically used for acceptance.

3.3.5 Mean Time Between Events (MTBE) Line Graph

The Mean Time Between Events (MTBE) command can be found in the Graphical-Analysis menu. This command generates a line graph of the Mean Time Between Events, and its upper and lower bounds at a specified confidence level. You will be asked to specify a confidence level and to select a set of records (based on *start time*, *end time*, *start date*, and *end date*) for the estimation.

The confidence level is a value between .5 and .99 which represents the user's desired confidence that an actual mean will be guaranteed to fall somewhere between the upper and lower bounds/curves calculated by the program. Please take note that the confidence level **does not** affect the calculation of the mean itself. The closer the confidence level is to .99, the larger the gap will be between the upper and lower bounds/curves, thereby giving greater assurance that the actual mean will fall somewhere between them.

After you have inputted all your desired Range Specifications, you are now ready to generate the line graph. You can do this by clicking "OK". The resulting values are calculated by the chi-squared function and the exponential distribution is assumed in estimating upper and lower bounds.

Once the chart is displayed on the screen, buttons will appear just below the chart. These buttons enable you to:

- print the chart
- output the chart to a Windows metafile or
- copy it to the clipboard for pasting into another application.

3.4 Parameter Estimation

Three parameters can be estimated from data by DEA:

- Failure Rate and Mean Time Between Events (MTBE)
- Recovery/Repair Rate and Mean Time To Recovery/Repair (MTTR)
- Coverage

For these parameters, MEADEP estimates the following three quantities:

- the point estimate
- the lower bound at a user-defined level of confidence and
- the upper bound at a user-defined level of confidence

DEA enables you to insert these estimates into a text modeling file for binding to model parameters (see Section 6.1). Parameter estimation can be specified by the user through multiple window dialogs (query sessions) and can also be specified by a predefined query command file. See Section 3.4.7 for a detailed description on query files.

3.4.1 Mean Time Between Events (MTBE)

This command can be found in both the Statistics-Estimation menu and Query Processing menu. Use this command to estimate the Mean Time Between Events, and its upper and lower bounds at a specified confidence level.

When you run this command, you will be first prompted to specify a confidence level (see Section 3.3.4). Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the “Specification of Criteria in Selecting Records” form (similar to the Query command discussed in Section 3.2.1). Then, you will be prompted to choose whether you want to include any additional records in the analysis. If you choose “No,” then the results will be displayed. However, if you choose “Yes,” the “Specification of Criteria in Selecting Records” form will be displayed again, where you will be able to select the additional records. After completing your record selection, choose “OK” and the results will be displayed.

When results are displayed on the screen, you will be given an option to open a text modeling file (*.mdt files produced in the Model Generator Module) and to bind (i.e. used to set the value of) the results to parameters in the file.

3.4.2 Mean Time To Recovery/Repair (MTTR)

This command can be found in both the Statistics-Estimation menu and Query Processing menu. Use this command to estimate Mean Time To Recovery/Repair, and its upper and lower bounds at a specified confidence level. In order for DEA to calculate the required results, you will be asked to:

- specify a confidence level (see Section 3.3.4)
- define a default value for the Recovery/Repair time for those records which do not contain the event duration information (a suggested value is provided)
- choose whether to use a normal distribution or an exponential distribution (needed for the calculation of the upper and lower bounds)

Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the “Specification of Criteria in Selecting Records” form (similar to the Query command discussed in Section 3.2.1). Then, you will be prompted to choose whether you want to include any additional records in the analysis. If you choose “No,” then the results will be displayed. However, if you choose “Yes,” the “Specification of Criteria in Selecting Records” form will be displayed again, where you will be able to select the additional records. After completing your record selection, choose “OK” and the results will be displayed.

When results are displayed on the screen, you will be given an option to open a text modeling file (*.mdt files produced in the Model Generator Module) and to bind the results to parameters in the file.

3.4.3 Failure Rate

This command can be found in both the Statistics-Estimation menu and Query Processing menu. Use this command to estimate the Mean Failure Rate, and its upper and lower bounds at a specified confidence level.

When you run this command, you will be first prompted to specify a confidence level (see Section 3.3.4). Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the “Specification of Criteria in Selecting Records” form (similar to the Query command discussed in Section 3.2.1). Then, you will be prompted to choose whether you want to include any additional records in the analysis. If you choose “No,” then the results will be displayed. However, if you choose “Yes,” the “Specification of Criteria in Selecting Records” form will be displayed again, where you will be able to select the additional records. After completing your record selection, choose “OK” and the results will be displayed.

When results are displayed on the screen, you will be given an option to open a text modeling file (*.mdt files produced in the Model Generator Module) and to bind the results to parameters in the file.

3.4.4 Recovery/Repair Rate

This command can be found in both the Statistics-Estimation menu and Query Processing menu. Use this command to estimate the mean recovery/repair rate, and its upper and lower bounds at a specified confidence level. In order for DEA to calculate the required results, you will be asked to:

- specify a confidence level (see Section 3.3.4)
- define a default value for the Recovery/Repair time for those records which do not contain the event duration information (a suggested value is provided)
- choose whether to use a normal distribution or an exponential distribution (needed for the upper and lower bounds confidence limit calculation)

Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the “Specification of Criteria in Selecting Records” form (similar to the Query command discussed in Section 3.2.1). Then, you will be prompted to choose whether you want to include any additional records in the analysis. If you choose “No,” then the results will be displayed. However, if you choose “Yes,” the “Specification of Criteria in Selecting Records” form will be displayed again, where you will be able to select the additional records. After completing your record selection, choose “OK” and the results will be displayed.

When results are displayed on the screen, you will be given an option to open a text modeling file (*.mdt files produced in the Model Generator Module) and to bind the results to parameters in the file.

3.4.5 Coverage

This command can be found in both the Statistics-Estimation menu and Query Processing menu. Use this command to estimate fault tolerance (or failure) coverage, and its upper and lower bounds at a specified confidence level. Coverage is the probability of failure detection and recovery given that a failure has occurred. The binomial distribution is assumed in estimating upper and lower bounds.

When you run this command, you will be first prompted to specify a confidence level (see Section 3.3.4). Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the "Specification of Criteria in Selecting Records" form (similar to the Query command discussed in Section 3.2.1). Then, you will be prompted to choose whether you want to include any additional records in the analysis. If you choose "No," then the results will be displayed. However, if you choose "Yes," the "Specification of Criteria in Selecting Records" form will be displayed again, where you will be able to select the additional records. After completing your record selection, choose "OK" and the results will be displayed.

When results are displayed on the screen, you will be given an option to open a text modeling file (*.mdt files produced in the Model Generator Module) and to bind the results to parameters in the file.

3.4.6 Multiple Statistics

The "Multiple Statistics" command can be found in both the Statistics-Estimation menu and Query Processing menu. This command is used to generate a set of commonly used statistics and dependability measures from the selected data.

When you run this command, you will be first prompted to specify a confidence level (see Section 3.3.4). Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the "Specification of Criteria in Selecting Records" form (similar to the Query command discussed in Section 3.2.1). After completing your record selection, choose "OK" and the following results will be displayed.

- *Total Number of Events*
- *Total Operating Time*: Elapsed time multiplied by the number of copies
- *Total Event Duration*: Sum of the event duration field of all selected records
- *Availability*: (Total Operating Time - Total Event Duration)/(Total Operating Time)
- *Unavailability*: (Total Event Duration)/(Total Operating Time)
- *Failure Rate Mean*: (Total Number of Events)/(Total Operating Time)
- *Failure Rate Lower Bound*: Assuming the failure arrivals follow an exponential distribution, this number represents the lowest failure rate that can be expected with the confidence level specified by the user.

- *Failure Rate Upper Bound*: Assuming the failure arrivals follow an exponential distribution, this number represents the highest failure rate that can be expected with the confidence level specified by the user.
- *Recover/Repair Rate Mean*: (Total Number of Events)/(Total Event Duration)
- *Recovery/Repair Rate Lower Bound*: Assuming the recovery/repair times follow an exponential distribution, this number represents the lowest recovery/repair rate that can be expected with the confidence level specified by the user.
- *Recovery/Repair Rate Upper Bound*: Assuming the recovery/repair times follow an exponential distribution, this number represents the highest recovery/repair rate that can be expected with the confidence level specified by the user.
- *TBE Mean*: Mean time between events occurring on any copy of the systems/components
- *TBE Standard Deviation*: The standard measure of the divergence of the times between events from the TBE mean
- *TBE Minimum*: The minimum time between events
- *TBE Maximum*: The maximum time between events
- *TTR Mean*: The average event duration (Time-To-Recovery/Repair)
- *TTR Standard Deviation*: The standard measure of the divergence of the event durations (Times-To-Recovery/Repair) from the TTR mean
- *TTR Minimum*: The minimum event duration (Time-To-Recovery/Repair)
- *TTR Maximum*: The maximum event duration (Time-To-Recovery/Repair)

3.4.7 Query Files

A query file is a text file that represents one or more query specifications. The file contains the same information that you would have entered in one or more query sessions (see Section 3.2.1 on Querying Records). Each command in the Query-Processing menu reads a query file created by the user prior to command execution. Query files are useful when well-defined reliability/availability analyses need to be run on multiple data sets (e.g. monthly failure data analysis).

The following is an example of a query file:

```
StartDate    95/6/12
EndDate      96/6/30
Type         G/G
Location     ZSE
Copies       8

StartDate    95/6/13
EndDate      96/6/30
Type         G/G
Location     ZLC
Copies       6

StartDate    95/8/5
EndDate      96/6/30
Type         G/G
Location     ZDV
Copies       8
```

```
StartDate     95/9/29
EndDate       96/6/30
Type          G/G
Location      ZAN
Copies        5

StartDate     95/10/27
EndDate       96/6/30
Type          G/G
Location      ZTL
Copies        10
```

This query file can be used to estimate the failure rate for the G/G type failures. The data were collected from five different locations: ZSE, ZLC, ZDV, ZAN, and ZTL. Each location has a different start date when the system started operation. Each system has a different number of the G/G components from which the data were collected.

A query file can contain one or more query segments, each separated by a single blank line. Each query segment is equivalent to a screen query specification. A query segment can have from one to 14 lines, each line starting with one of the following keywords:

- StartDate
- EndDate
- StartTime
- EndTime
- MaximumDuration
- MinimumDuration
- Type
- Location
- Subsystem
- Component
- Cause
- Criticality
- Coverage
- Copies

Following each keyword is one or more spaces. Then one or more values can be specified, depending on the field. For the keywords: StartDate, EndDate, StartTime, EndTime, MaxDuration, MinDuration, Coverage, and Copies, only one value can be specified. For all other keywords, one or more values can be specified.

The format for the StartDate or EndDate value is yyyy/mm/dd.

The format for the StartTime or EndTime value is hh:mm:ss.

The value for MaxDuration and MinDuration is a real number between 0 and 1,000,000 (hours).

The value for Coverage is either 0 or 1.

The value for Copies is an integer of 1 or greater. This value represents the number of systems or components from which the current selected data were collected.

For keywords: Type, Location, Subsystem, Component, Cause, and Criticality, multiple values can be specified where each value must be separated by a comma. The wild-card character, %, can be used to match any substring. For example, HW% can match HW-CPU, HW-Memory, HW-Bus, etc.

If any of the above keywords is not included in the segment, no restriction will be applied to the corresponding field in the record selection.

3.5 Clustering Analysis

This command can be found in both the Statistics-Estimation menu and Query Processing menu. Use this command to merge multiple events into clusters. A cluster is a group of one or more events, each occurring within a specified time interval of each other.

You will be asked to specify this time interval in days, hours, or minutes. Then, you will be asked to select a set of records. If you chose the command from the Statistics-Estimation menu, you will be asked to select a set of records from the "Specification of Criteria in Selecting Records" form (similar to the Query command discussed in Section 3.2.1). After completing your record selection, choose "OK" and the results will be displayed.

Otherwise, if you chose the command from the Query Processing Menu, you will be prompted to open a query file which would select a set of records for you (as indicated in the query file). Once you open the query file, the results will be displayed.

Results will be displayed in terms of Cluster Density (the number of events in a cluster). For each cluster density, the following information will be calculated:

- *Cluster-Count* — number of clusters with that cluster density
- *Average-Span* — average time span between the first and last events in clusters of that density and
- *MTBE-Within-Cluster* — Mean Time Between Events in all clusters of that density

Note: For a cluster density of one (clusters with only a single event), the values for Average-Span and MTBE-Within-Cluster are undefined, and are therefore left blank in the output.

4. Data Pre-Processor (DPP) Module

The Data Pre-Processor (DPP) Module enables you to translate existing reliability and failure databases (not in MEADEP format) to the MEADEP required format. Data formats supported by MEADEP include ASCII delimited text and a variety of databases such as Access, dBASE, and Paradox. MEADEP also supports other formats on your system which have existing Open DataBase Connectivity (ODBC) Drivers attached (for more information on ODBC see the web page in the following location: www.microsoft.com/odbc/wpapers/odbcbg.htm). MEADEP data are stored in records, where each record represents a single event, in the Access database format.

The following sections describe the data translation process and how to get started using the DPP module.

4.1 Getting Started

The first operation in DPP is to open an existing data source. A data source includes the data a user wants to access and the information needed to get to the data. A data source may contain information about a specific database (i.e. location, name) or can be a directory containing a set of files you want to access. To open an existing data source, do the following:

1. Choose "Select Source Database" under the File menu.
2. In the "Select Data Source" box, under the "Machine Data Source" tab, select the data source that contains the data that you want to convert into the MEADEP format and click "OK".
3. In the "Input Table Selection" box, select the table you wish to open.

After you have done the above procedures successfully, DPP's main form will pop up. DPP's main form is shown in Figure 18 below.

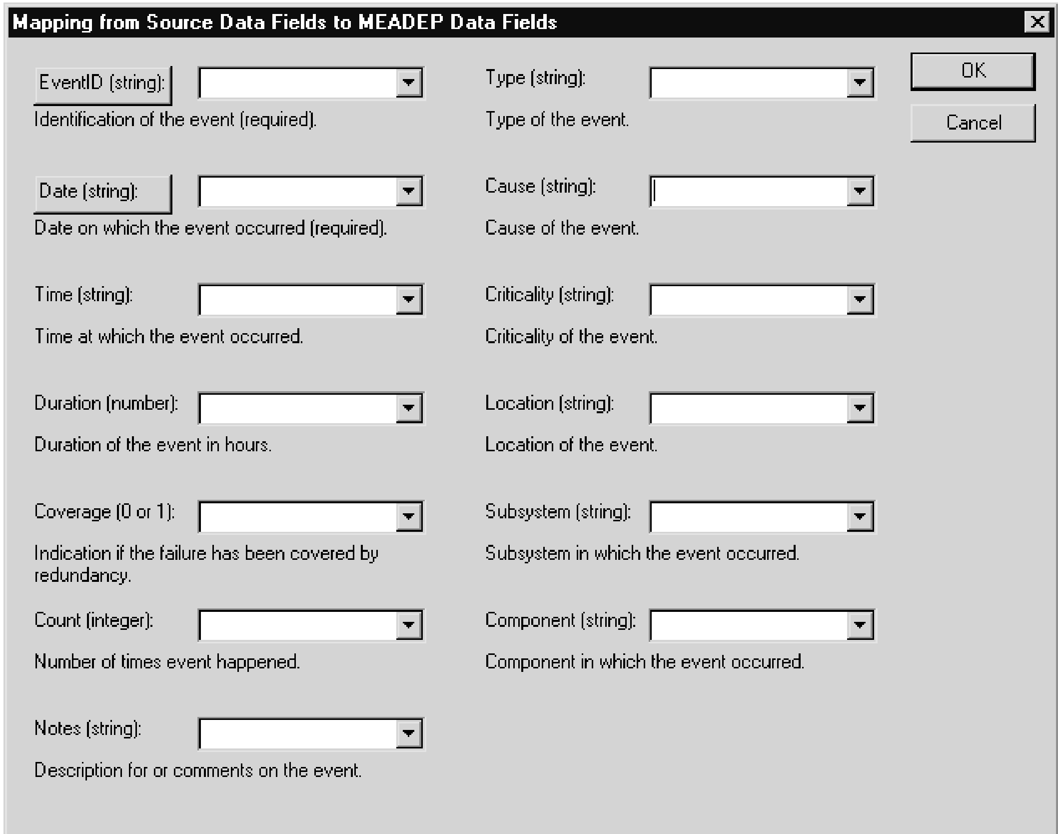

Figure 18 DPP's Main Form

4.2 Data Conversion

The data conversion performed by the DPP module is guided by a mapping between source data fields (fields in your database) and the MEADEP data fields. Figure 18 shows the MEADEP data scheme consisting of 13 fields. See Section 3.1 for a listing and description of these fields.

The main form enables you to map the fields in your database to the MEADEP specific fields shown on the form. Next to each field in the form is a text box with a down arrow. Clicking this arrow will display a list of all the fields that exist in your database. An example is shown in Figure 19 below.

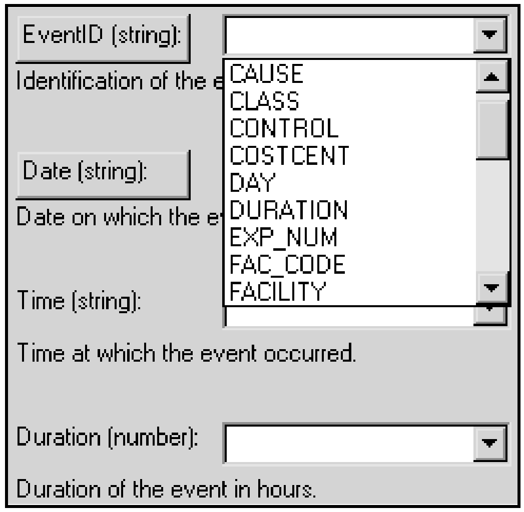

Figure 19 Mapping Fields

At a minimum, the “EventID” **and** “Date” fields have to be paired with an appropriate field from your database. Each field’s content must be in the format which is prescribed in parenthesis. After you are done assigning the desired fields, click “OK”. A box should appear telling you that you have finished the mapping process. It will also prompt you to open an Access database where it will be able to display the converted data. After clicking “OK”, go to the File menu and select the “Select Destination Database” command. The “Select Data Source” box will be displayed again. Under the “Machine Data Source” tab, you must choose an existing **Access data source** or create a new **Access data source** by pressing the “New” button.

If you choose an existing **Access data source**, then you will be prompted to choose from a table in the database or create a new one. If you choose from an existing table **(make sure that the table is in the MEADEP required format)**, then you will be given the option of overwriting the current data or appending to it.

Otherwise, if you choose to create a new **Access data source and database**, follow these instructions:

1. In the “Create New Data Source” box, select either the “User Data Source” or the “System Data Source” option and click Next. If you are running Windows NT, and you choose the “User Data Source” option, then other users must use the same logon as you to see this data. However, if you choose the “System Data Source” option, than other users can also access the data even if they use a different logon.
2. Then, select the “Microsoft Access Driver” and click Next and then Finish.
3. In the “ODBC Microsoft Access 97 Setup” box, select “Create” and enter the database’s name and location.
4. Choose “OK”.
5. Enter information about the data source, such as its name and description.

6. Choose “OK”.
7. In the Select Data Source box, choose the data source you just created under the “Machine Data Source” tab and Choose “OK”.
8. Choose “Create New Table” and enter the table’s name.
9. Choose “OK” twice.

This will start converting the data and will prompt you when complete.

Converting Date Information

Because of the large variety of date and time representations in existing databases, MEADEP provides you with the capability of parsing these formats to convert them into the appropriate form.

This command can be found in the Options menu and can be used to extract the necessary information from the current date field and convert it into the MEADEP required date format. Figure 20 shows the “Date Extraction” dialog box.

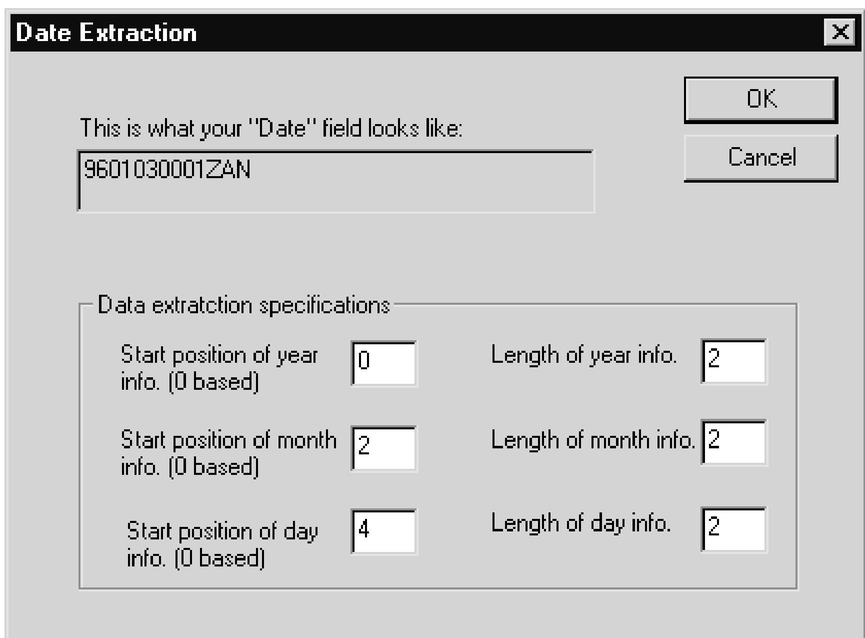

Figure 20 Date Extraction Dialog Box

In the figure above, an example is shown where the necessary date information is extracted from the current date field and converted into the MEADEP format. The “Date extraction specifications” are used to do this. In this particular example, the specified “start position” and “length” values will extract:

- “96” for the year
- “01” for the month

- “03” for the day

The result will be in the following MEADEP format: **1996/01/03**

After completing the conversion, you can open the database you created in the Data Editor and Analyzer (DEA) module and perform the desired operations.

5. Model Generator (MG) Module

The Model Generator (MG) is a graphical drag and drop interface for constructing reliability and availability models. A model is developed hierarchically, from the top level down. Each level can be one of the following:

- A diagram of serial or parallel reliability blocks including the k-out-of-n block (reliability block diagram)
- A diagram of weighted blocks including the k-out-of-n block (weighted block diagram)
- A Markov chain (Markov chain diagram)

Figure 21 shows an example of a model hierarchy that contains both Block and Markov diagrams.

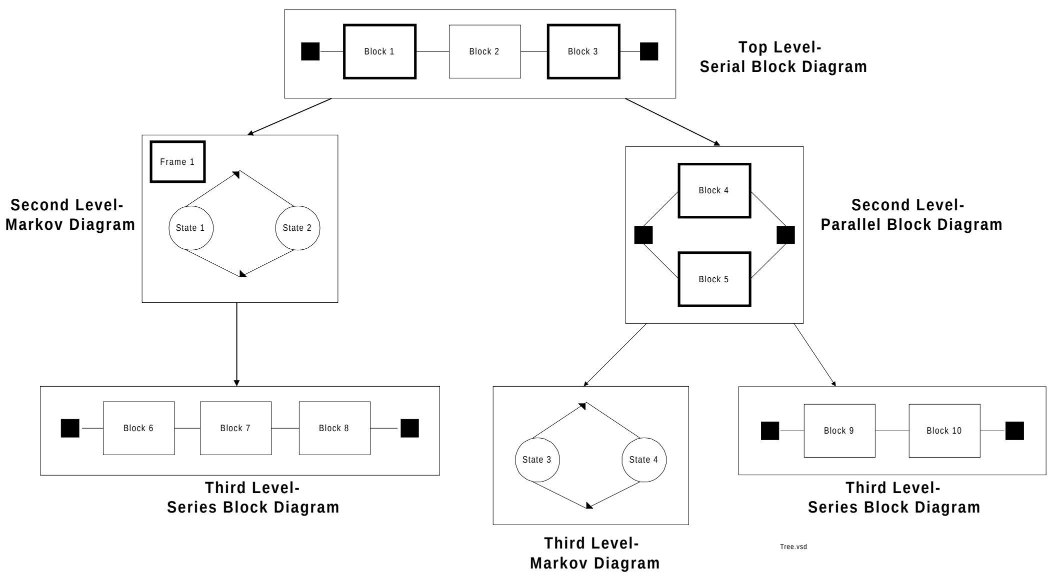

Figure 21 MEADEP Model Hierarchy Example

For a block diagram, you can draw blocks and links between blocks (see Section 5.1.1). For a Markov diagram (Section 5.1.2), you can:

- Draw states and transition arcs between states,
- Specify a reward value for each state,
- Specify a transition rate for each transition arc and
- Specify the initial state and the failure state for the model.

When the model construction is completed, the diagrams are saved in a graphical modeling file (*.mdg) for reuse.

From the model, MG can generate a text modeling file (*.mdt). This modeling file contains the model specifications which the Model Evaluator (ME) module uses to evaluate the model and obtain results (see Section 6.1 for more information on text modeling files).

MG is also capable of using pre-designed library files (*.mdl) for increasing productivity. A library file is a graphical modeling file that defines the structure of a dependability model but does not contain parameter values. This capability allows you to re-use previously developed and tested models and can greatly reduce model construction time (see Section 5.1.13 for more information on library files).

MG also allows you to save a model diagram as a Microsoft Windows metafile. This metafile can then be imported into word processors and other Windows programs.

5.1 Starting A Design

To start a new design, click the "New" command under the File menu. You will be presented with a dialog box asking you which type of diagram you want to create as your top-level diagram. After you choose the type of diagram, it will prompt you to give it a name. Then, the top level diagram window will be displayed. The next sections describe the type of diagrams you can choose from.

5.1.1 Block Diagrams

Both reliability block diagrams and weighted block diagrams are called *block diagrams*. A block diagram is a graphical method of depicting the components in a system and their connections in terms of functioning requirements. Each component can be represented by a block. A block can be a parent block which has a sub-diagram or an elemental block which has no sub-diagram.

Block diagrams must be in the following format:

- At least one block
- Exactly two terminals (source and destination)
- At least two links

5.1.1.1 Reliability Block Diagram

In a reliability block diagram, blocks may be connected in a serial pattern or a parallel pattern (see Figure 22 and Figure 23 below). If two or more blocks are connected in a **serial** system, this would require that **all** blocks be functional for the system to be functional. If two or more blocks are connected in a **parallel** system, this would require that at least **one** of the blocks be functional for the system to be functional. You cannot have part of the diagram in a serial pattern and part in a parallel pattern. However, you are able to model a series and parallel system as seen in Figure 24.

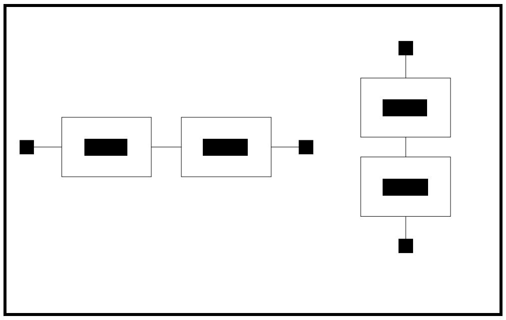

Figure 22 Blocks in Series

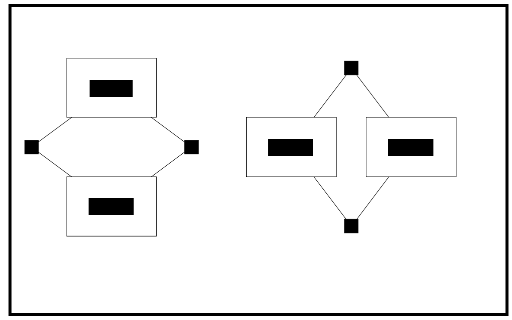

Figure 23 Blocks in Parallel

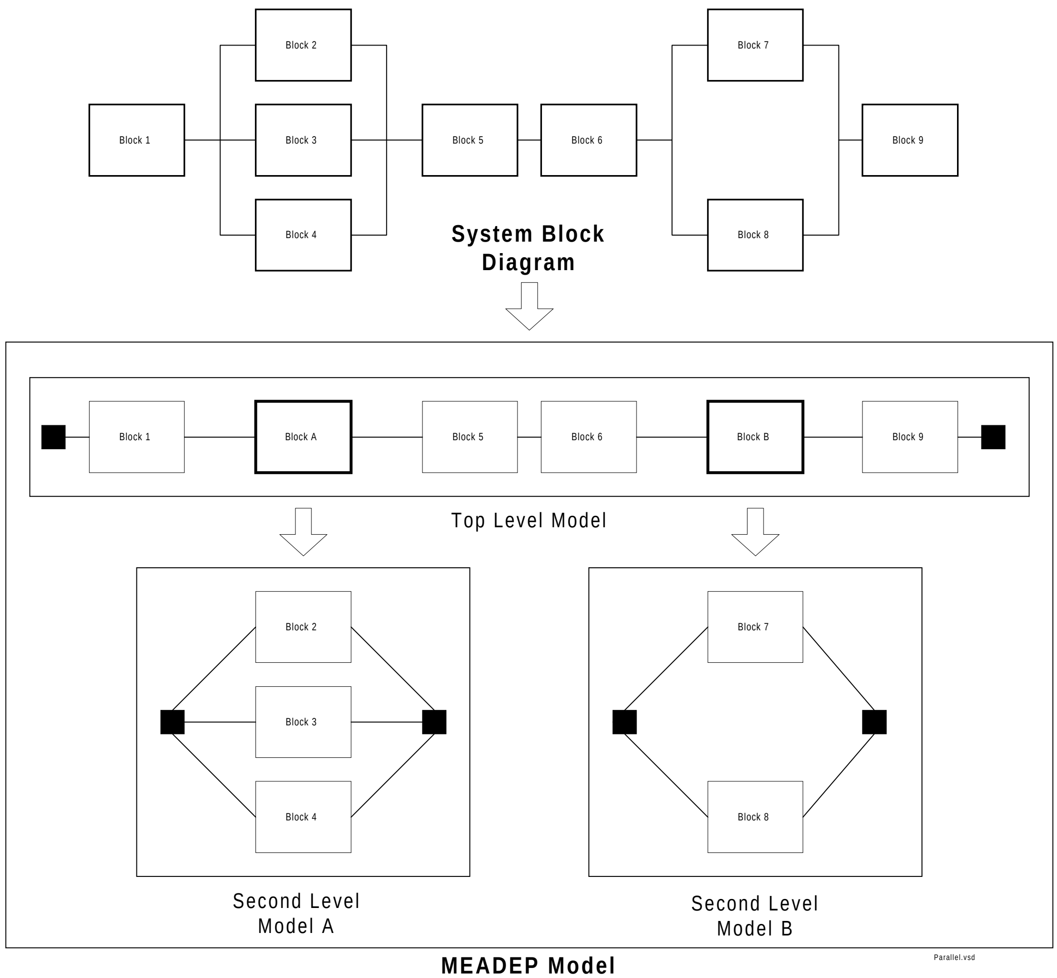

Figure 24 Modeling a Series and Parallel System in MEADEP

Block diagrams can only be drawn in one direction, starting from the source terminal and ending at the destination terminal.

Block diagrams can be expanded to lower level diagrams using expandable blocks (see Section 5.1.6).

5.1.1.2 Weighted Block Diagram

A weighted block diagram represents a system consisting of a number of components. Each component contributes to the system availability or reliability with a certain probability, or *weight*. For a weighted block diagram, the diagram level availability (or reliability), *A* (or *R*) is calculated by

$$A = W1*A1 + W2*A2 + \ldots + Wn*An$$

where *Wi* and *Ai* represent the weight and availability for component *i*.

In a weighted block diagram, each block represents a component. Blocks are connected by links in series, like a serial block diagram. To distinguish with the reliability block diagram, a link connecting two weighted blocks has a small circle at the center of the link. A weighted block diagram must have at least two block, exactly two terminals and links to connect between blocks and terminals. An example of weighted block diagram is shown in Figure 25 where λ, μ, and w represent failure rate, recovery rate, and weight, respectively.

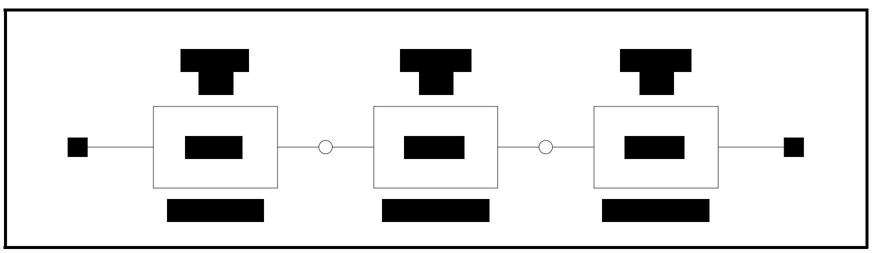

Figure 25 A Weighted Block Diagram

5.1.1.3 K-out-of-n Block Model

A k-out-of-n model is a model in which *k* out of the *n* components in the modeled system must operate for the system to operate properly. A “k-out-of-n” model can only be set to a parent block (which has a sub-diagram). There are two integer parameters associated with a k-out-of-n block: *k* and *n*. To set a block to the k-out-of-n model, just run the Set k-out-of-n Block command under the Options menu (see Section 5.1.13). You will be asked for the *n* and *k* values for the block. Note that *k* should not be greater than *n*.

5.1.2 Markov Chain Diagram

A Markov model consists of system states and transitions from one state to another. A system state represents a combination of both operational and failed components in the system. The system stays in a state for a random time, defined by an exponential distribution, and then goes into another state. A transition from one state to another state is characterized by a transition rate. A Markov model can be solved mathematically to obtain reliability and availability measures. For example, the expected proportion of time that the system spends in the failure states, which is called the system unavailability, can be calculated.

Markov diagrams must be in the following format:

- At least two states.
- At least one transition out of every state such that each state is connected to all other states directly or indirectly.
- Each transition must have a transition rate (see "Adding Transitions" Section 5.1.3.5).
- An initial state and a failure state must be specified for each Markov diagram.

For example, as you can see in the Markov diagram below (Figure 26), there are at least two states, at least one transition with its appropriate transition rate, an initial state and a final state. In this example, the parameter λ represents the failure rate and the parameter μ represents the recovery rate.

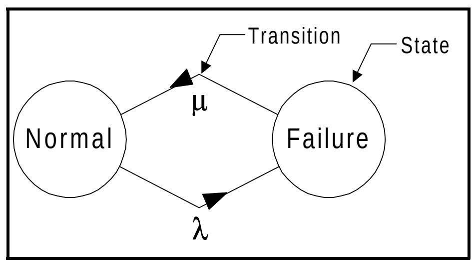

Figure 26 Markov Model

Since a system can be partially functioning (e.g., in a 4-processor system, one processor can fail while the other three processors can still be working), a reward value must be assigned to each state to reflect the system performance. A reward value of 1 means that the system is fully functioning. A reward value of 0 means that the whole system has failed. A reward value between 0 and 1 means that the system is partially functioning. The reward values will be used in the availability/reliability calculation by the ME module.

Markov diagrams can be organized hierarchically. That is, they can be expanded to lower level diagrams using frames (see Section 5.1.3.6). This hierarchical organization simplifies the model thereby facilitating understanding and reducing the likelihood of errors.

The following subsections describe some of the commands associated specifically with Markov Diagrams.

5.1.2.1 Edit Expression/Reward

The "Edit Expression/Reward" command can be found in the Options menu. Use this command to edit an expression belonging to a transition or a reward belonging to a state.

When you choose this command, the cursor will appear as an arrow with a question mark inside it. Go to the object you want to edit and click on it. For a transition, click on the transition arrow. A dialog box will appear enabling you to change the current value. Change the current value to the desired one and click "OK". If you changed a transition's expression, the new expression will be shown on the diagram.

5.1.2.2 Replace Parameter Names

The "Replace Parameter Names" command can be found in the Options menu. When you choose this command, the "Parameter Replacement" dialog box will appear. This box will enable you to edit the parameter names that are in the diagram. When this box appears, it will display a parameter. Edit the parameter and click "OK". Otherwise, if you don't want to edit it, click "Cancel". Another parameter will appear. Follow the above procedures until no other parameters are displayed. This command is particularly useful when you read a library file containing Markov models, because you normally want to change the parameter names in an imported Markov model.

5.1.2.3 Build Parameter-Value List

The "Build Parameter-Value List" command can be found in the Options menu. When you run this command, a list of all parameter names and associated values in the current Markov diagram will be displayed as a text object. Only those parameters which were assigned values will appear in the "Parameter-Value" list. For information about assigning parameters, see Section 5.1.11.

5.1.2.4 Set Initial State

The "Set Initial State" command can be found in the Options menu. A valid Markov model must have an initial state. An initial state is usually a normal, working state. Use this command to set the initial state for a Markov model. After you click this menu item, the cursor will appear as an arrow with a question mark inside it. Go to the state that you want to be the initial state and left click inside it. This state will now represent the initial state.

5.1.2.5 Set Failure State

The "Set Failure State" command can be found in the Options menu. A valid Markov model must have a failure state. A failure state is when a system fails to perform its function(s). Use this command to set the failure state for a Markov model. After you click this menu item, the cursor will appear as an arrow with a question mark inside it. Go to the state that you want to be the failure state and left click inside it. This state will now represent the failure state.

5.1.3 Adding Objects

Objects to be added to a diagram depend on the type of the diagram. As shown in Figure 27, a block diagram has blocks, terminals and links. As shown in Figure 28, a Markov diagram has states, transitions and frames. The following sub-sections describe these objects and how to add them.

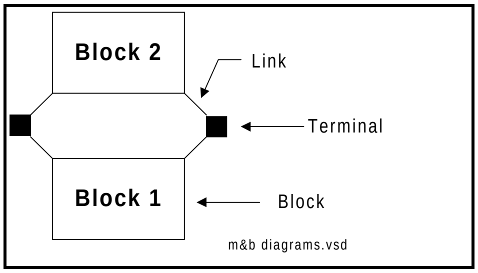

Figure 27 Block Diagram with Blocks, Terminals, and Links

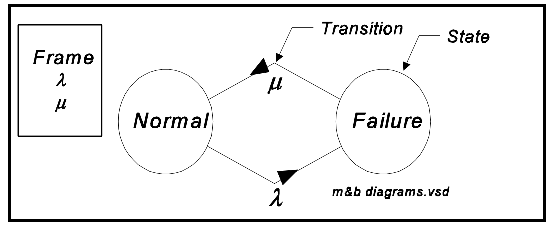

Figure 28 Markov Model with Frame, States, and Transitions

5.1.3.1 Adding Blocks

This command is only applicable in block diagrams. To add a block in a block diagram, choose the "New Block" command from the Items menu. You will be first asked to enter a name for the block. A name must start with a letter followed by up to 31 letters, digits, or underscores. After entering a name, you will be asked which of the following block types you want:

- Expandable block
- Constant block
- Exponential block
- Weibull block

An expandable block means that the block can later be expanded to a lower level diagram. It is initially not associated with any parameter. The other three block types are all elemental blocks which have no sub-diagrams. A constant block means that the block will be assigned an availability or reliability value (between 0 and 1 including 1) but cannot be expanded to lower levels. An exponential block is associated with a failure rate (λ) and a recovery rate (μ), and the failure arrival time is assumed to follow the exponential distribution determined by λ. A Weibull block is associated with two failure rate parameters (α and β) and a failure rate (μ), and the failure arrival time is assumed to follow the Weibull distribution determined by α and β. If you choose any of these three elemental blocks, you will be asked to enter values for the associated parameter in a following dialog box. Both exponential and Weibull blocks can later be expanded to a lower level diagram, but the associated parameters will be deleted. Any expanded block (which already has a sub-diagram) can be set to a k-out-of-n block.

After choosing the block type and entering parameters (for elemental blocks), the block will then appear on the screen waiting for your next command.

5.1.3.2 *Adding Terminals*

This command is only applicable in Block diagrams. To add a terminal to a block diagram, just choose the "New Terminal" command from the Items menu. The new terminal will appear on the screen where you will be able to move it and link it to other objects.

5.1.3.3 *Adding Links*

This command is only applicable in block diagrams. A link is used to connect two objects (block or terminal) in a block diagram. To add a new link in a block diagram, choose the "New Link" command from the Items menu. Then, click inside the source object and hold the button down. Drag the mouse to the destination object and release the button inside it. A link will then appear between the source object and destination object. When adding links, be sure to always add them in the same direction.

5.1.3.4 *Adding States*

This command is only applicable in Markov diagrams. A state is a status combination of all components in your system. To add a new state to a Markov diagram, choose the "New State" command from the Items menu and give it a name. You will then be asked to assign a reward value for the state (see Section 5.1.2 for an explanation on reward values).

5.1.3.5 *Adding Transitions*

This command is only applicable in Markov diagrams. A transition starts from a state and ends at another state. To add a new transition to the current Markov diagram, choose the "New Transition" command from the Items menu. Then, click inside the source object and hold the button down. Drag the mouse to the destination object and release the button inside it. You will then be asked to enter an expression for it. The expression represents the transition rate from the source state to the destination state and can contain numbers, parameters and operators.

- A number must be an integer or real number.
- A parameter must start with an English or Greek letter and can have up to 31 letters or digits. An underscore is also acceptable as part of the parameter string.
- An operator must be a +, -,*, /, or ^ for powers.

5.1.3.6 *Adding Frames*

This command is only applicable in Markov diagrams. A frame is what is used in a Markov diagram to expand to lower-level diagrams. To add a new frame to the current Markov diagram, choose the "New Frame (submodel)" command from the Items menu. You will be prompted to give it a name and to choose two parameters. The first is a failure rate and the second is a recovery/repair rate. Because the model is evaluated starting from the lowest level up, the values of the failure and recover/repair rates will be taken from the sub-diagram and assigned to the user-defined parameters in the parent-diagram.

For example, as you can see in the Markov diagram below (Figure 29), the parameter λ represents the failure rate and the parameter μ represents the recovery/repair rate. As we mentioned above, the values of the failure rate and recovery/repair rate will be taken from sub-diagram "Frame" and will be assigned to the parameters λ and μ, respectively.

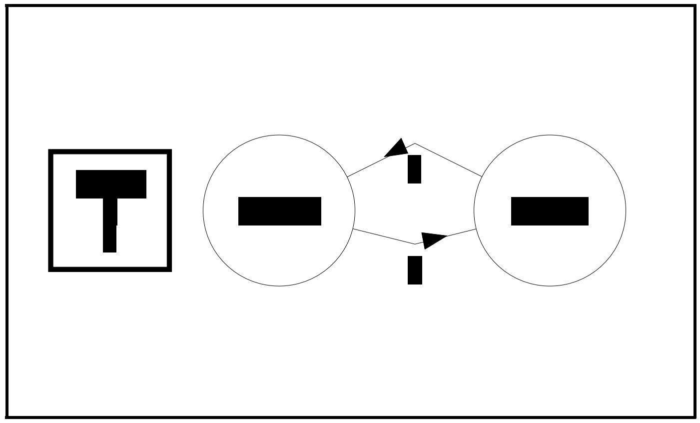

Figure 29 Frame with Failure and Recovery Rates

5.1.3.7 Adding Text Objects

To add a text object to the current diagram, choose the "New Text Object" command in the Items menu. A text object contains one or more lines of text. After clicking the command, you will be asked to enter text. When you finish entering the text and click "OK", the text will appear in your diagram and you will be able to move the text to any place in the diagram.

5.1.4 Moving Objects

To move an object, just click inside it and drag it to a new location. Only objects having an independent location may be moved, i.e. blocks, terminals, states and frames. A link or transition cannot be moved, for it is dependant on the location of the objects it is connected to. However, you may click on a transition and drag it, thereby forming a midpoint if one did not exist.

5.1.5 Deleting Objects

To delete an object, choose the "Delete Object" command in the Items menu. The cursor will change its shape to a deletion cursor. Then, click the object you want deleted. The clicked object and all other objects that are dependant on it will be deleted. For example, when a block is deleted, any links connected to the block and any sub-diagram belonging to the block will also be deleted.

5.1.6 Expanding Diagrams

A non-constant block in a block diagram and a frame in a Markov diagram can be expanded to lower level diagrams. To do this, choose the "Expand" command in the Diagram menu. The cursor will change its shape to a magnifying glass with a plus sign in it. Click the block or frame you wish to expand and you will be prompted to choose which type of sub-diagram you want (Block diagram or Markov diagram). After you choose the type, a new, empty diagram will be created. The new diagram will have the same name as the object which owns it, i.e. the block or frame which was expanded to form this diagram.

This command can also be used to view lower-level diagrams.

5.1.7 Contracting Diagrams

A lower level diagram may be contracted in order to return to the higher level diagram, i.e., the parent of the lower-level diagram. To do this, choose the "Contract" command in the Diagram menu. When you click on this command, the higher level diagram will be displayed. Since the main diagram is the highest level, it cannot be contracted.

5.1.8 Copying and Pasting Diagrams

Use the "Copy Diagram" command in the Diagram menu to copy the current diagram (including all of its sub-diagrams). After you choose this command, navigate (by using the Expand and Contract commands) to the place where you want to paste the diagram.

Then, use the "Paste Diagram" command found in the same menu to paste the diagram(s) that you had just copied. After the paste operation, you may want to change block/state names (see Section 5.1.12 Change Block/State Name) and replace parameter names in the diagram (see Section 5.1.2.2 Replace Parameter Names). **Please note that when pasting, MG will draw over any objects that are in the current diagram.**

5.1.9 Validating Models

Use the "Validate Model" command in the Options menu to check the validity of your diagrams. You can validate the entire model or a sub-model by navigating to the diagram you want to validate and choosing this command. MG will then check the current diagram and all its sub-diagrams to see if they are valid. If any part of the model is invalid, you will be informed of the problem. If you want to check the validity of the entire model, go to the top-level diagram and run this command.

5.1.10 Entering and Displaying Design Information In Diagrams

The "Enter Design Information" command can be found in the Options menu and can be used to enter the following information about the diagram:

- who designed it
- when it was designed
- who checked it and
- version or control number

This information is not required, but is useful for large scope design and management.

You can display this information in your diagram by choosing the “Display Design Information” command in the same menu. The information will be displayed in the same way as a text object is displayed.

5.1.11 Assigning Parameter Values

The “Assign Parameter Values” command can be found in the Options menu. Most expressions (associated with transitions in Markov diagrams) have parameters inside them. An elemental block in reliability block diagrams has one to three associated parameters: either a constant availability/reliability value or one (for the exponential distribution) or two (for the Weibull distribution) failure rate parameters plus a recovery/repair rate. A k-out-of-n block has the *k* and *n* parameters. A block (for both elemental block and parent block) in weighted block diagrams has an additional parameter: weight. Before the model can be evaluated, these parameters must be given a value. You can assign values to parameters during the model construction time or at the time the text modeling file is generated. If you wish to assign/reassign a value to a parameter during the model construction time, choose this command from the Options menu. The cursor will then appear as an arrow with a question mark inside it. Left click the block or transition which is associated with the parameters you want to assign values to and assign a value to each of the parameters.

If you assign parameter values to an expandable block, it will become an exponential block by default. You can later change it to a Weibull block if you wish.

5.1.12 Change Block/State Name

The “Change Block /State Name” command can be found in the Options menu. Use this command to change the name of a block or state. When you choose this command, the cursor will then appear as an arrow with a question mark inside it. Left click the object for which you want to change the name of and you will be presented with a dialog box containing the current name. Change the current name to the desired one (in the format described) and click “OK”. The new name should appear in the object.

5.1.13 Set k-out-of-n Block

The “Set k-out-of-n Block” command can be found in the Options menu. Use this command to set an expanded block (which already has a sub-diagram) to the k-out-of-n block. When you choose this command, the cursor will then appear as an arrow with a question mark inside it. Left click the block which you want to set to the k-out-of-n block and you will be presented with a series of two dialogs for you to input the “n” and “k” values for the block. There is no difference between a regular block and a k-out-of-n block on the screen. But if you turn on the “Parameters” switch under the View menu, *k*-out-of-*n* (where *k* and *n* are the actual values you defined) will show above each k-out-of-n block.

5.1.14 Set Exponential Distribution

The "Set Exponential Distribution" command can be found in the Options menu. Use this command to set the failure arrival time distribution to the exponential function for an elemental or expandable block (which has no sub-diagram). The cursor will then become an arrow with a question mark inside. Right click the block to which you want to set the exponential distribution. You will be presented with a dialog box for you to enter the λ (failure rate) and μ (recovery rate) values. If you turn on the Parameter switch under the View menu, the entered values will show above the block.

For more information on the exponential distribution function used in MEADEP, see Appendix B.3.

5.1.15 Set Weibull Distribution

The "Set Weibull Distribution" command can be found in the Options menu. Use this command to set the failure arrival time distribution to the Weibull function for an elemental or expandable block (which has no sib-diagram). The cursor will then become an arrow with a question mark inside. Right click the block to which you want to set the Weibull distribution. You will be presented with a dialog box for you to enter the α, β (parameters for the Weibull distribution), and μ (recovery rate) values. If you turn on the Parameter switch under the View menu, the entered values will show above the block.

For more information on the Weibull distribution function used in MEADEP, see Appendix B.3.

5.1.16 Library Files

A helpful capability of the Model Generator module is the use of library files. This capability allows you to re-use previously developed and tested models. A list and description of the library files provided by in the MEADEP package can be found in Appendix A.

A library file (*.mdl) is a graphical modeling file that defines the structure of a dependability model but does not contain parameter values. It can be read into a diagram during the modeling process at any time. To load a library file into your model, navigate to the diagram where you want the library file to be loaded and choose the "Read Library File" command from the Diagram menu. You will be asked for the filename. After you give the filename, the file will be loaded, **replacing any objects you previously had in your current diagram.**

In addition, you can also save frequently used model diagrams as library files for reuse. This provision can greatly reduce model construction time. To save a part of a model or the whole model as a library file, navigate to the diagram you want to save. Choose the "Write Library File" command from the Diagram menu and give it a filename and location. The current diagram and all of its sub-diagrams will be saved as a library file. Parameter values (if they exist) will not be saved to the library file except for the reward values associated with the states in Markov models.

5.1.17 Generating Text Modeling Files

To evaluate the model you designed, you must generate a text modeling file (see Section 6.1). This file can then be used by the Model Evaluator (ME) module to obtain results.

To generate the text modeling file, choose the "Generate Text Modeling File" command in the File menu. First, MG will perform a validation check on the model (Section 5.1.9). If the model is not valid, you will be prompted to correct the problem. If the model is valid, you will be asked for a filename and location. Then you will be asked if you want to generate a text modeling file for both availability and reliability evaluation or for reliability evaluation only. In the latter case, you don't have to specify parameter values for all recovery rates and the generated file can be used to evaluate reliability only.

Next, MG will process your model and produce the text modeling file. During this process, you will be asked to bind (assign) values to parameters by going through a series of dialog boxes. Parameter values can be entered manually at this time or can also be initialized by the DEA and ME modules at a later time.

For each parameter displayed in the dialog box, enter the value with which you wish to initialize the parameter or click "OK" to keep its original value (if it has one). You can also choose to define the parameter as an additional expression by clicking "Define" in the dialog box. Any expression you enter will be added to the output file and you will be asked to initialize any new parameters introduced in the new expression. During this process, if you forget where a parameter was defined, you can click the "View diagram containing the parameter" button to view the diagram that contains the parameter.

The generated text modeling file consists of the following four sections:

- Parameter Initialization — Parameter names and their bound values
- Evaluation Sequence — A sequence of mathematical expressions
- Markov Definition — Description of states, transitions and rewards for all Markov chains
- Output Specification — Names of models/submodels for which results will be generated

You should normally not edit the Markov Definition section of the file. However, you can change parameters, evaluation sequence, and output specification manually as described in the next section.

6. Model Evaluator (ME) Module

The MEADEP Model Evaluator (ME) module has two major functions:

- Editing text modeling files and
- Evaluating models defined in the text modeling file.

ME enables you to revise parameters and models and then to calculate results based on these revisions. In addition, ME can also perform parametric analysis on the data and can graphically display the results. For this analysis, you can choose from the following four loop types:

- Loop by Increment (Section 6.1.3)
- Loop by Value Set (Section 6.1.4)
- Loop by Time Increment (Section 6.1.5)
- Loop by Time Set (Section 6.1.6)

ME also allows you to create and edit parameter files and include them in the model evaluation process. This provision allows you to include a standard parameter list in multiple modeling files without having to input these parameter values into each file (see Section 6.1.1 for more information).

The following section describes text modeling files and how to get started using them.

6.1 Getting Started with Text Modeling Files

To begin using the Model Evaluator (ME) module, you must have an existing text modeling file. Text modeling files can be generated using the Model Generator (MG) module. Please refer to Section 5.1.14 on how to do this. A text modeling file (*.mdt) is a text file that contains the following four sections:

- *Parameter Initialization* — This section lists the model's parameter names and their bound values.
- *Evaluation Sequence* — This section holds a sequence of mathematical expressions.
- *Markov Definition* — This section describes the states, transitions and rewards for all Markov chains.
- *Output Specification* — This section lists the names of the models/submodels for which results will be generated.

To open a text modeling file, choose the "Open" command in the File menu. After opening the file, it should appear on the screen. You can now start generating the desired results, or run a parametric analysis that will enable you to display your results graphically. You should normally not edit the Markov Definition section of the file.

Instead, you should make modeling changes using the MG module in order to ensure consistency.

The following section describes parameter files and how to use them with your text modeling file. Then, the subsequent sections describe the results you can generate with the ME module.

6.1.1 Parameter Files

A parameter file is a text file containing a list of parameters and their initial values. This provision allows a standard parameter list to be included in multiple modeling files without having to input these parameter values into each file. Any parameter in a model can be initialized in the parameter file, modeling file, or both. Since parameter files are processed before text modeling files, if a parameter is initialized in both files, then **the value in the modeling file will override the value in the parameter file.** The parameter file may also contain parameters that are not defined in the modeling file.

To create a Parameter file, choose the "Create Parameter File" command under the File menu. Input the parameters with their corresponding values in the format shown in the box below and save it.

```
parameter_1   value_1
parameter_2   value_2
parameter_3   value_3
   .
   .
   .
parameter_n   value_n
```

Each line contains one parameter name and its corresponding value. There should be **at least** one space separating a parameter from its value.

To edit exiting parameter files, select "Open" under the File menu. In the "Files of type" box, select the "Text Files (*.txt)" option. Then go to the location of the parameter file and open it for editing.

To include a parameter file in your calculations, choose the "Include Parameter File" command under the Option menu. When you select this command, you will be asked to select a parameter file. After you choose a file, the contents of the selected file will then appear on the screen in a separate dialog box. You cannot edit the contents of this box. When this dialog box is on the screen, every calculation you run from the Solution menu will include the selected file in the evaluation. The dialog box will not disappear until you turn off the option. To turn off the option, just click the command again.

A sample parameter file (named "Parameters.txt") can be found in the Library directory under your MEADEP directory.

6.1.2 Regular Results

The “Regular Results” command can be found in the Solution menu. When you run this command, the current text modeling file will be evaluated once and the following measures will be generated:

- Failure Rate
- Recovery/Repair Rate
- Availability
- Unavailability, if the “Output Reliability” option is not selected
- Reliability, if the “Output Reliability” option is selected (see Section 6.1.2.2).

Only models (or submodels) specified in the output specification section of the text modeling file will be included in the calculation. An example output for regular results is shown in the box below.

Model Name	Failure Rate (per hour)	Recovery Rate (per hour)	Availability	Unavailability
Channel	0.00067126	1	0.999383255	0.00061450164
SafSys	2.254e-006	1	0.999977075	2.292532e-006
Plant	1.113e-008	0.01	0.999988209	1.179126e-006

As you can see, only those results for the “Channel”, “SafSys”, and “Plant” models were calculated and displayed. The reason for this (as was explained above) is because these three models were the only models listed in the output specification section of the text modeling file. In addition, you can also see that there is no “Reliability” value displayed. This is because (as is explained in Section 6.1.2.2) the “Output Reliability” command in the Option menu was not selected before running this command.

The next subsections describe the “Regular Results” related commands.

6.1.2.1 *Set Time Period*

The “Set Time Period” command can be found in the Option menu. Before generating results, use this command to set a time period (or interval) for calculating reliability. The time period given will be stored in a variable called “TIME”, and reliability will be calculated for the given “TIME”. When you use this command to set the time period, the “Output Reliability” option (in the same menu) will be turned on automatically. A default value of 100 hours will be used for the “TIME” variable if you do not specify one. The unit of “TIME” is in hours and the value of “TIME” could be between 0 and 1,000,000,000 hours.

6.1.2.2 *Output Reliability*

The “Output Reliability” command can be found in the Option menu. Before generating “Regular Results”, choose this option if you want to include reliability values in its output. The reliability results will be calculated based on the specified value of “TIME”. You can assign a value to the “TIME” variable using the “Set Time Period” command found in the same menu (see Section 6.1.2.1 for more details). When you choose this command, the reliability results for the given “TIME” value will be calculated and displayed in the output list. If you do not choose this command, the “Unavailability” values will be calculated and displayed instead.

6.1.3 Loop by Increment

The “Loop by Increment” command is a parametric analysis command and can be found in the Solution menu. When you run this command, a dialog box will appear prompting you to do the following:

- Select a parameter from the parameter list
- Specify an initial value for the parameter
- Specify an upper bound value for the parameter
- Specify an increment for the parameter
- Select a model from the model list to evaluate (optional)
- Select a measure from a measure list to generate (optional)

The evaluation process consists of a number of loops. In each loop cycle, the specified parameter is increased by the increment amount and results are calculated for each new parameter value. This loop continues until the parameter value exceeds the specified upper bound value.

After you specify a parameter with its initial, upper bound, and increment values, you will have to choose which model you want evaluated and which measure you want generated.

The steady-state dependability measures that can be generated by this command include:

- MTBF (Mean Time Between Failures)
- Availability
- Unavailability
- Yearly-Downtime

The transient dependability measures that can be generated by this command include:

- Reliability
- Interval-Reliability (average reliability over a time interval)

If you choose a single model and a single measure, then only the selected measure will be calculated for the selected model. This selection will generate a box containing a set of values for your parameter and their corresponding measure values. You will be able to graph the results and save the graph as a Windows Metafile (*.wmf) for inputting into other programs.

However, if both the “Model to evaluate” and “Measure to generate” boxes are left blank, then the same measures as those listed in the “Regular Results” section (Section 6.1.2) will be calculated for each parameter value. Also, only the models (or sub models) specified in the output specification section of the text modeling file will be included in the calculation. Please note that the results generated from this selection cannot be graphed.

6.1.4 Loop by Value Set

The “Loop by Value Set” command is a parametric analysis command and can be found in the Solution menu. When you run this command, you will be asked to specify a parameter and a set of values for the parameter. The number of loops depends on the number of values you specify in the “set of values” box. In each loop cycle, a different value in the value set will be assigned to the specified parameter and results will be calculated for each new value until all values have been used.

After you specify a parameter and a set of values for it, you will have to choose which model you want evaluated and which measure you want generated. The steady-state and transient dependability measures that can be generated by this command are the same as those listed in “Loop by Increment”. If you choose a single model and a single measure, then only the selected measure will be calculated for the selected model. This selection will generate a box containing a set of values for your parameter and their corresponding measure values. You will be able to graph the results and save the graph as a Windows Metafile (*.wmf) for inputting into other programs.

However, if both the “Model to evaluate” and “Measure to generate” boxes are left blank, then the same measures as those listed in the “Regular Results” section (Section 6.1.2) will be calculated for each parameter value. Also, only the models (or sub models) specified in the output specification section of the text modeling file will be included in the calculation. Please note that the results generated from this selection cannot be graphed.

6.1.5 Loop by Time Increment

The “Loop by Time Increment ” command can be found in the Solution menu. This is a parametric analysis command for evaluating reliability. When you run this command, you will be asked to specify an initial time, an end time, and a time increment. The evaluation process consists of a number of loops. In each loop cycle, the Time variable, “TIME”, is increased by the increment amount and reliability is calculated for each new Time value. This loop continues until the value of “TIME” exceeds the specified end time value.

After you specify the above values, you can now select a model and a measure to evaluate. Only transient dependability measures can be selected in this command. These transient measures are:

- Reliability
- Interval-Reliability (average reliability over a time interval)

The selected transient measure will be generated only for the model you select. You can also choose to leave the “Model to evaluate” box blank, but then the “Measure to evaluate” box must be “Reliability”. In such a case, the same measures as those listed in the “Regular Results” section (Section 6.1.2) will be calculated for each “TIME” value (the “Output Reliability” switch will be turned on automatically before the calculation). Also, only those models that are specified in the output section of your text modeling file will be included in the calculation. Please note that the results generated from this selection cannot be graphed.

6.1.6 Loop by Time Set

The “Loop by Time Set” command can be found in the Solution menu. This is a parametric analysis command for evaluating reliability. When you run this command, you will be asked to specify a set of values for the Time variable, “TIME”. The number of loops depends on the number of values you specify in the “set of values” box. In each loop cycle, a different value in the specified set will be assigned to the Time variable and reliability will be calculated for each new value until all values have been used.

After you specify a set of values for the Time variable, you will also be asked to select a model and a transient measure to evaluate. The measures that can be generated by this command are the same as those in the “Loop by Time Increment” command. The selected transient measure will be generated only for the model you select. You can also choose to leave the “Model to evaluate” box blank, but then the “Measure to evaluate” box must be “Reliability”. In such a case, the same measures as those listed in the “Regular Results” section (Section 6.1.2) will be calculated for each “TIME” value (the “Output Reliability” switch will be turned on automatically before the calculation). Also, only those models that are specified in the output section of your text modeling file will be included in the calculation. Please note that the results generated from this selection cannot be graphed.