

## **Formal Software Construction Limited**

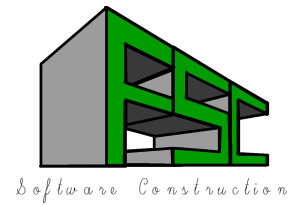
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# ***OpenFTA***

Version 1.0

## **User Manual**

### Disclaimer

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## Chapter 1 - Introduction

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### Overview

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This manual describes how OpenFTA is used for the drawing and analysis of fault trees. It includes a step-by-step tutorial and a reference section describing each of the tool's facilities.

### What is OpenFTA?

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OpenFTA is a sophisticated engineering tool for drawing, analysing and printing fault trees. The task of the analyst is aided by the tool's many facilities and features, which include:

- a point-and-click graphical user interface enabling rapid drawing of fault trees
- support for the full set of fault tree symbols in accordance with NUREG-0492
- a database for storing primary event definitions
- qualitative analysis of fault trees to determine minimal cut sets
- quantitative analysis of fault trees (including a Monte Carlo Simulation facility).

### Pre-Requisites

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This manual assumes that the user is familiar with modern software packages that have graphical user interfaces (GUIs).

This manual is not intended to be a textbook on fault tree analysis. It is assumed that the user is familiar with the methodologies involved in the drawing and analysis of fault trees and the terminology employed in the discipline.

### This Manual

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This manual is divided into two main sections:

- the OpenFTA Tutorial introduces the facilities offered by OpenFTA by working through the process of drawing and analysing a fault tree
- the OpenFTA Reference provides a comprehensive description of each of the facilities and functions provided by OpenFTA.

Throughout the document, when a new term is introduced in the text, it is highlighted in a **bold** font. Text that is in an *italic* font is text that is displayed by the OpenFTA user interface.

## Chapter 2 - OpenFTA Tutorial

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### Overview

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This chapter introduces key concepts and provides a guide to the facilities offered by OpenFTA. For more detailed information on any particular facility of OpenFTA, refer to Chapter 3.

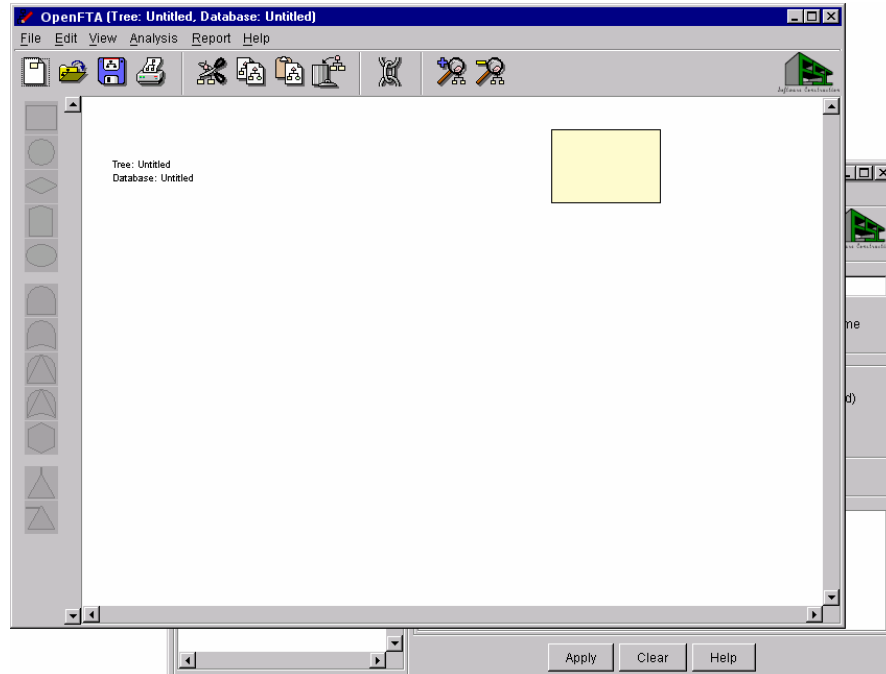
This tutorial describes:

- how to start OpenFTA
- getting on-line help from OpenFTA
- how to create and modify fault tree drawings
- how to specify primary event definitions
- how to analyse fault trees
- exporting data to other packages.

### Starting OpenFTA

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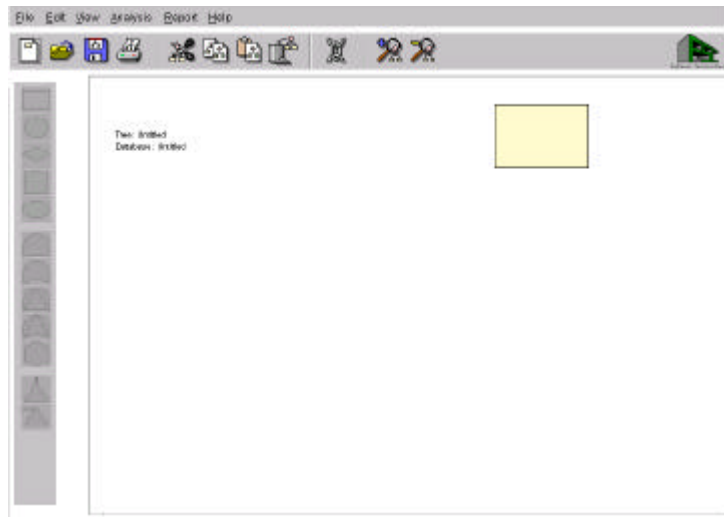
OpenFTA is started by selecting OpenFTA from the windows “Start” menu. The default location for this is inside a group called “Formal Software Construction -> OpenFTA”



**Figure 1: OpenFTA's Initial Display.**

Figure 1 shows the windows displayed when OpenFTA is first started i.e. **OpenFTA** and **OpenPED**. The OpenFTA window and the OpenPED window provide facilities for constructing fault trees and are discussed in more detail in the following sections.

The OpenFTA window consists of the following four elements:



**Figure 2: Components of the OpenFTA window.**

The **menubar** consists of a number of menus of options that can be applied to the fault tree being drawn.

The **toolbar** consists of shortcuts (in the form of icon buttons) to frequently used menu options.

When the mouse cursor is placed over an icon button, a small description (a **Tool Tip**) is displayed to provide a hint about the function of the button. Tool tips are also provided on the controls of dialog boxes.

Many frequently used menu options also have **accelerators** and **mnemonics**.

The **symbol palette** on the left of the OpenFTA window presents the drawable elements of a fault tree. If any symbol is not permitted (e.g. AND gate if a gate is selected on the canvas area), the **symbol button** is **greyed-out**. Thus, only syntactically valid fault trees can be drawn using OpenFTA.

The **canvas** area of OpenFTA is a scrollable area on which a fault tree is drawn. Note that only one tree may be drawn at a time. The top-level intermediate event of the fault tree is always present at the top centre of the canvas, with all child symbols laid out automatically by OpenFTA. This ensures that the fault tree is laid out in an efficient and aesthetic manner.

The OpenPED window allows access to the **primary events database** capability of OpenFTA. The provision of a separate capability to handle the management of primary events allows fault trees to be

constructed with emphasis on how the system decomposes without knowledge of the details behind the primary events.

The OpenPED window will be discussed in more detail later in this chapter.

## Getting Help

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OpenFTA assists the user by providing help screens. Overall help for OpenFTA is available under the Help menu option. Context sensitive help is available from the *Help* buttons on the dialogs. Tool tips are also provided on menu options and dialog controls.

To display help on a particular topic, select *Help->Index* to popup the help index list, and click on any item to display its help screen.

## Drawing A Fault Tree

---

The basic mode of operation when drawing a fault tree with OpenFTA is to select a parent symbol on the canvas, then select a control to manipulate that symbol. The insertion of fault tree symbols is achieved by such a mechanism. Selecting one of the available symbols from the symbol palette inserts that symbol below the selected symbol. As usual, if any symbol is inapplicable, it is greyed out.

As the fault tree is extended, it may become too large to be viewed on the canvas. Hidden areas of the fault tree can be viewed by using the scrollbars to navigate around, or by selecting the *View->Tree Overview* option. This presents a resizable window, which contains a scaled version of the fault tree. Selecting a symbol within the overview causes the corresponding symbol of the fault tree to be selected and centred on the main canvas area. Thus large trees can be easily navigated.

When drawing a fault tree, mistakes will be made, or changes will be required from time to time. OpenFTA supports standard editing operations and some application specific ones.

Any symbol on a fault tree can be viewed as the parent of a sub-tree, even a symbol on its own. Thus, as a fault tree is made up of smaller sub-trees, the smaller trees can be cut, copied and pasted to other parts of the fault tree drawing. Obviously, there are some restrictions (e.g. the top level intermediate event cannot be cut from the drawing), but OpenFTA provides warnings to prevent the tree becoming syntactically invalid and an *Undo* option that can revert a tree to a previous state.

In addition, OpenFTA allows some manipulation of the fault tree for aesthetic reasons. It is possible to change the order in which symbols are drawn below their parents (with *Edit->Shift Left* and *Edit->Shift Right*). This has no impact on the analysis of the tree, only on how it is displayed.

As symbols are added, they can be annotated. All symbols can be given an ID, as well as other information according to their type. To enter the annotations (for all but the primary events) multi-click the left mouse button with the cursor anywhere within the boundary of a symbol. This causes the symbol to become selected and displays an associated dialog. The descriptive text entered may be longer than that which can be displayed within a symbol's boundary. In this case, the text is truncated and ended with a continuation indicator (...) to show that more text exists.

Primary event IDs and details are entered in a different manner, consistent with their characteristics within OpenFTA. Multi-clicking on a primary event symbol does not popup a dialog, but selects the primary event in the database. This will be described later in this chapter.

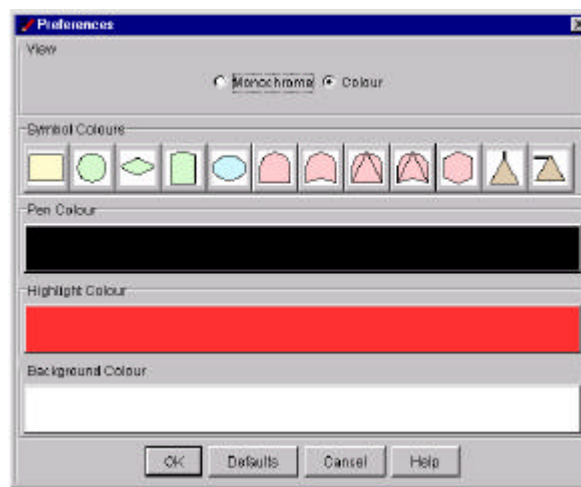
If the cursor falls outside the boundary of any symbol, a dialog allowing free format descriptive text for the whole tree is displayed. This text is always displayed in the top left of the canvas area and on any hardcopy of the tree.

The gate dialog provides the ability to change a gate's type if necessary.

## Preferences

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The preferences dialog allows the colours of the FTA canvas to be specified. This can be invoked by selecting *Edit->Preferences....*



**Figure 3: OpenFTA preferences dialog.**

The two radio buttons switch the canvas between colour and monochrome views. Clicking on any of the symbol or colour buttons launches a selection dialog that changes the colour of the selected item.

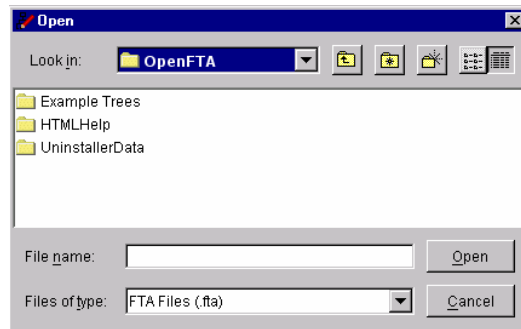
Clicking the *OK* button applies the changes and closes the dialog. Clicking the *Cancel* button aborts the changes and closes the dialog. Clicking the *Defaults* button reverts back to the original colours set when OpenFTA was first installed. Clicking the *Help* button brings up the context sensitive help for the preferences dialog.

## File Storage

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Fault trees can be saved or opened from the *File* menu (or via the toolbar). The *File* operations provide a degree of protection e.g. from destroying unsaved trees by opening an existing tree. All fault trees are stored in files with the extension *.fta*. When using the file selection dialog to access fault trees, the *.fta* extension may be omitted from the selection field.

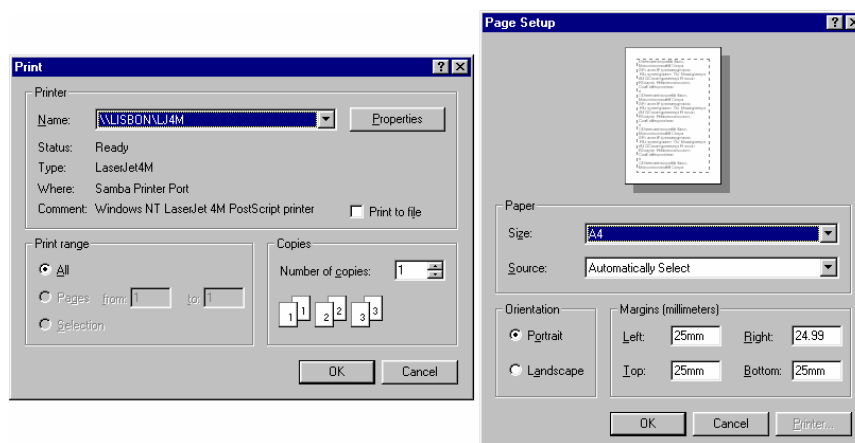




**Figure 4: File Selection Dialog.**

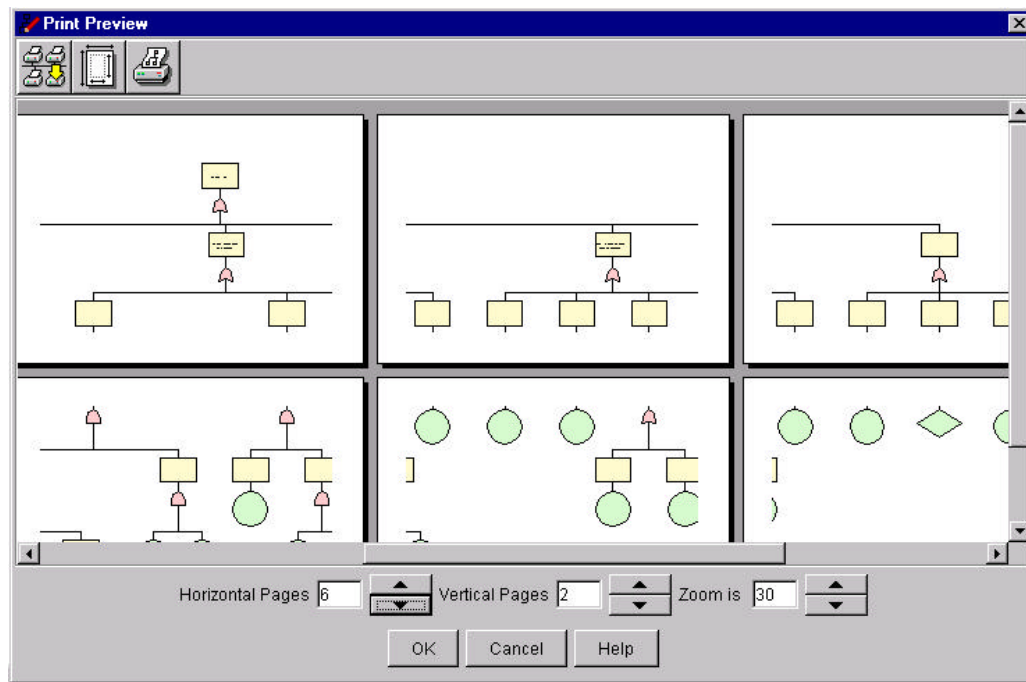
## Printing

Fault trees can be printed to any printer (via *File->Print*). The destination printer and the details of the required paper size and orientation can be changed by selecting the *File->Printer Setup...* and *File->Page Setup...* menu items.



**Figure 5: Print and Page Setup Dialogs.**

It is possible to print fault trees over multiple pages. Choosing *File->Print Preview...* launches the Print Preview dialog. This allows the number of pages, both horizontally and vertically, to be specified. The toolbar provides access to the Printer and Page Setup dialogs along with a button to print the tree.



**Figure 6: Print Preview Dialog.**

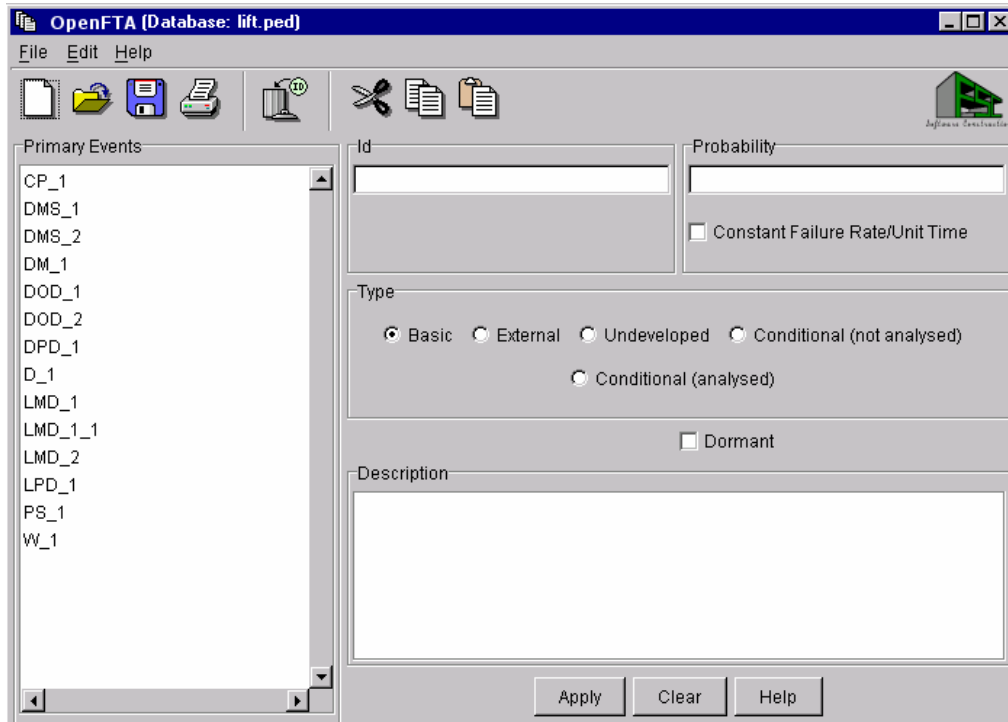
### *Providing Primary Event Information*

To complete the drawing of a fault tree, information on the primary events within the tree must be supplied. This is achieved either by retrieving the events from an existing primary events database or by creating a new database.

Databases are accessed through the OpenPED window. This window has a menubar and toolbar akin to those found on the OpenFTA window, a scrolled list of the primary events within the open database and the details of the selected primary event.

Separating the primary events from the fault tree drawing allows many benefits, including the partitioning of work and allowing multiple trees to share a single database. It decouples the process of producing a fault tree for a system from the mechanics of describing the individual events that influence the system.

This separation also allows a single primary event to appear in a tree, or in many trees, without the need to duplicate the primary event details for every occurrence. Primary event details can exist in a database without appearing in a tree.



**Figure 7: OpenPED Window.**

Adding an event to a database requires a minimum amount of information for that event. Every event must have a unique ID within the primary events database, it must have a probability of failure and it must have a type. In practice, the events will include a textual description to distinguish them, or provide further information.

The probabilities are applied by one of two models, **probability model** (P-model) or **lambda-model** (?-model). The P-model is used to state the probability of a primary event failing as an absolute value. The ?-model is used to state the probability that a primary event will fail within a unit time period i.e. as a function of time. Each event's probability can be set according to the model that is appropriate. See Appendix A for more details.

An event is added to the database by filling in the minimum information in the details area of the OpenPED window and pressing *Apply*. If the information supplied is valid, the event *ID* is added to the list of events in the database.

An event may be modified by selecting it in the *Primary Events* list (which causes its details to be displayed), modifying the required information and selecting *Apply*. If the details are invalid, the database is unaffected and if the changes cannot be corrected or should be discarded, *Clear* can be pressed.

The OpenPED window provides similar *File* options to the OpenFTA window.

## Connecting Trees With Databases

---

When a primary events database has been saved, it can be **associated** with the fault tree. This is performed by selecting the *File->Database* option on the OpenFTA window. Note that a fault tree may be associated with only one database.

Opening a saved fault tree automatically opens the associated primary events database in the OpenPED window.

Associating a database with a fault tree is only the first step in preparing the fault tree for analysis. Every primary event symbol on the fault tree must be **linked** to a primary event definition in the database. This is performed by selecting a primary event on the tree, selecting the required primary event in the primary events database and selecting *Edit->Link* (or the corresponding toolbar icon) on the OpenFTA window. The tree will now display the event ID next to the symbol, together with its probability and any descriptive text within the symbol.

## Validation

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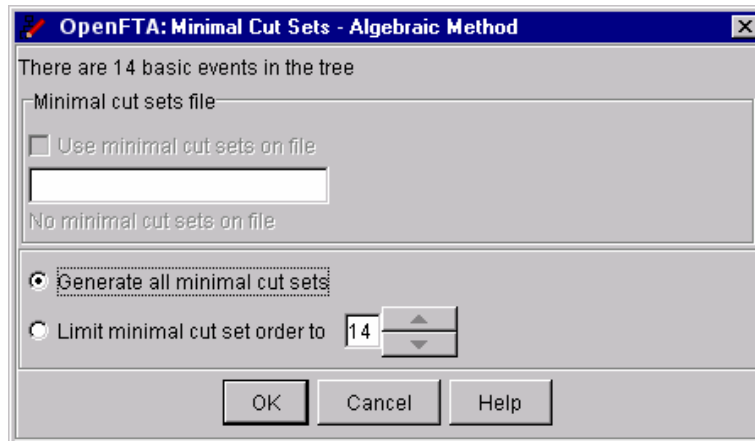
Once the fault tree is considered complete, it can be **validated**. Validation ensures that the tree is syntactically and semantically correct (e.g. all events have been linked to valid, defined primary events). A fault tree is validated by selecting *Analysis->Validate* which produces an on-screen report. This report will list all the **errors** that prevent the tree being considered valid, together with any **warnings**. The most common error is that an event is not found in a database, either because the link has never been made between the tree event and the database event, because the linked primary event has been deleted from the primary events database, or because the incorrect database has been associated with the tree.

## Analysing The Fault Tree

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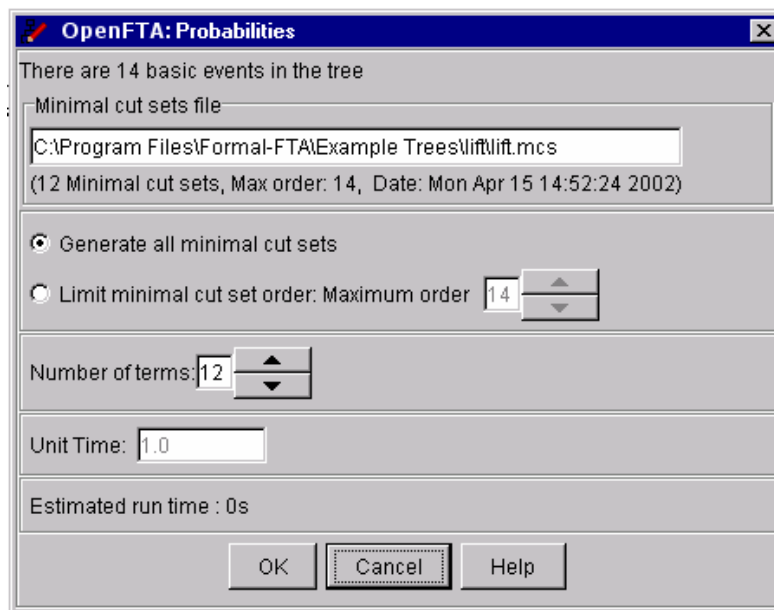
When a fault tree is valid, a full analysis of the fault tree can be performed. With OpenFTA this can be performed in two ways. A **deterministic** analysis may be achieved by a qualitative analysis to generate **minimal cut sets**. This enables a quantitative evaluation to be performed (on a logically reduced tree represented by the minimal cut sets). Alternatively a **statistical** analysis may be performed using the **Monte Carlo Simulation** facility. OpenFTA implements an **algebraic** generation of minimal cut sets which is very quick for most developed trees. Minimal cut set generation is performed by selecting *Analysis->Minimal Cut Sets...*

Pressing *OK* on the resulting dialog displays a report file associated with the fault tree, which is valid until the tree is next edited. The report contains a list of all the minimal cut sets identified for the tree.



**Figure 8: Minimal Cut Set Generation Dialog.**

When minimal cut sets for a tree have been generated, the quantitative analysis of the tree is performed by selecting *Analysis->Numerical Probability...* This displays the numerical probabilities dialog.



**Figure 9: Numerical Probabilities Dialog.**

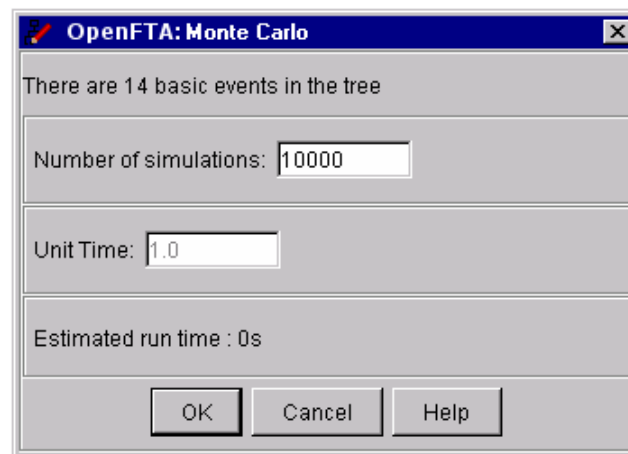
Pressing *OK* on the dialog displays a report file associated with the fault tree, which is valid until the tree is next edited. The report contains the calculated probability of the top level event occurring, together with the probabilities for each of the minimal cut sets occurring and the contribution that each

of the primary events makes to the top level failure. The top-level event calculation uses the appropriate P-model or  $\gamma$ -model according to how each primary event probability is defined.

The Monte Carlo Simulation allows a statistical determination of the cut sets for a tree and an approximation of the system failure by randomly failing events and determining the probability of overall system failure.

The Monte Carlo Simulation provides a statistical approximation and, although it does not guarantee that all minimal cut sets will be found, the likelihood is that the approximation will be adequate for very large trees for which even the algebraic generation of cut sets is too time consuming. The report generated gives statistical information on the accuracy of the result. The more simulations run at a time, the more accurate the result will be, but at the expense of processing time.

The Monte Carlo Simulation analysis of the tree is performed by selecting *Analysis->Monte Carlo Simulation...*



**Figure 10: Monte Carlo Dialog.**

Pressing *OK* on the resulting dialog displays a report file associated with the fault tree, which is valid until the tree is next edited.

At any later time reports can be viewed and printed. This is achieved through the options of the *Report* menu.

## *Decomposing Fault Trees*

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The **transfer-in** facility supports the splitting of large fault trees into more manageable chunks. Because each tree transferred in exists as a fault tree in its own right, all of the OpenFTA operations including analyses can be applied to that tree individually. Any tree may be transferred into any other tree, any number of times. Trees may be broken up to support team working, to reflect redundancy in the systems or maybe to defer working on a little known area of a system.

Transfer-in trees make large trees easier to manage but have no impact on the analysis. Each sub-tree can be analysed in isolation, or the analysis may be performed on the top level tree.

To include a transferred in tree add a transfer-in symbol at the required position in the tree, and multi-click on the transfer-in symbol. This displays a dialog to add an *ID*. This *ID* is equivalent to a tree name (and is displayed on the tree with a *.fta* extension to reinforce this concept).

If a sub-tree has been identified as a candidate for converting into a transfer-in tree, the sub-tree can be cut or copied, the *File->New* option selected and the sub-tree pasted onto the canvas area and saved in the normal manner. A transfer-in symbol with the ID of the newly created tree can then be added to the original tree.

If a tree is used as a transfer-in tree, the top level intermediate event may have a **transfer-out** symbol added and annotated, but this is not obligatory.

## **Chapter 3 - *OpenFTA Reference***

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### *Overview*

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This reference section describes each of the user interface controls provided by OpenFTA.

For each control, brief descriptions of form and function are followed by an explanation of usage and effect.



## Analysis

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### Control Type

Pulldown Menu

### Function

Provides access to facilities for analysing fault trees.

### Location

OpenFTA menubar -> Analysis

### Shortcuts

Accelerator: None

Toolbar: None

### Pre-conditions

None

### Operation

This menu provides the following options:

- *Validate* - determines if the fault tree currently displayed is valid and hence ready for further analysis
- *Minimal Cut Sets...* - displays a dialog from which minimal cut set generation is initiated
- *Numerical Probability...* - displays a dialog from which a deterministic qualitative analysis of the fault tree is initiated
- *Monte Carlo Simulation...* - displays a dialog from which a statistical analysis of the fault tree is initiated.

### Cross References

Minimal Cut Sets, Monte Carlo Simulation, Numerical Probability and Validate.

## *Apply (OpenPED)*

---

### **Control Type**

Push Button

### **Function**

Provides a means to accept a new or modified entry into the primary events database.

### **Location**

OpenPED -> Apply

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

On activation, the data in the *ID*, *Probability* and *Description* text fields, the *Type* radio buttons and the *Constant Failure Rate/Unit Time* and *Dormant* toggle buttons are validated.

If the *ID* is valid and an event with that *ID* does not already exist in the database, a new entry with the supplied data is added to the database and the Primary Events list updated accordingly.

If the *ID* is valid and an event with that *ID* does exist in the database, then if the *Type* of event has been altered, OpenFTA requests confirmation before overwriting the existing database entry with the supplied data.

### **Cross References**

Clear (OpenPED).

## *Clear (OpenPED)*

---

### **Control Type**

Push Button

### **Function**

Provides a means to clear the fields in the primary events database window.

### **Location**

OpenPED -> Clear

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

On activation, this causes the *ID* and *Description* text fields to be cleared, the *Type* radio buttons to be deselected and the *Constant Failure Rate/Unit Time* and *Dormant* toggle buttons to be deselected and the probability set to zero.

### **Cross References**

Apply (OpenPED).

## *Copy(OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**

Copies the current selection and the entire sub-tree below it, from the fault tree displayed in the OpenFTA window, to the clipboard.

### **Location**

OpenFTA menubar -> Edit -> Copy

### **Shortcuts**

Accelerator: Ctrl+C.

Toolbar:



### **Pre-conditions**

A symbol on the canvas is selected.

### **Operation**

Used to place a copy of the current selection and the sub-tree below it to the clipboard.

Selections copied to the clipboard are available for the Paste operation. Any information previously held on the clipboard is lost when a Copy operation is carried out.

### **Cross References**

Cut, Paste and Undo.

## *Copy(OpenPED)*

---

### **Control Type**

Menu Option

### **Function**

Copies the current selected text from the Id, Probability or Description fields to the clipboard.

### **Location**

OpenPED menubar -> Edit -> Copy

### **Shortcuts**

Accelerator: Ctrl+C.

Toolbar:



### **Pre-conditions**

Text in one of the text fields is selected.

### **Operation**

Used to place a copy of the currently selected text from the *ID*, *Probability* or *Description* text fields onto the clipboard.

Selections copied to the clipboard are available for the *Paste* operation. Any information previously held on the clipboard is lost when a *Copy* operation is carried out.

### **Cross References**

Cut and Paste.

## *Constant Failure Rate/Unit Time*

---

### **Control Type**

Toggle Button

### **Function**

Provides a means to state a primary event's failure rate in terms of the probability that it will fail within a given time period i.e. as a function of time (? -model) rather than as an absolute probability (P-model).

### **Location**

OpenPED -> Constant Failure Rate/Unit Time

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

If set, on activation of the Apply button, the probability of the current event will be entered into the primary events database as a function of time (? -model), rather than as a function of probability, (P-model).

For more details please refer to Appendix B.

### **Cross References**

Apply (OpenPED), Monte Carlo Simulation and Numerical Probability.

## *Cut (OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**

Removes the current selection and sub-tree below it, from the fault tree displayed in the OpenFTA window and copies it to the clipboard.

### **Location**

OpenFTA menubar -> Edit -> Cut

### **Shortcuts**

Accelerator: Ctrl+X.

Toolbar:



### **Pre-conditions**

A symbol on the canvas is selected.

### **Operation**

Used to remove the current selection and sub-tree below it from the displayed fault tree and copies it to the clipboard.

Selections copied to the clipboard are available for the Paste operation. Any information previously held on the clipboard is lost when a Cut operation is carried out.

### **Cross References**

Copy, Paste and Undo.

## *Cut (OpenPED)*

---

### **Control Type**

Menu Option

### **Function**


Removes the current selected text from the *ID*, *Probability* or *Description* fields and copies it to the clipboard.

### **Location**

OpenPED menubar -> Edit -> Cut

### **Shortcuts**

Accelerator: Ctrl+X.

Toolbar: 

### **Pre-conditions**

Text is selected in one of the text fields.

### **Operation**

Removes the current selected text from the *ID*, *Probability* or *Description* fields and copies it to the clipboard.

Selections copied to the clipboard are available for the *Paste* operation. Any information previously held on the clipboard is lost when a *Cut* operation is carried out.

### **Cross References**

Copy and Paste.



## Database

---

### Control Type

Menu Option

### Function

Creates an association between a fault tree and a primary events database.

### Location

OpenFTA menubar -> File -> Database

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

The fault tree and primary events database have been saved.

### Operation

Associate the events database displayed in the OpenPED window with that currently displayed on the OpenFTA canvas. Any existing association between a tree and a database is overridden.

As a consequence of forming an association between a tree and a database, the data displayed in the tree's primary events will be updated to be consistent with the database i.e. each primary event will display the description and probability corresponding to the event's ID.

### Cross References

Link.

## Delete (OpenFTA)

---

### Control Type

Menu Option

### Function

Removes the current selection and sub-tree below it, from the fault tree displayed in the OpenFTA window.

### Location

OpenFTA menubar -> Edit -> Delete

### Shortcuts

Accelerator: Ctrl+D.

Toolbar:



### Pre-conditions

A symbol on the canvas is selected.

### Operation

Used to remove the current selection and sub-tree below it, from the displayed fault tree. Unlike *Cut*, the deleted sub-tree is not placed on the clipboard.

### Cross References

Cut, Undo.

## Delete Event (OpenPED)

---

### Control Type

Menu Option

### Function


Removes the currently selected primary event from the primary events database displayed in the OpenPED window.

### Location

OpenPED menubar -> Edit -> Delete

### Shortcuts

Accelerator: Ctrl+D.

Toolbar: 

### Pre-conditions

An item in the *Primary Events* list is selected.

### Operation

Used to remove the currently selected primary event from the database. Confirmation is requested before this action is completed since no *Undo* operation is available.

### Cross References

None.

## *Dormant*

---

### **Control Type**

Check Box

### **Function**

Provides a means to depict a primary event as being **dormant**.

### **Location**

OpenPED -> Dormant

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

If set, on activation of the *Apply* button, the current event will be entered into the primary events database as a dormant event.

*Dormant* events are special case primary events. They may fail with no visible external effects. An example is the failure of a filament in a warning lamp - if the light is not on, then it would normally be assumed that the system which it is monitoring does not require a warning to be issued. However, it could be that both the lamp filament and the subsystem it monitors have failed.

In OpenFTA, the dormant event is treated the same as any other primary event, with the exception that the symbol on the canvas is drawn with a double line.

### **Cross References**

None.

## *Edit (OpenFTA)*

---

### **Control Type**

Pulldown Menu

### **Function**

Provides access to facilities for manipulation and alteration of the currently displayed fault tree.

### **Location**

OpenFTA menubar -> Edit

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Used to invoke the operations that alter the fault tree displayed on the main OpenFTA canvas area.

### **Cross References**

Copy (OpenFTA), Cut (OpenFTA), Delete (OpenFTA), Link, Paste (OpenFTA), Preferences..., Selected..., Shift Left, Shift Right and Undo.

## *Edit (OpenPED)*

---

### **Control Type**

Pulldown Menu

### **Function**

Allows access to the facilities for editing the primary events database.

### **Location**

OpenPED menubar -> Edit

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

This menu is used to access the *Cut*, *Copy* and *Paste* operations used to manipulate data between the *ID*, *Probability* and *Description* fields. It also provides the facility to *Delete* Primary Events from the Primary Event Database.

### **Cross References**

Copy (OpenPED), Cut (OpenPED), Delete (OpenPED) and Paste (OpenPED).

## *Exit*

---

### **Control Type**

Menu Option

### **Function**

Shuts down OpenFTA.

### **Location**

OpenFTA menubar -> File -> Exit

### **Shortcuts**

Accelerator: Ctrl+Q.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Used to terminate the OpenFTA application.

If neither the primary events database nor the fault tree have been modified without saving, then the execution of the application is terminated and OpenFTA is removed from the display.

If the fault tree has been modified and not saved, then confirmation is requested before OpenFTA proceeds with the termination of the application.

If the database has been modified and not saved then the operator is informed and the operation is aborted.

### **Cross References**

Save (OpenFTA), Save (OpenPED), Save As... (OpenFTA) and Save As... (OpenPED).

## *Export Image...*

---

### **Control Type**

Menu Option

### **Function**

Exports the OpenFTA canvas as a JPEG image.

### **Location**

OpenFTA menubar -> File -> Export Image...

### **Shortcuts**

Accelerator: Ctrl+E

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Exports the OpenFTA canvas as a JPEG image. A file selection dialog is posted, allowing the target file to be specified.

### **Cross References**

None.



## *Export Text File...*

---

### **Control Type**

Menu Option

### **Function**

Exports the OpenPED database as a text file.

### **Location**

OpenPED menubar -> File -> Export Text File...

### **Shortcuts**

Accelerator: Ctrl+E

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Exports the OpenPED database as a text file. A file selection dialog is posted, allowing the target file to be specified.

### **Cross References**

None.

## *File (OpenFTA)*

---

### **Control Type**

Pulldown Menu

### **Function**

Provides access to facilities for manipulating fault tree files.

### **Location**

OpenFTA menubar -> File

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Used to invoke the following operations; *New, Open..., Save, Save As..., Export Image..., Printer Setup..., Page Setup..., Print Preview..., Print..., Database and Exit.*

### **Cross References**

Database, Exit, Export Image..., New (OpenFTA), Open (OpenFTA), Page Setup..., Page Setup Dialog, Print (OpenFTA), Print Dialog, Print Preview..., Printer Setup..., Save (OpenFTA) and Save As (OpenFTA).

## *File (OpenPED)*

---

### **Control Type**

Pulldown Menu

### **Function**

Provides access to facilities for manipulating primary events databases.

### **Location**

OpenPED menubar -> File

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Used to invoke the following operations; *New*, *Open...*, *Save*, *Save As...*, *Export Text File...*, *Printer Setup...*, *Page Setup...* and *Print...*

### **Cross References**

Export Text File..., New (OpenPED), Open (OpenPED), Page Setup..., Page Setup Dialog, Print (OpenPED), Print Dialog, Printer Setup..., Save (OpenPED) and Save As (OpenPED).

## *File Selection Dialog*

---

### **Control Type**

Dialog

### **Function**

Provides a means to open or store a file.

### **Location**

Invoked for all *File* operations.

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

The dialog consists of:

- a *Files of Type* drop down list: this shows the filter currently in use. A filter is a way of limiting the types of files displayed in the dialog. The default filter is currently displayed which means that only files with the specified extension will be displayed in the dialog.
- a scrollable list of Directories and Files: lists the files and directories below the current working directory. Movement between directories is performed by multi-clicking on any directory in the list.
- a *File name* text field: contains the filename of the currently selected file.

File selection takes place by either:

- multi-clicking on the required file
- selecting the file and activating the *Open/Save* button
- completing the selection text field and activating the *Open/Save* button.

On activation of the *Open/Save* button, the required file operation is attempted and if successful the dialog is removed from the screen.

On activation of the *Cancel* button, the file operation is aborted and the dialog is removed from the screen.

### **Cross References**

None.

## Help

---

### Control Type

Pulldown Menu

### Function

Provides access to the online help facility.

### Location

OpenFTA and OpenPED menubars -> Help

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

None.

### Operation

Used to access information on any aspect of the OpenFTA application. The categories of help provided are; *Help on Help*, *Index...*, *User Support* and *Copyright*.

The *Help on Help* option provides information on the help facility.

The *Index...* option opens a scrollable window which contains a list of all the help topics available. By selecting one and pressing the Ok button the information on that subject is displayed.

The *User Support* option details how to get technical support.

The *Copyright* option displays the version of the application and a copyright notice.

OpenFTA help is context-sensitive. The help topics may be accessed from within the application's dialogs, by using the *Help* button, where available.

### Cross References

None.

## Link

---

### Control Type

Menu Option

### Function


Connects the currently selected event symbol in the fault tree to the selected primary event in the database.

### Location

OpenFTA menubar -> Edit -> Link

### Shortcuts

Accelerator: Ctrl+I.

Toolbar: 

### Pre-conditions

A primary event is selected on the OpenFTA canvas area. The database displayed in the OpenPED window is associated with the fault tree depicted on the canvas and an event in the *Primary Events* list is selected.

### Operation

On activation, the currently selected event in the fault tree is linked to the selected primary event in the database. This causes the *ID*, *Probability* value and *Description* for the selected fault tree event symbol to be displayed on the canvas.

If the *Type* of event in the database differs from that of the selected event in the tree, then confirmation is requested before the action is completed. On completion the symbol on the canvas is changed to the type held within the database.

Note that a *Link* operation cannot be undone using the *Undo* option.

### Cross References

Database.

## Minimal Cut Sets...

---

### Control Type

Menu Option

### Function

Calculates the minimal cut sets for the currently displayed fault tree.

### Location

OpenFTA menubar -> Analysis -> Minimal Cut Sets...

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

The fault tree has been saved and is logically valid.

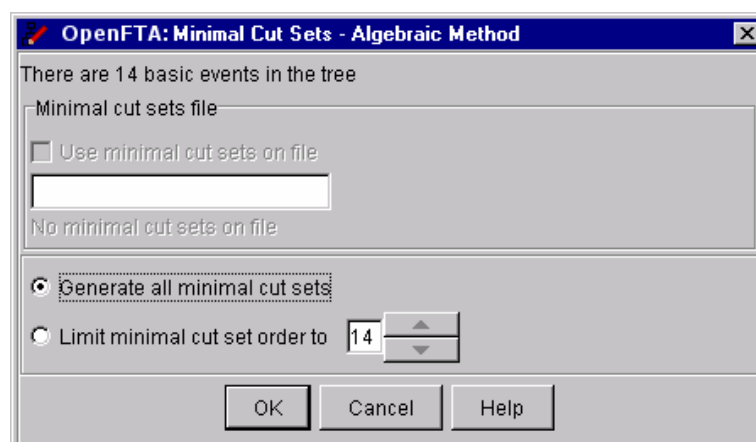
### Operation

This menu option is used to initiate the generation of the minimal cut sets for a fault tree.

When invoked, a minimal cut sets dialog with the title *OpenFTA: Minimal Cut Sets* is presented. This dialog is used to specify whether or not to use the minimal cut sets already on file and to specify which orders of minimal cut sets should be generated.

If a minimal cut sets file already exists then the *Use minimal cut sets on file* toggle button is selected and the directory path to the minimal cut sets file is displayed, as well as the number and order of the available minimal cut sets.

If the *Generate all minimal cut sets* toggle button is selected, all orders of minimal cut sets for the fault tree will be calculated. If the *Limit minimal cut set order to* toggle button is selected, only minimal cut sets up to a specific order will be generated. The required maximum cut set order is specified using the stepper (the two, back-to-back arrows).



**Figure 11: Minimal Cut Sets Dialog.**

On activation of the *OK* button, OpenFTA displays a working dialog and carries out the minimal cut set generation, using the parameters requested. The *Stop* button on the working dialog may be pressed to abort the generation of the minimal cut sets.

Note that the generation of minimal cut sets may take a long time for very large trees, when large order minimal cut sets are required.

On activation of the *Cancel* button, the operation is aborted and the dialog is removed.

On activation of the *Help* button, context sensitive help information is displayed.

On completion of the operation, a Qualitative Report is generated (to a file named: <fault tree name> .mcs) and displayed in a dialog. The report consists of:

- the directory path to the file used to store the fault tree analysed in this report
- the date and time of the report's creation
- the method used to calculate the minimal cut sets
- the number of unique primary events in the fault tree, including those in any transfer trees
- the range of cut set orders possible for the fault tree
- a list of the minimal cut sets separated into the orders that have been located
- a table titled *Qualitative Importance Analysis*. The table represents the distribution of the number of minimal cut sets found per order of cut sets that are possible for the fault tree.

## Cross References

Analysis, Print (OpenFTA, Report), Report, Validate and View (OpenFTA, Report).



## Monte Carlo Simulation...

---

### Control Type

Menu Option

### Function

Calculates the probability of occurrence of the top level event of the displayed fault tree and generates (and displays) an associated analysis report.

### Location

OpenFTA menubar -> Analysis -> Monte Carlo Simulation...

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

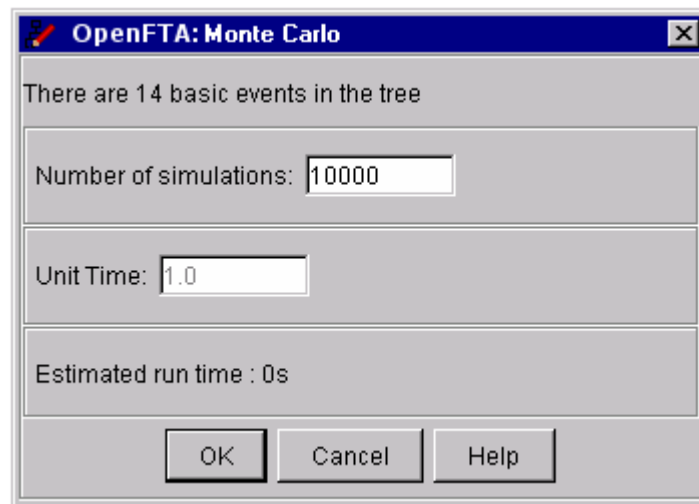
The fault tree has been saved and is valid.

### Operation

Determines the probability of the top event occurring by using a Monte Carlo Simulation (statistical) algorithm. Also determines (statistically) the cut sets and minimal cut sets, but note that not all cut sets may be determined.

On activation a *OpenFTA: Monte Carlo* dialog is displayed containing:

- a statement of the total number of unique primary events in the displayed fault tree (including those in any transfer-in trees)
- a *Number of simulations* text field. This contains the number of Monte Carlo Simulations that will be performed upon the fault tree. A default value will be displayed, but can be altered. Since a random number generator is used in this method, if the number of simulations is increased, the accuracy of the results obtained will increase, but with the penalty of a longer execution time for the calculations
- a *Unit Time* text field. This text field stipulates the number of unit times for which each Monte Carlo Simulation run is to simulate. This is only required if there are primary events whose probabilities have been entered into the primary events database as a function of time (?-model), rather than as a function of probability (P-model). A default value will be displayed, but can be altered to suit experimental needs. See Appendix B for more details
- an *Estimated run time* statement. This is an estimate of how long the calculation will take, depending upon the parameters stipulated in the dialog.



**Figure 12: Monte Carlo Dialog.**

On activation of the *OK* button, a working dialog is displayed and the Monte Carlo Simulation is executed. The *Stop* button on the dialog may be pressed to abort the simulation at any time.

On activation of the *Cancel* button, the procedure is aborted and the *OpenFTA: Monte Carlo* dialog removed from the screen.

On activation of the *Help* button, context sensitive help information is displayed.

On completion of the simulation, the *OpenFTA: Monte Carlo* dialog is removed from the screen, a Monte Carlo Report is generated (to a file named: <fault tree name>.mrp) and displayed in a dialog. The report consists of:

- the directory path of the file used to store the fault tree analysed in this report
- the date and time of the report's creation
- the number of unique primary events in the displayed fault tree (including any transfer-in trees)
- the number of Monte Carlo Simulation runs that have been performed upon the displayed fault tree
- the number of unit times simulated for each run
- the number of system failures that occurred, (occurrences of the top level event) due to primary events being failed during the calculations
- the probability of at least one component in the tree failing during the simulation
- the probability of the top level event occurring
- a table of the cut sets found during the simulations. Each row of the table consists of: the cut set, the number of failures attributed to it in the simulations, the estimated probability of one of the events in that cut set occurring and the percentage importance of the cut set in comparison to the other cut sets found
- a table titled *Compressed*. This is the same as the previous table, but those cut sets which are less minimal versions of others are subsumed by the more minimalistic ones. The other fields such as the estimated probability are adjusted accordingly
- a table titled *Basic Event Analysis*. This contains a list of all of the primary events in the fault tree and their failure contribution towards the top level event occurring. This contribution is also stated as a percentage importance value for each primary event.

## Cross References

Analysis, Minimal Cut Sets, Print (OpenFTA), Report, Validate and View (OpenFTA, Report).



## *New (OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**

Provides a blank canvas area for the drawing of a new fault tree in the OpenFTA window.

### **Location**

OpenFTA menubar -> File -> New

### **Shortcuts**

Accelerator: Ctrl+N.

Toolbar:



### **Pre-conditions**

None.

### **Operation**

Used to create a canvas displaying a single empty intermediate top-level event. The application is then ready for the drawing of a new fault tree.

If the fault tree currently on display has been modified and not saved, then confirmation is requested before OpenFTA proceeds with the *New* operation.

### **Cross References**

None.

## *New (OpenPED)*

---

### **Control Type**

Menu Option

### **Function**

Provides an empty primary events database.

### **Location**

OpenPED menubar -> File -> New

### **Shortcuts**

Accelerator: None.

Toolbar:



### **Pre-conditions**

None.

### **Operation**

Used to create an empty primary events database.

If the database currently on display has been modified and not saved, then confirmation is requested before OpenPED proceeds with the *New* operation.

### **Cross References**

None.

## Numerical Probability...

---

### Control Type

Menu Option

### Function

Calculates the probability of occurrence of the top level event of the displayed fault tree and generates (and displays) an associated analysis report.

### Location

OpenFTA menubar -> Analysis -> Numerical Probability...

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

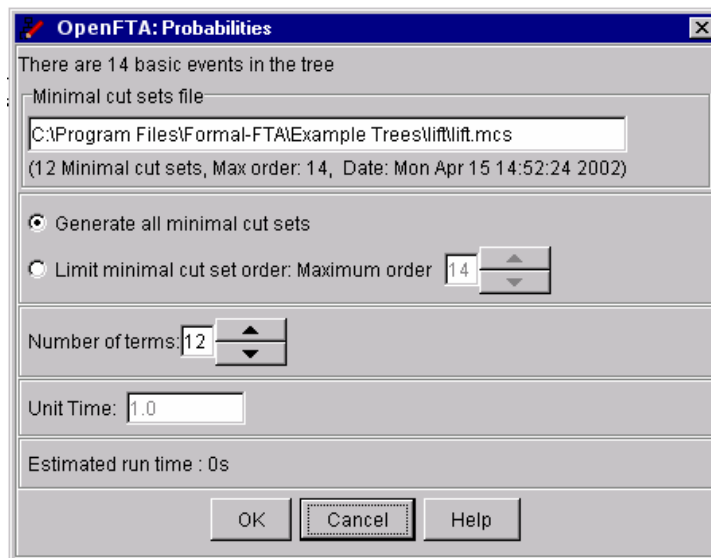
Fault tree has been saved, is valid and the minimal cut sets have been generated.

### Operation

Calculates the minimal cut set probabilities for the fault tree and the probability of the top level event occurring (system failure).

On activation a *OpenFTA: Probabilities* dialog is displayed containing:

- a statement of the total number of unique primary events in the displayed fault tree (including those in any transfer-in trees)
- a text field containing the directory path to the generated *minimal cut sets file*
- a description of the file consisting of the number of minimal cut sets, their maximum order and the date and time of file generation
- a *Use all minimal cut sets* radio button. If this is selected, then all the generated minimal cut sets are used in the numerical probabilities calculation



**Figure 13: Numerical Probabilities Dialog.**

- a *Limit minimal cut set order* radio button. This is only available if the *Use all minimal cut sets* radio button is not selected. This limits the order of the minimal cut sets used in the calculation to the value chosen using the stepper (the two, back-to-back arrows)
- a *Number of terms* option which is altered through the use of a stepper. The option is provided in order to limit the number of terms used in the probability calculation. This uses a **series expansion** in which there are  $n$  terms each with  $^nC_r$  sub terms making a total number of  $2^n$  possible terms. By limiting the number of terms used, the calculation is speeded up at a cost of precision. In practice, the terms used get smaller rapidly and it is rarely necessary to go past the third term in the calculations for a large tree. See Appendix B for more details
- a *Unit Time* text field. This text field stipulates unit time for which the numerical probability is to be calculated. This is required if there are primary events whose probabilities have been entered into the primary events database as a function of time (?-model), rather than as an absolute probability, (P-model). A default value will be displayed, but can be altered to suit experimental needs. See Appendix B for more details
- an *Estimated run time* statement. This is an estimate of how long the calculation will take, depending upon the parameters stipulated in the dialog.

On activation of the *OK* button, a working dialog is displayed and the numerical probabilities calculation is initiated. The *Stop* button on the dialog may be pressed to abort the process at any time.

On activation of the *Cancel* button, the procedure will be aborted and the *OpenFTA: Probabilities* dialog will be removed from the screen.

On activation of the *Help* button, a dialog containing context sensitive help information will be displayed.

On completion of the operation, the *OpenFTA: Probabilities* dialog is removed, a Probability Report is generated (to a file named: <fault tree name>.prp) and displayed in a dialog. The report consists of:

- the directory path to the file used to store the fault tree analysed in this report
- the date and time of the report's creation
- the number of unique primary events in the displayed fault tree (including those in any transfer-in trees)

- the number of minimal cut sets available for the fault tree
- the maximum order of the minimal cut sets available for use in the probability calculations for the displayed fault tree
- a statement of the order of minimal cut sets utilised in the probability calculations, if less than the maximum order available is used
- the unit time span used for the calculations
- a table titled *Minimal cut set probabilities*. This consists of a list of all the minimal cut sets and the probabilities of each and every event in a minimal cut set failing in order to cause the top level event to occur (system failure)
- the probability of the top level event occurring given the cut set probabilities calculated previously
- a table titled *Basic Event Analysis*. This contains a list of all the primary events in the fault tree and their failure contribution towards the top-level event occurring. This contribution is also stated as a percentage importance value for each primary event.

### Cross References

Analysis, Minimal Cut Sets, Print Dialog, Print (OpenFTA, Report), Report, Validate and View (OpenFTA, Report).



## *Open (OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**


Opens a previously stored fault tree for display and possible modification.

### **Location**

OpenFTA menubar -> File -> Open

### **Shortcuts**

Accelerator: Ctrl+O.

Toolbar: 

### **Pre-conditions**

None.

### **Operation**

Used to open a fault tree that has been previously stored. On activation, a file selection dialog titled *Open* is displayed. For more details on the use of this dialog read the section titled File Selection Dialog.

Note that on activation of the *OK* button, the currently selected file is opened and the *Open* dialog is removed. If no file, or non-existent or inaccessible files are selected then, an error dialog is displayed.

If a fault tree has been modified without saving, then confirmation is requested before OpenFTA proceeds with the *Open* Operation.

On successful completion of the operation, the newly chosen fault tree is displayed.

### **Cross References**

File Selection Dialog.

## *Open (OpenPED)*

---

### **Control Type**

Menu Option

### **Function**

Opens a previously stored primary events database for display and possible modification.

### **Location**

OpenPED menubar -> File -> New

### **Shortcuts**

Accelerator: Ctrl+O.

Toolbar:



### **Pre-conditions**

None.

### **Operation**

Used to open a primary events database that has been previously stored. On activation, a file selection dialog titled *Open* is displayed. For more details on the use of this dialog read the section titled File Selection Dialog.

Note that on activation of the *OK* button the currently selected file is opened and the *Open* dialog is removed. If no file, or non-existent or inaccessible files are selected then an error dialog is displayed.

If a database has been modified without saving, then confirmation is requested before OpenFTA proceeds with the *Open* Operation.

On successful completion of the operation the newly chosen database is displayed in the OpenPED window.

### **Cross References**

File Selection Dialog.

## Page Setup...

---

### Control Type

Menu Option

### Function

Invokes the page setup dialog.

### Location

OpenFTA and OpenPED menubar -> File -> Page Setup...

Print Preview dialog toolbar.

### Shortcuts

Accelerator: None.

Toolbar (Print Preview dialog only):



### Pre-conditions

None.

### Operation

Invokes the page setup dialog that allows the paper size/orientation to be selected.

### Cross References

Page Setup Dialog, Print, Print Dialog, Print Preview..., Printer Setup...

## Page Setup Dialog

---

### Control Type

Dialog

### Function

Sets the paper size and orientation.

### Location

Invoked from *Page Setup...* (OpenFTA), *Page Setup...* (OpenPED) and *Page Setup...* (Print Preview).

### Operation

The dialog consists of:

- a *Paper* panel allowing the *Size* and *Source* of the paper to be specified
- an *Orientation* panel that sets the output to be either *Landscape* or *Portrait*
- a *Margin* panel where the *Left*, *Right*, *Top* and *Bottom* margin distances can be adjusted.

On activation of the *OK* button, the settings are confirmed and the dialog is removed from the screen.

On activation of the *Cancel* button, the procedure is aborted and the dialog is removed from the screen.

### Cross References

Page Setup..., Print, Print Dialog, Print Preview..., Printer Setup...

## *Paste (OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**

Places the clipboard contents as a child of the currently selected fault tree symbol.

### **Location**

OpenFTA menubar -> Edit -> Paste

### **Shortcuts**

Accelerator: Ctrl+V.

Toolbar:



### **Pre-conditions**

A symbol in the drawing area is selected.

### **Operation**

A copy of the clipboard contents, usually a sub-tree of gates and events, is added as a child of the currently selected fault tree symbol. If this operation would cause the fault tree to become invalid, then an error dialog is displayed and the operation is aborted. The *Paste* operation can be repeated several times, since the clipboard retains its contents until they are overwritten by a *Copy* or *Cut* operation.

### **Cross References**

Copy (OpenFTA), Cut (OpenFTA) and Undo.

## *Paste (OpenPED)*

---

### **Control Type**

Menu Option

### **Function**

Places the clipboard contents to the place marked by the cursor into the Id, Probability or Description fields.

### **Location**

OpenPED menubar -> Edit -> Paste

### **Shortcuts**

Accelerator: Ctrl+V.

Toolbar:



### **Pre-conditions**

Text has previously been *Cut* or *Copied* onto the clipboard or, to paste into the *Probability* fields, data in a decimal or exponential format has previously been *Cut* or *Copied* onto the clipboard.

### **Operation**

A copy of the clipboard contents is added into one of the text fields where the cursor is currently situated. If text is currently highlighted the clipboard contents replace the highlighted text. If non numerical data is pasted into the *Probability* field, white space will be pasted instead. The *Paste* operation can be repeated several times, since the clipboard retains its contents until they are overwritten by a *Copy* or *Cut* operation.

### **Cross References**

Copy (OpenPED), Cut (OpenPED).

## *Preferences...*

---

### **Control Type**

Menu Option

### **Function**

Invokes the preferences dialog.

### **Location**

OpenFTA menubar -> Edit -> Preferences...

### **Shortcuts**

Accelerator: None.

Toolbar : None.

### **Pre-conditions**

None.

### **Operation**

Invokes the preferences dialog that allows the colours of the OpenFTA canvas to be changed. The colour of all the symbols can be specified, along with the pen, background and highlight colours.

### **Cross References**

None.

## *Print... (OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**

Prints the currently displayed fault tree either to a printer, or to a file.

### **Location**

OpenFTA menubar -> File -> Print...

### **Shortcuts**

Accelerator: Ctrl+P.

Toolbar:



### **Pre-conditions**

None.

### **Operation**

Used to print the fault tree. On activation, a dialog titled *Print* is displayed. For more details on the use of this dialog read the section entitled Print Dialog.

### **Cross References**

Print Dialog.



## *Print... (OpenPED)*

---

### **Control Type**

Menu Option

### **Function**

Prints the currently displayed primary events database either to a printer or to a file.

### **Location**

OpenPED menubar -> File -> Print...

### **Shortcuts**

Accelerator: None.

Toolbar:



### **Pre-conditions**

None.

### **Operation**

Used to print the primary events database either to a connected printer or to a file. On activation, a dialog titled *Print* is displayed. For more details read the section entitled Print Dialog.

### **Cross References**

Print Dialog.

## *Print... (OpenFTA, Report)*

---

### **Control Type**

Menu Option

### **Function**

Prints any of the three generated reports: Qualitative Report, Probability Report and Monte Carlo Report.

### **Location**

OpenFTA menubar -> Report -> Print

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

On activation a slide right menu is displayed containing three options: *Qualitative Report...*, *Probability Report...* and *Monte Carlo Report...*

By choosing any one of the available reports, a dialog titled *Print* is displayed. For more details on the use of this dialog read the section titled Print Dialog.

Note that if the appropriate analyses that generate the reports have not been performed, then the relevant options are greyed-out. For the Qualitative Report to be available for printing, the minimal cut sets must have been generated. For the Probability Report, the Numerical Probability analysis must have been carried out and for the Monte Carlo Report, the Monte Carlo Simulation must have been performed.

### **Cross References**

Minimal Cut Sets..., Monte Carlo Simulation..., Numerical Probability... and Print Dialog.

## *Print Dialog*

---

### **Control Type**

Dialog

### **Function**

Prints an image to a printer.

### **Location**

Invoked from *Print...* (OpenFTA), *Printer Setup...* (OpenFTA), *Print...* (OpenPED), *Printer Setup...* (OpenPED) and *Print...* (OpenFTA, Report).

### **Operation**

The dialog consists of:

- a *Printer Name* list allowing the destination printer to be specified
- a *Properties* button that invokes the properties dialog specific to the currently selected printer
- a *Print Range* panel allowing a subset of pages to be selected for printing
- a *Copies* panel where the number of required copies can be set.

On activation of the *OK* button, the document is sent to the selected printer and the dialog is removed from the screen.

On activation of the *Cancel* button, the procedure is aborted and the dialog is removed from the screen.

On activation of the *Help* button a dialog containing context sensitive help information is displayed.

### **Cross References**

None.

## *Print Preview...*

---

### **Control Type**

Menu Option

### **Function**

Invokes the Print Preview Dialog.

### **Location**

OpenFTA menubar -> File -> Print Preview...

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Invokes the Print Preview Dialog that controls the layout of the printed FTA canvas.

### **Cross References**

Print Preview Dialog.

## *Print Preview Dialog*

---

### **Control Type**

Dialog

### **Function**

Controls the layout of the printed FTA canvas.

### **Location**

Invoked from *Print Preview...*

### **Operation**

The dialog consists of:

- a toolbar containing 3 buttons:
  - A Printer Setup button that launches the Print Dialog allowing the selection of the current printer.
  - A Page Setup button that launches the Page Setup Dialog allowing the specification of the paper size/orientation.
  - A Print button that launches the Print Dialog allowing the FTA Canvas to be sent to the selected printer.
- a window previewing what the output will look like using the current settings.
- a *Horizontal Pages* spin button that adjusts the number of horizontal pages required.
- a *Vertical Pages* spin button that adjusts the number of vertical pages required.
- a *Zoom* spin button that adjusts the scale of the preview window.

On activation of the *OK* button, the current setting are confirmed and the dialog is removed from the screen.

On activation of the *Cancel* button, the current settings are discarded and the dialog is removed from the screen.

On activation of the *Help* button a dialog containing context sensitive help information is displayed.

### **Cross References**

Page Setup Dialog, Print Dialog and Print Preview...

## *Printer Setup...*

---

### **Control Type**

Menu Option

### **Function**

Allows the selection of the target printer.


### **Location**

OpenFTA and OpenPED menubar -> File -> Printer Setup...

Print Preview dialog toolbar.

### **Shortcuts**

Accelerator: None.

Toolbar (Print Preview dialog only): 

### **Pre-conditions**

None.

### **Operation**

Invokes the print dialog that allows the target printer to be selected.

### **Cross References**

Print, Print Dialog, , Print Preview, Page Setup...

## Report

---

### Control Type

Pulldown Menu

### Function

Provides access to the analysis reports generated by OpenFTA.

### Location

OpenFTA menubar -> Report.

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

None.

### Operation

Used to access the analysis reports generated by the OpenFTA application.

### Cross References

Minimal Cut Sets, Monte Carlo Simulation, Numerical Probability, Print (OpenFTA, Report), Validate and View (OpenFTA, Report).

## Save (OpenFTA)

---

### Control Type

Menu Option

### Function

Stores the current fault tree to a file.

### Location

OpenFTA menubar -> File -> Save

### Shortcuts

Accelerator: Ctrl+S.

Toolbar:



### Pre-conditions

None.

### Operation

Used to store the currently displayed fault tree to a file. On activation, if the fault tree has been previously stored, then the tree is stored to the same file. This overwrites any previous contents held within the file. The file name is of the form `<name of tree>.fta`.

If the tree has not been stored previously then the *Save* operation acts in the same way as the *Save As...* operation.

If the output file does not have write access, then an error dialog is displayed. In order to save the fault tree the permissions must be changed or the *Save As...* operation must be used to store the fault tree to a file with a different name and/or directory location.

### Cross References

Save As (OpenFTA).



## Save (OpenPED)

---

### Control Type

Menu Option

### Function

Stores the current primary events database to a file.

### Location

OpenPED menubar -> File -> Save

### Shortcuts

Accelerator: Ctrl+S.

Toolbar:



### Pre-conditions

None.

### Operation

Used to store the currently displayed primary events database to a file. On activation, if the database has been previously stored, then it is stored to the same file. This overwrites any previous contents held within the file. The file name is of the form <name of database>.ped.

If the database has not been stored previously, then the *Save* operation acts in the same way as the *Save As...* operation.

If the output file does not have write access, then an error dialog is displayed. In order to save the database the permissions must be changed or the *Save As...* operation must be used to store the database to a file with a different name and/or directory location.

### Cross References

Save As (OpenPED).

## *Save As... (OpenFTA)*

---

### **Control Type**

Menu Option

### **Function**

Stores the current fault tree to a named file.

### **Location**

OpenFTA menubar -> File -> Save As...

### **Shortcuts**

Accelerator: Ctrl+A.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Used to store the open fault tree to a named file. The file name is usually of the form <name of tree>.fta.

On activation a file selection dialog titled *Save*, is displayed. For more details on the use of this dialog read the section titled File Selection Dialog.

Note that on activation of the *OK* button the fault tree is stored to the currently selected file and the *Save* dialog is removed. If no file is selected then an error dialog is displayed.

If the output file does not have write access, then an error dialog is displayed. In order to save the fault tree the permissions must be changed or the *Save As...* operation must be used to store the fault tree to a file with a different name and/or directory location.

### **Cross References**

File Selection Dialog, Save(OpenFTA).

## *Save As... (OpenPED)*

---

### **Control Type**

Menu Option

### **Function**

Stores the current primary events database to a named file.

### **Location**

OpenPED menubar -> File -> Save As...

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Used to store the open primary events database to a named file. The file name is of the form <name of database>.ped.

On activation a selection dialog titled *Save*, is displayed. For more details on the use of this dialog read the section titled File Selection Dialog.

Note that on activation of the *OK* button the database is stored to the currently selected file and the *Save* dialog is removed. If no file is selected then an error dialog is displayed.

If the output file does not have write access, then an error dialog is displayed. In order to save the database the permissions must be changed or the *Save As...* operation must be used to store the database to a file with a different name and/or directory location.

### **Cross References**

File Selection Dialog, Save (OpenPED).

## *Selected...*

---

### **Control Type**

Menu Option

### **Function**

Displays the selected fault tree symbol's associated information.

### **Location**

OpenFTA menubar -> Edit -> Selected...

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

A symbol on the canvas is selected.

### **Operation**

On activation, the selected fault tree symbol's details are displayed. For a chosen intermediate event, transfer symbol or logic gate, a dialog is displayed containing the pertinent information about the symbol. For a primary event, the relevant database entry in the *OpenPED* window is highlighted and information is displayed.

The operation can also be activated by multi-clicking within the boundary of the required symbol in the fault tree.

### **Cross References**

None.

## *Set Zoom...*

---

### **Control Type**

Menu Option

### **Function**

Set's the zoom value of the OpenFTA canvas.

### **Location**

OpenFTA menubar -> View -> Set Zoom...

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

Invokes a dialog that allows the current zoom to be set. The zoom can be entered manually or a preset value selected from the drop down list.

### **Cross References**

Zoom In, Zoom Out.

## *Shift Left*

---

### **Control Type**

Menu Option

### **Function**

Shifts the currently selected fault tree symbol and the sub-tree below it one position to the left.

### **Location**

OpenFTA menubar -> Edit -> Shift Left

### **Shortcuts**

Accelerator: Ctrl+L.

Toolbar: None.

### **Pre-conditions**

A symbol on the canvas is selected.

### **Operation**

On activation, the selected fault tree symbol and the sub-tree below it are shifted one place to the left. The layout of the fault tree is handled automatically. The operation is available for purely aesthetic reasons and has no effect upon the analysis of the tree.

Note that Conditioning Events may not be shifted and if this operation is attempted an error dialog is displayed.

### **Cross References**

Shift Right and Undo.

## *Shift Right*

---

### **Control Type**

Menu Option

### **Function**

Shifts the currently selected fault tree symbol and the sub-tree below it one position to the right.

### **Location**

OpenFTA menubar -> Edit -> Shift Right

### **Shortcuts**

Accelerator: Ctrl+R.

Toolbar: None.

### **Pre-conditions**

A symbol on the canvas is selected.

### **Operation**

On activation, the selected fault tree symbol and the sub-tree below it are shifted one place to the right. The layout of the fault tree is handled automatically. The operation is available for purely aesthetic reasons and has no effect upon the analysis of the tree.

Note that Conditioning Events may not be shifted and if this is attempted an error dialog is displayed.

### **Cross References**

Shift Left and Undo.

## Symbol Palette

---

### Control Type

Push Buttons

### Function

The set of symbols available to draw a fault tree.

### Location

Left hand side of the OpenFTA window

### Shortcuts

Accelerator: None.

Toolbar: None.

### Pre-conditions

A symbol on the canvas is selected.

### Operation

Selecting a symbol from the palette adds the chosen symbol as the right most child of the symbol selected on the canvas.

Note that the tree layout is managed automatically and that the symbol palette is context sensitive and thus prevents illogical additions to the tree by greying out inappropriate symbols.

The Symbol Palette is made up of events, gates and transfer symbols.

### Event Symbols:



Intermediate Event: Used to specify a failure event that occurs due to one or more causes acting through logic gates below it in the fault tree.



Basic Initiating Event: Used to specify a failure event that does not require any further development i.e. it is a “leaf” of the fault tree and has no gates or events below it in the tree.



Undeveloped Event: Used to specify a failure event that is not developed as far as it could be, either because the event is of no importance in this fault tree, or because there is not enough information available.



External Event: Used to specify a failure event that is expected to occur and is therefore not directly a failure. The event can only have a probability attached to it of 0 (Failed) or 1 (Working).



Conditioning Event: Used to specify certain conditions upon any logic gate. There are two



states for this type of event: *Analysed* - a probability is assigned to the event and it forms part of the analysis of the tree; *Not Analysed* - no probability is assigned to the event and it's role is to add pertinent comments. This type of event is mainly used in conjunction with the *Priority And* and *Inhibit* gates and is displayed to the right of a gate.

#### Logic Gate Symbols:



And Gate: Used to show that the output fault will only happen if all of the inputs occur.



Or Gate: Used to show that the output fault will only occur if one or more of the input faults take place.



Priority And Gate: The output only occurs if the input faults take place in a certain order. The sequence of events is usually stated in a conditioning event, situated to the right of the gate.



Exclusive Or Gate: The output only occurs if exactly one of the input faults happens.



Inhibit Gate: The output fault only occurs if the single input happens and the attached *Conditioning Event* is satisfied. The gate is in effect a special case *And* gate.

#### Transfer Symbols:

These symbols are used to modularise a fault tree. For example, if there is a sequence of events that occurs in more than one place in the fault tree, then it can be removed and placed into a separate sub-tree and just referenced by the main fault tree.



Transfer In: Used to depict a sub-tree that has been stored in a separate `.fta` file. The name of the file is used as the identifier for the transfer in symbol. Note that the `.fta` suffix is added automatically to the file name.



Transfer Out: Used to depict that the tree shown below a transfer out symbol is a sub-tree of a fault tree that is stored in a different file. The name of the sub-tree may be used as the identifier for the transfer out symbol. Note that the `.fta` suffix is added automatically to the file name.

#### Cross References

None.

## *Tree Overview*

---

### **Control Type**

Menu Option

### **Function**

Displays the entire fault tree in a resizable window.

### **Location**

OpenFTA menubar -> View -> Tree Overview

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

On activation a resizable dialog entitled *OpenFTA: Tree* is displayed. The dialog contains a scaled image of the fault tree currently displayed on the OpenFTA canvas area. Symbols can be selected on the overview causing them to become centered on OpenFTA's canvas area. This aids navigation around large fault trees.

### **Cross References**

None.

## Undo

---

### Control Type

Menu Option

### Function

Undoes the last edit action carried out upon the fault tree.

### Location

OpenFTA menubar -> Edit -> Undo

### Shortcuts

Accelerator: Ctrl+U.

Toolbar: None.

### Pre-conditions

One of the edit actions; *Copy*, *Cut*, *Delete*, *Paste*, *Shift Left* or *Shift Right* has been carried out or a symbol has been added to the fault tree.

### Operation

On activation, the last edit action or symbol addition to the fault tree is undone. Note that if the *Undo* option is selected twice in a row it undoes the first undo action.

### Cross References

Copy, Cut, Delete (OpenFTA), Paste, Shift Left, Shift Right and Symbol Palette.

## *Validate*

---

### **Control Type**

Menu Option

### **Function**

Verifies that the current fault tree is logically correct and ready for analysis.

### **Location**

OpenFTA menubar -> Analysis -> Validate

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

The fault tree displayed on the canvas has been associated with a primary events database and been saved.

### **Operation**

On selection of this option, a validation report is produced and displayed. The report contains any warnings or errors found with the fault tree and states if the tree is logically correct.

The report is stored in the file named <fault tree name>.vrp. If the output file does not have write access, then an error dialog is displayed. The permissions for the file or directory must be changed before activating this option again.

### **Cross References**

Analysis, Minimal Cut Sets, Monte Carlo Simulation and Numerical Probability.

## View

---

### Control Type

Pulldown Menu

### Function

Provides access to facilities for displaying different views of the fault tree.

### Location

OpenFTA menubar -> View

### Shortcuts

Accelerator: None.

Toolbar: None.

### Operation

Tree Overview shows the entire tree in a window. Zoom facilities allow inspection of an area of the tree in greater or lesser detail.

### Pre-conditions

None.

### Cross References

Set Zoom..., Tree Overview..., Zoom In and Zoom Out.

## *View (OpenFTA, Report)*

---

### **Control Type**

Menu Option

### **Function**

Provides a means to view any of the three generated reports: Qualitative Report, Probability Report and Monte Carlo Report.

### **Location**

OpenFTA menubar -> Report -> View

### **Shortcuts**

Accelerator: None.

Toolbar: None.

### **Pre-conditions**

None.

### **Operation**

On selection of the View option a slide right menu is displayed containing three options: *Qualitative Report*, *Probability Report* and *Monte Carlo Report*. By choosing any one of the available reports, a OpenFTA: View Report dialog containing the associated information is displayed.

Note that for the Qualitative Report to be available for viewing, the minimal cut sets must have been generated. For the Probability Report, the Numerical Probability analysis must have been performed and for the Monte Carlo Report, the Monte Carlo Simulation must have been performed. If the appropriate analyses that generate the reports have not been done, then the relevant options are greyed-out.

### **Cross References**

Minimal Cut Sets, Monte Carlo Simulation and Numerical Probability.

## Zoom In

---

### Control Type

Menu Option

### Function


Increases the zoom value of the OpenFTA canvas.

### Location

OpenFTA menubar -> View -> Zoom In

### Shortcuts

Accelerator: None.

Toolbar: 

### Pre-conditions

None.

### Operation

Increases the zoom value of the OpenFTA canvas by 10%.

### Cross References

Set Zoom..., Zoom Out.

## Zoom Out

---

### Control Type

Menu Option

### Function


Decreases the zoom value of the OpenFTA canvas.

### Location

OpenFTA menubar -> View -> Zoom Out

### Shortcuts

Accelerator: None.

Toolbar: 

### Pre-conditions

None.

### Operation

Decreases the zoom value of the OpenFTA canvas by 10%.

### Cross References

Set Zoom..., Zoom In.



## Appendix A - Analysis Methods

---

### Overview

---

This appendix describes the analysis methods used to:

- carry out the numerical probability calculations
- carry out Monte Carlo Simulations.

It then briefly details the Pmodel and ?-model used to define the probability of occurrence of a primary event.

### Numerical Probability Analysis

---

This is calculated using a method of direct computation from the probabilities of the primary events, which are independent in OpenFTA. The method depends upon the logically reduced tree, but the precision of the result does not. This relies on the number of terms calculated in the expression for the top level probability (see below). Note that the same information is generated stochastically by the Monte Carlo method.

The complexity of this calculation arises because the same primary event may occur in several places in a fault tree or, in other words, the component probabilities in the tree are not independent.

If the minimal cut sets are  $M_1, M_2, \dots, M_n$ , then the tree is logically equivalent to the expression:  $(M_1 \text{ OR } M_2 \text{ OR } \dots \text{ OR } M_n)$ . It is this expression that is evaluated. Note that the minimal cut sets are neither mutually exclusive nor independent. The general expression for the probability of the OR of  $n$  arbitrary events is:

$$\begin{aligned}
 P(M_1 \cup M_2 \cup \dots \cup M_n) = & \sum_{i=1}^n P(M_i) \\
 & - \sum_{i=2}^n \sum_{j=1}^{i-1} P(M_i \cap M_j) \\
 & + \sum_{i=3}^n \sum_{j=2}^{i-1} \sum_{k=1}^{j-1} P(M_i \cap M_j \cap M_k) \\
 & - \dots \\
 & + (-1)^{n-1} P(M_1 \cap M_2 \cap \dots \cap M_n)
 \end{aligned}$$

This is a sum of terms each of which is the probability of the AND of minimal cut sets. The probability of the AND of several minimal cut sets is not simply the product of their individual probabilities, as they may share primary events. Assuming the primary events are independent, it is the product of the probabilities of all the primary events that occur in any cut set, taking each one only once.

This series however has  $2^N$  terms where  $N$  is the number of minimal cut sets. In general it would take a prohibitively long time to evaluate all the terms in this series, even for fairly small trees. For example, a tree with 20 basic events could have 100 minimal cut sets, which would imply more than  $10^{30}$  terms. In

fact it is not necessary to evaluate all the terms. The following series gives ever-closer approximations to the exact result.

$$\begin{aligned}
 P_1 &\equiv \sum_{i=1}^n P(M_i) \\
 P_1 &\equiv P_1 - \sum_{i=2}^n \sum_{j=1}^{i-1} P(M_i \cap M_j) \\
 P_1 &\equiv P_2 - \sum_{i=3}^n \sum_{j=2}^{i-1} \sum_{k=3}^{j-1} P(M_i \cap M_j \cap M_k) \\
 &\dots
 \end{aligned}$$

The series has N terms, each of which has  ${}^N C_r$  sub-terms, giving 2N terms in all. The first term is simply the sum of probabilities of the minimal cut sets. The increments in the series alternate in sign and it can be shown that the terms always bracket the answer i.e. the first term is an upper bound, the second a lower bound, the third a better upper bound, etc.

Thus, the result can be made arbitrarily accurate by specifying a sufficient number of terms i.e.

$$\forall x \exists n : |P_i - P| < x \quad \forall i > n$$

where

$$P = P(M_1 \cup M_2 \cup \dots \cup M_n)$$

In practice the terms get smaller rapidly and it is rarely necessary to go past the third term for a large tree. For 100 minimal cut sets, the first term has 100 sub-terms, the second 4950, the third 161,700 and the fourth 3,921,225. It is safest to calculate the default two terms first, progressing to higher terms one at a time, if necessary.

## Monte Carlo Simulation

---

The principle behind the Monte Carlo methodology is to simulate occurrences of the primary events (component failures), using a random number generator.

For each trial, each primary event is simulated by generating a (pseudo-)random real number in the range 0 to 1 inclusive. If this number is less than or equal to the probability of the primary event, the event is deemed to have occurred and its value is set to TRUE. Otherwise it is deemed not to have occurred and its value is set to FALSE.

The fault tree is then evaluated with these values for the primary events to see if the top event occurs (system failure). The number of top event occurrences is stored, together with the corresponding failure mode (the list of primary events which occurred to cause the top event).

The data is then used to obtain both the top-level probability and the probabilities of individual cut sets. For example, for N trials resulting in F failures the probability would be estimated as  $(F \pm \sqrt{F})/N$ .

One refinement of this scheme is made. Consider a tree with 30 primary events, with probabilities of the order of  $10^{-3}$ . In this case in approximately 97% of trials, no primary event would occur and the fault tree would be evaluated with no faults. All these runs would be effectively useless and therefore a waste of computational time.

To avoid this, only trials in which at least one primary event occurs are simulated. The probability, P, of at least one primary event occurring is evaluated exactly. Thus, the probability of the top event occurring is estimated as  $P \cdot (F \pm \sqrt{F})/N$ .

It should be noted that the failure modes generated by this method are not minimal. For example, if {A} and {BC} are minimal cut sets, the Monte Carlo method will report {A}, {AB}, {AC}, {BC} and {ABC} separately. To deal with this, the Monte Carlo Report generated by OpenFTA provides a *Compressed* list of cut sets, in which supersets of other cut sets are removed.

These compressed cut sets are likely to be, but are not guaranteed to be, minimal. When a set is removed, its failure count is added to each of its subsets. Consider the previous example, a failure {ABC} would count as both {A} and {BC}.

Note that the sum of failures for all the compressed cut sets will therefore be greater than the total number of failures. This is consistent with the probabilities generated in the numerical probability analysis.

### *The P-model and the ?-model*

---

OpenFTA supports the P-model or ?-model definition of the probability of a primary event occurring.

A P-model definition is used to state the probability of an event occurring when the time to failure (event occurring) is unknown or unpredictable.

A ?-model definition is used to state the probability that a primary event will occur within a given period of time. A ?-model definition is appropriate for events within systems that are continuously operating and have a known probability of failure during a unit time period.

Each event defined in terms of the ?-model has a probability of failure given by:

$$1 - e^{-\lambda t}, \text{ where } t = \text{unit time to event occurring and } \lambda = \text{constant.}^1$$

Events defined in terms of the P-model do not have to be modified for time. The probability of a cut set is the multiplication of the probabilities of the events within it, as determined by the P or ? models.

---

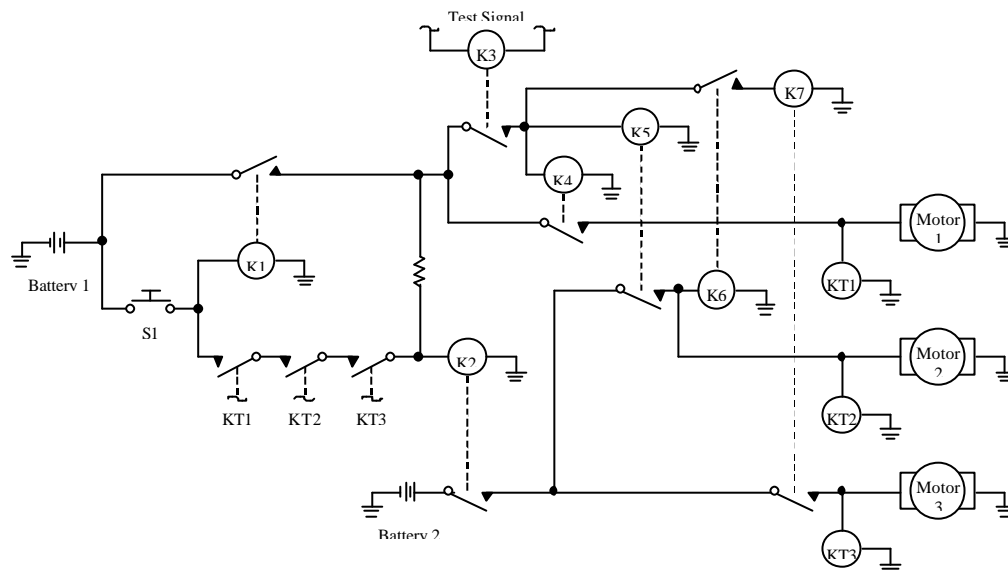
<sup>1</sup>. For more details see the Fault Tree Handbook, U.S. Nuclear Regulatory Commission, NUREG-0492 and Introduction to Reliability Engineering, E. E. Lewis.

## Appendix B - The Three Motor Example

### Overview

This appendix briefly describes an example<sup>2</sup> of a system suitable for analysis by OpenFTA and presents the results of such an analysis. The data files generated are included in the OpenFTA delivery package.

### Three Motor Example



**Figure 14: Power Distribution Box.**

The above figure displays a power distribution box. With contacts KT1, KT2 and KT3 normally closed, a momentary depression of button S1 applies power from Battery 1 to the coils of relays K1 and K2. K1 and K2 close and remain electrically latched.

Next, a 60 second signal is passed through K3, in order to test the operation of Motors 1, 2 and 3. Once K3 has closed, power from Battery 1 is applied to the coils of relays K4 and K5. The closure of K4 starts Motor 1. The closure of K5 applies power from Battery 2 to the coil of K6 and also starts Motor 2. Finally, the closure of K6 applies power from Battery 1 to the coil of K7. Closure of K7 starts Motor 3.

<sup>2</sup> This example is based on one presented in the Fault Tree Handbook, U.S. Nuclear Regulatory Commission, NUREG-0492.

After 60 seconds, K3 is supposed to open, shutting down all three motors. Should K3 fail closed after this time, all three timers (KT1, KT2, KT3) open, de-energizing the coil of K1, thus shutting down the system.

Suppose K3 opens properly after the 60 seconds, but K4 fails closed. In that case KT1 opens to denegize K1 and Motor 1 stops. KT2 and KT3 act similarly to stop Motor 2 or Motor 3 should either K5 or K7 fail closed.

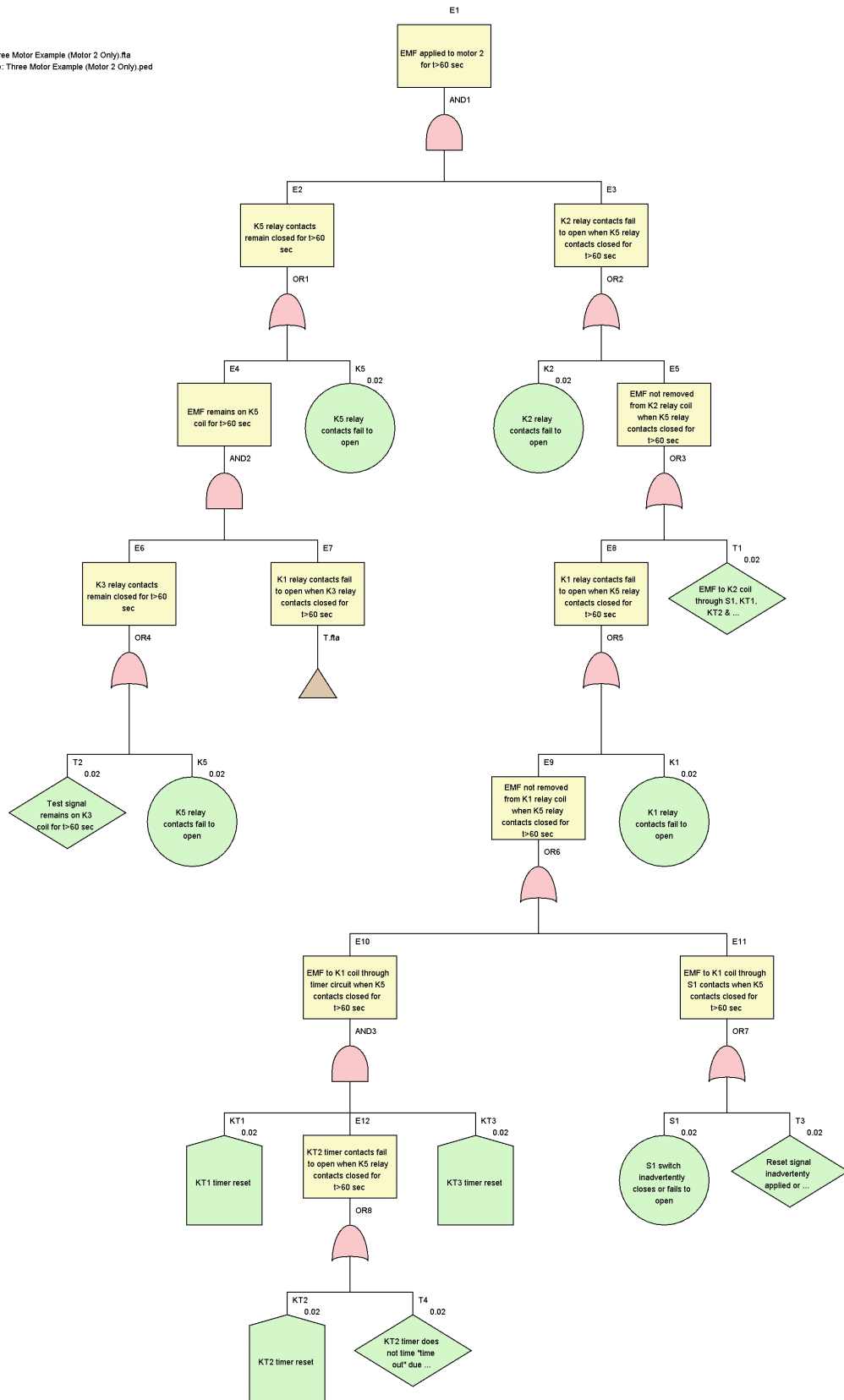
Now it can be seen that the main concern is the application of ElectroMotive Force (EMF) to the motors overrunning the 60 seconds.

For this problem we will concentrate on the failures of relays and switches pertaining to Motor 2. Thus the top level event for the fault tree will be: EMF applied to Motor 2 for  $t > 60$  seconds.

## *The Top Level Fault Tree*

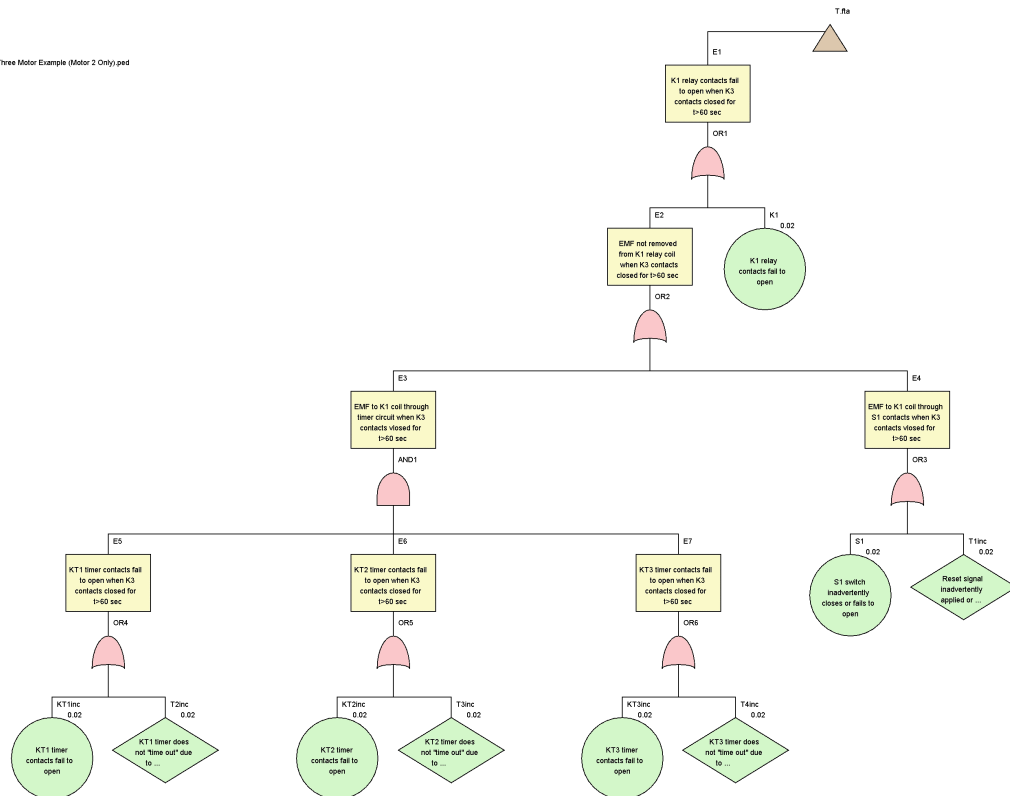
---

Tree: Three Motor Example (Motor 2 Only).fta  
Database: Three Motor Example (Motor 2 Only).ped



## The Transferred Fault Tree

Tree: T.Ra  
Database: Three Motor Example (Motor 2 Only).ped





## *The Qualitative Analysis Report*

---

This report shows an example of the results obtained by generating minimal cut sets for a fault tree. The minimal cut sets for each order and the distribution of minimal cut sets to orders is displayed.

Minimal Cut Sets

=====

Tree : Three Motor Example (Motor 2 Only).fta

Time : Thu Feb 28 13:19:13 2002

Method : Algebraic

No. of primary events = 18

Minimal cut set order = 1 to 18

Order 1:

Order 2:

- 1) K1 K5
- 2) K1 T2
- 3) K2 K5
- 4) K5 S1
- 5) K5 T1
- 6) K5 T3
- 7) S1 T2

Order 3:

- 1) K2 Tlinc T2
- 2) T1 Tlinc T2
- 3) Tlinc T2 T3

Order 4:

- 1) K5 KT1 KT2 KT3
- 2) K5 KT1 KT3 T4

Order 5:

- 1) K2 KTlinc KT2inc KT3inc T2
- 2) K2 KTlinc KT2inc T2 T4inc
- 3) K2 KTlinc KT3inc T2 T3inc
- 4) K2 KTlinc T2 T3inc T4inc
- 5) K2 KT2inc KT3inc T2 T2inc
- 6) K2 KT2inc T2 T2inc T4inc
- 7) K2 KT3inc T2 T2inc T3inc
- 8) K2 T2 T2inc T3inc T4inc
- 9) KT1 KT2 KT3 Tlinc T2
- 10) KT1 KT3 Tlinc T2 T4
- 11) KTlinc KT2inc KT3inc T1 T2
- 12) KTlinc KT2inc KT3inc T2 T3
- 13) KTlinc KT2inc T1 T2 T4inc
- 14) KTlinc KT2inc T2 T3 T4inc
- 15) KTlinc KT3inc T1 T2 T3inc
- 16) KTlinc KT3inc T2 T3 T3inc
- 17) KTlinc T1 T2 T3inc T4inc
- 18) KTlinc T2 T3 T3inc T4inc
- 19) KT2inc KT3inc T1 T2 T2inc
- 20) KT2inc KT3inc T2 T2inc T3
- 21) KT2inc T1 T2 T2inc T4inc
- 22) KT2inc T2 T2inc T3 T4inc
- 23) KT3inc T1 T2 T2inc T3inc
- 24) KT3inc T2 T2inc T3 T3inc
- 25) T1 T2 T2inc T3inc T4inc
- 26) T2 T2inc T3 T3inc T4inc

Order 6:

Order 7:

- 1) KT1 KTlinc KT2 KT2inc KT3 KT3inc T2
- 2) KT1 KTlinc KT2 KT2inc KT3 T2 T4inc
- 3) KT1 KTlinc KT2 KT3 KT3inc T2 T3inc
- 4) KT1 KTlinc KT2 KT3 T2 T3inc T4inc
- 5) KT1 KTlinc KT2inc KT3 KT3inc T2 T4
- 6) KT1 KTlinc KT2inc KT3 T2 T4 T4inc
- 7) KT1 KTlinc KT3 KT3inc T2 T3inc T4
- 8) KT1 KTlinc KT3 T2 T3inc T4 T4inc
- 9) KT1 KT2 KT2inc KT3 KT3inc T2 T2inc

- 10) KT1 KT2 KT2inc KT3 T2 T2inc T4inc
- 11) KT1 KT2 KT3 KT3inc T2 T2inc T3inc
- 12) KT1 KT2 KT3 T2 T2inc T3inc T4inc
- 13) KT1 KT2inc KT3 KT3inc T2 T2inc T4
- 14) KT1 KT2inc KT3 T2 T2inc T4 T4inc
- 15) KT1 KT3 KT3inc T2 T2inc T3inc T4
- 16) KT1 KT3 T2 T2inc T3inc T4 T4inc

Order 8:

Order 9:

Order 10:

Order 11:

Order 12:

Order 13:

Order 14:

Order 15:

Order 16:

Order 17:

Order 18:

Qualitative Importance Analysis:

Order	Number
-----	-----
1	0
2	7
3	3
4	2

5	26
6	0
7	16
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
ALL	54

## *The Probability Analysis Report*

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This report shows an example of the results obtained when a quantitative evaluation is performed upon the minimal cut sets of a fault tree. The evaluation produces the minimal cut set probabilities according to the defined primary event probabilities. A series expansion is then performed to calculate the probability of occurrence of the top level event of the fault tree for the given minimal cut sets. This series expansion is detailed in Appendix A. The number of terms is user definable, but the calculation time of the series will increase quickly as the number of terms is increased, with only a relatively small gain in precision.

A primary event analysis is carried out and the failure contribution and importance of each primary event is displayed.

### Probabilities Analysis

=====

Tree : Three Motor Example (Motor 2 Only).fta

Time : Thu Feb 28 13:19:37 2002

Number of primary events = 18

Number of minimal cut sets = 54

Order of minimal cut sets = 18

Unit time span = 1.000000

### Minimal cut set probabilities :

1	K1 K5	4.000000E-004
2	K1 T2	4.000000E-004
3	K2 K5	4.000000E-004
4	K5 S1	4.000000E-004
5	K5 T1	4.000000E-004
6	K5 T3	4.000000E-004
7	S1 T2	4.000000E-004
8	K2 T1inc T2	8.000000E-006
9	T1 T1inc T2	8.000000E-006
10	T1inc T2 T3	8.000000E-006
11	K5 KT1 KT2 KT3	1.600000E-007
12	K5 KT1 KT3 T4	1.600000E-007
13	K2 KT1inc KT2inc KT3inc T2	3.200000E-009

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14	K2 KTlinc KT2inc T2 T4inc	3.200000E-009
15	K2 KTlinc KT3inc T2 T3inc	3.200000E-009
16	K2 KTlinc T2 T3inc T4inc	3.200000E-009
17	K2 KT2inc KT3inc T2 T2inc	3.200000E-009
18	K2 KT2inc T2 T2inc T4inc	3.200000E-009
19	K2 KT3inc T2 T2inc T3inc	3.200000E-009
20	K2 T2 T2inc T3inc T4inc	3.200000E-009
21	KT1 KT2 KT3 Tlinc T2	3.200000E-009
22	KT1 KT3 Tlinc T2 T4	3.200000E-009
23	KTlinc KT2inc KT3inc T1 T2	3.200000E-009
24	KTlinc KT2inc KT3inc T2 T3	3.200000E-009
25	KTlinc KT2inc T1 T2 T4inc	3.200000E-009
26	KTlinc KT2inc T2 T3 T4inc	3.200000E-009
27	KTlinc KT3inc T1 T2 T3inc	3.200000E-009
28	KTlinc KT3inc T2 T3 T3inc	3.200000E-009
29	KTlinc T1 T2 T3inc T4inc	3.200000E-009
30	KTlinc T2 T3 T3inc T4inc	3.200000E-009
31	KT2inc KT3inc T1 T2 T2inc	3.200000E-009
32	KT2inc KT3inc T2 T2inc T3	3.200000E-009
33	KT2inc T1 T2 T2inc T4inc	3.200000E-009
34	KT2inc T2 T2inc T3 T4inc	3.200000E-009
35	KT3inc T1 T2 T2inc T3inc	3.200000E-009
36	KT3inc T2 T2inc T3 T3inc	3.200000E-009
37	T1 T2 T2inc T3inc T4inc	3.200000E-009
38	T2 T2inc T3 T3inc T4inc	3.200000E-009
39	KT1 KTlinc KT2 KT2inc KT3 KT3inc T2	1.280000E-012
40	KT1 KTlinc KT2 KT2inc KT3 T2 T4inc	1.280000E-012
41	KT1 KTlinc KT2 KT3 KT3inc T2 T3inc	1.280000E-012
42	KT1 KTlinc KT2 KT3 T2 T3inc T4inc	1.280000E-012
43	KT1 KTlinc KT2inc KT3 KT3inc T2 T4	1.280000E-012
44	KT1 KTlinc KT2inc KT3 T2 T4 T4inc	1.280000E-012
45	KT1 KTlinc KT3 KT3inc T2 T3inc T4	1.280000E-012

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46	KT1 KTlinc KT3 T2 T3inc T4 T4inc	1.280000E-012
47	KT1 KT2 KT2inc KT3 KT3inc T2 T2inc	1.280000E-012
48	KT1 KT2 KT2inc KT3 T2 T2inc T4inc	1.280000E-012
49	KT1 KT2 KT3 KT3inc T2 T2inc T3inc	1.280000E-012
50	KT1 KT2 KT3 T2 T2inc T3inc T4inc	1.280000E-012
51	KT1 KT2inc KT3 KT3inc T2 T2inc T4	1.280000E-012
52	KT1 KT2inc KT3 T2 T2inc T4 T4inc	1.280000E-012
53	KT1 KT3 KT3inc T2 T2inc T3inc T4	1.280000E-012
54	KT1 KT3 T2 T2inc T3inc T4 T4inc	1.280000E-012

Probability of top level event (minimal cut sets up to order 18 used):

1 term	+2.824405E-003	= 2.824405E-003 (upper bound)
2 terms	-1.072849E-004	= 2.717120E-003 (lower bound)
3 terms	+3.382002E-006	= 2.720502E-003 (upper bound)

Primary Event Analysis:

Event	Failure contrib.	Importance
K1	8.000000E-004	29.41%
K2	4.080256E-004	15.00%
K5	2.000320E-003	73.53%
KT1	3.264205E-007	0.01%
KTlinc	3.841023E-008	0.00%
KT2	1.632102E-007	0.01%
KT2inc	3.841023E-008	0.00%
KT3	3.264205E-007	0.01%

KT3inc	3.841023E-008	0.00%
S1	8.000000E-004	29.41%
T1	4.080256E-004	15.00%
T1inc	2.400640E-005	0.88%
T2	8.240832E-004	30.29%
T2inc	3.841023E-008	0.00%
T3	4.080256E-004	15.00%
T3inc	3.841023E-008	0.00%
T4	1.632102E-007	0.01%
T4inc	3.841023E-008	0.00%



## The Monte Carlo Report

This report shows an example of the results obtained when a Monte Carlo Simulation is performed upon a fault tree. The simulation produces the probability of at least one component failing, the probability of the top-level event occurring and the cut sets of the fault tree. It does this using the method detailed in Appendix A. The number of tests (simulations) is user definable, but the calculation time of the probabilities will increase as the number of tests is increased.

A primary event analysis is carried out and the failure contribution and importance of each primary event is displayed.

Monte Carlo Simulation

=====

Tree : Three Motor Example (Motor 2 Only).fta

Time : Thu Feb 28 13:22:20 2002

Note: Only runs with at least one component failure are simulated

Number of primary events = 18

Number of tests = 250000

Unit Time span used = 1.000000

Number of system failures = 2288

Probability of at least = 3.048647E-001 ( exact )

one component failure

Probability of top event = 2.790121E-003 ( +/- 5.833042E-005 )

Rank	Failure mode	Failures	Estimated Probability	Importance
1	K5 T3	267	3.255955E-004 ( +/- 1.992612E-005 )	11.67%
2	K5 S1	261	3.182787E-004 ( +/- 1.970096E-005 )	11.41%
3	K2 K5	257	3.134009E-004 ( +/- 1.954941E-005 )	11.23%
4	S1 T2	252	3.073036E-004 ( +/- 1.935831E-005 )	11.01%
5	K5 T1	235	2.865728E-004 ( +/- 1.869395E-005 )	10.27%
6	K1 K5	231	2.816949E-004 ( +/- 1.853417E-005 )	10.10%
7	K1 T2	217	2.646225E-004 ( +/- 1.796375E-005 )	9.48%
8	K1 T2 T2inc	11	1.341405E-005 ( +/- 4.044487E-006 )	0.48%
9	K1 KT1inc T2	9	1.097513E-005 ( +/- 3.658376E-006 )	0.39%

10	K1 K5 T4	9	1.097513E-005 ( +/- 3.658376E-006 )	0.39%
11	K5 KTlinc T1	8	9.755669E-006 ( +/- 3.449150E-006 )	0.35%
12	KT3 S1 T2	8	9.755669E-006 ( +/- 3.449150E-006 )	0.35%
13	K2 K5 T4inc	8	9.755669E-006 ( +/- 3.449150E-006 )	0.35%
14	K2 Tlinc T2	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
15	K1 K5 T3	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
16	K1 K5 KT2	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
17	K5 KTlinc S1	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
18	K1 KT3 T2	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
19	K5 KT1 S1	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
20	K5 KT3 T3	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
21	S1 T2 T3inc	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
22	K5 S1 T2	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
23	K5 T1 T2inc	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
24	S1 T2 T2inc	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
25	K2 K5 T2inc	7	8.536211E-006 ( +/- 3.226384E-006 )	0.31%
26	K5 T2inc T3	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
27	K1 S1 T2	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
28	S1 T2 T3	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
29	S1 T2 T4	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
30	K2 K5 T3inc	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
31	K1 T2 T4	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
32	KT2inc S1 T2	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
33	K2 K5 T1	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
34	K1 KT3inc T2	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
35	K5 T3 T4inc	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
36	K5 KTlinc T3	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
37	K5 S1 T3inc	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
38	S1 T1 T2	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
39	K5 KT3inc T1	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
40	K5 KT2 S1	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
41	K5 KT3inc T3	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
42	K1 K5 KT2inc	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
43	K5 S1 T4	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
44	K5 KT3 S1	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
45	K5 KT2inc S1	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
46	K2 K5 T4	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
47	Tlinc T2 T3	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
48	K5 T1 T4inc	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%

49	K2 K5 T3	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
50	K1 T1 T2	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
51	K1 T1inc T2	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
52	K5 KT2 T3	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
53	K5 KT2inc T1	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
54	K2 K5 KT1	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
55	K1 K5 T1	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
56	K5 S1 T1inc	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
57	K5 T3 T4	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
58	S1 T1inc T2	5	6.097293E-006 ( +/- 2.726792E-006 )	0.22%
59	K1 T2 T3inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
60	K5 KT2inc T3	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
61	K5 S1 T1	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
62	K1 KT1 T2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
63	K1 K2 T2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
64	K5 T1 T1inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
65	K1 K5 T2inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
66	K5 S1 T4inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
67	K1 K5 S1	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
68	K2 K5 S1	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
69	K5 T1inc T3	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
70	K5 KT3inc S1	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
71	KT2 S1 T2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
72	K1 KT2 T2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
73	K1 K2 K5	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
74	K5 T1 T3	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
75	KT1inc S1 T2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
76	K1 K5 KT3	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
77	K1 K5 KT1	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
78	K2 K5 KT1inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
79	K5 S1 T2inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
80	K1 T2 T4inc	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
81	K5 T2 T3	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
82	K2 K5 KT2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
83	K2 K5 T2	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
84	K1 T2 T3	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
85	KT1 S1 T2	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
86	K1 K5 KT3inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
87	K2 S1 T2	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%

88	K2 K5 T1inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
89	KT3inc S1 T2	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
90	K1 K5 T4inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
91	S1 T2 T4inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
92	T1 T1inc T2	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
93	K5 T1 T2	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
94	K1 K5 T1inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
95	K5 KT3 T1	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
96	K5 T1 T3inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
97	K1 K5 KT1inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
98	K5 KT1 T3	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
99	K5 S1 T3	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
100	K5 T3 T3inc	3	3.658376E-006 ( +/- 2.112164E-006 )	0.13%
101	K1 KT3 T2 T4	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
102	K1 KT2inc T2	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
103	K1 K5 T3inc	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
104	K2 K5 KT2inc	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
105	K2 K5 KT3	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
106	K5 KT2 S1 T4	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
107	K5 KT1inc KT2inc T1	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
108	K5 KT1 T1	2	2.438917E-006 ( +/- 1.724575E-006 )	0.09%
109	K5 KT2inc T1 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
110	K5 KT1 KT3inc S1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
111	K5 T1inc T3 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
112	KT2inc KT3 S1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
113	K2 S1 T2 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
114	K1 KT2inc KT3inc T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
115	K1 KT1 KT3inc T1inc T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
116	K1 K2 T2 T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
117	S1 T2 T2inc T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
118	K1 K5 KT1inc KT2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
119	K2 K5 KT3inc T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
120	K1 K5 KT2inc T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
121	K5 KT2inc T1inc T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
122	S1 T1inc T2 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
123	K5 T1 T3 T3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
124	K2 K5 KT1inc KT3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
125	K1 K2 K5 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%

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126	KT3 KT3inc S1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
127	K1 K5 KT2 T1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
128	K1 KT2inc T2 T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
129	S1 T1inc T2 T3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
130	K5 KT2 KT3 S1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
131	K1 K5 S1 T1inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
132	K1 K5 KT1inc KT2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
133	K2 K5 KT3 S1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
134	K5 KT3inc T1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
135	K5 T2 T2inc T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
136	K5 T1 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
137	K1 K5 T2inc T3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
138	K5 KT2inc T3 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
139	K2 T1inc T2 T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
140	K5 KT2inc KT3 T1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
141	K5 KT2 T1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
142	K2 K5 T4 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
143	K1 K5 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
144	K5 KT3inc T3 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
145	K5 KT1 KT3 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
146	K5 T1 T3 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
147	K2 K5 T3 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
148	K1 KT1inc KT2 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
149	K5 KT3 KT3inc S1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
150	K2 KT3 T1inc T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
151	KT1inc KT2 S1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
152	K5 KT3 T1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
153	K5 KT1 S1 T3 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
154	K1 K5 T2 T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
155	K2 K5 T2 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
156	K1 K5 KT2 T3 T3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
157	K5 S1 T1inc T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
158	K2 K5 KT1 T1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
159	K1 K5 T1inc T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
160	K1 K2 K5 KT1inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
161	K2 K5 KT3 T1 T4inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
162	K2 K5 KT2 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
163	K5 KT2 KT2inc T1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
164	K2 K5 KT1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%

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165	K5 KTlinc S1 Tlinc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
166	KTlinc S1 T2 T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
167	K2 K5 KT1 T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
168	K1 K5 S1 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
169	K2 K5 KT2 KT3 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
170	K1 KT3 T1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
171	K1 S1 T2 T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
172	KT3inc T1 Tlinc T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
173	K2 Tlinc T2 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
174	K5 KT3inc S1 T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
175	K2 S1 T2 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
176	K5 T1 T2inc T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
177	K1 KT3inc Tlinc T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
178	K2 K5 KT3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
179	K1 K5 KT3 T3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
180	K1 K2 K5 T1	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
181	K5 KT3 T1 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
182	K2 KT2 S1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
183	K1 KT2inc T1 T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
184	K1 K5 Tlinc T3inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
185	K2 K5 Tlinc T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
186	K5 S1 T1 T3	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
187	K2 KT2 Tlinc T2	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
188	K1 K5 KTlinc T2inc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%
189	K1 K2 K5 Tlinc	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%

Compressed:

Rank	Failure mode	Failures	Estimated Probability	Importance
1	K5 T3	358	4.365662E-004 ( +/- 2.307324E-005 )	15.65%
2	K5 S1	356	4.341273E-004 ( +/- 2.300870E-005 )	15.56%
3	K2 K5	343	4.182743E-004 ( +/- 2.258469E-005 )	14.99%
4	S1 T2	348	4.243716E-004 ( +/- 2.274871E-005 )	15.21%
5	K5 T1	318	3.877879E-004 ( +/- 2.174606E-005 )	13.90%
6	K1 K5	317	3.865684E-004 ( +/- 2.171184E-005 )	13.85%
7	K1 T2	311	3.792516E-004 ( +/- 2.150539E-005 )	13.59%
8	K2 Tlinc T2	11	1.341405E-005 ( +/- 4.044487E-006 )	0.48%

9	Tlinc T2 T3	6	7.316752E-006 ( +/- 2.987051E-006 )	0.26%
10	T1 Tlinc T2	4	4.877835E-006 ( +/- 2.438917E-006 )	0.17%
11	K5 KT1 KT3 T4	1	1.219459E-006 ( +/- 1.219459E-006 )	0.04%

Primary Event Analysis:

Event	Failure contrib.	Importance
K1	7.658200E-004	27.45%
K2	4.316884E-004	15.47%
K5	2.064544E-003	73.99%
KT1	1.219459E-006	0.04%
KTlinc	0.000000E+000	0.00%
KT2	0.000000E+000	0.00%
KT2inc	0.000000E+000	0.00%
KT3	1.219459E-006	0.04%
KT3inc	0.000000E+000	0.00%
S1	8.584989E-004	30.77%
T1	3.926657E-004	14.07%
Tlinc	2.560863E-005	0.92%
T2	8.292320E-004	29.72%
T2inc	0.000000E+000	0.00%
T3	4.438829E-004	15.91%
T3inc	0.000000E+000	0.00%
T4	1.219459E-006	0.04%
T4inc	0.000000E+000	0.00%

## *The Primary Event Database Report*

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This report shows an example of the primary events in a primary events database. It details the *Id*, *Type*, *Description*, *Probability* of each and every event in the database.

Primary Events Database

=====

Database Filename: Three Motor Example (Motor 2 Only).ped

ID: T3

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: Reset signal inadvertently applied or not removed from switch S1

ID: S1

Probability: 0.02

Type: Basic

Dormant: No

Description: S1 switch inadvertently closes or fails to open

ID: T4

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: KT2 timer does not time "time out" due to improper installation or setting

ID: KT2

Probability: 0.02

Type: External

Dormant: No

Description: KT2 timer reset

ID: KT3

Probability: 0.02

Type: External

Dormant: No



Description: KT3 timer reset

ID: KT1

Probability: 0.02

Type: External

Dormant: No

Description: KT1 timer reset

ID: T1

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: EMF to K2 coil through S1, KT1, KT2 & KT3 circuits

ID: K2

Probability: 0.02

Type: Basic

Dormant: No

Description: K2 relay contacts fail to open

ID: T2

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: Test signal remains on K3 coil for  $t > 60$  sec

ID: K5

Probability: 0.02

Type: Basic

Dormant: No

Description: K5 relay contacts fail to open

ID: K1

Probability: 0.02

Type: Basic

Dormant: No

Description: K1 relay contacts fail to open

ID: KTlinc

Probability: 0.02

Type: Basic

Dormant: No

Description: KT1 timer contacts fail to open

ID: KT2inc

Probability: 0.02

Type: Basic

Dormant: No

Description: KT2 timer contacts fail to open

ID: KT3inc

Probability: 0.02

Type: Basic

Dormant: No

Description: KT3 timer contacts fail to open

ID: T1inc

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: Reset signal inadvertently applied or not removed from switch S1

ID: T2inc

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: KT1 timer does not "time out" due to improper installation or setting

ID: T3inc

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: KT2 timer does not "time out" due to improper installation or setting

ID: T4inc

Probability: 0.02

Type: Undeveloped

Dormant: No

Description: KT3 timer does not "time out" due to improper installation or setting