Software Training Guide

ReliaSoft's
BlockSim 7

Born of ReliaSoft ingenuity,
Bred to set new standards…

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1 BlockSim 7 Training Guide

1.1 About this Training Guide

This training guide is intended to provide you with many examples of BlockSim. It begins with step-by-step examples and then proceeds into more advanced examples and questions. At any time during the training, please feel free to ask the instructor(s) any questions you might have.

1.2 BlockSim Documentation

Like all of ReliaSoft's standard software products, BlockSim is shipped with detailed printed documentation on the product (*BlockSim 7 User's Guide*) and on the underlying principles and theory (*ReliaSoft's System Analysis Reference: Reliability, Availability and Optimization*). This training guide is intended to be a supplement to those references.

1.3 Contacting ReliaSoft

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For up-to-date product information, visit our Web site at:
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2 Features Summary

BlockSim 7 allows you to perform complex system reliability, maintainability and availability analysis and optimization using a reliability block diagram (RBD) approach, a fault tree diagram (FTD) approach or a combination of both.

The examples in this training guide have been designed to introduce you to the features available in BlockSim 7. This section presents a brief summary of these features. If you are already familiar with BlockSim's features, you can proceed to Chapter 3, First Steps.

2.1 Using BlockSim 7

BlockSim 7 allows you to analyze any process or product to obtain exact system reliability results (including system reliabilities, mean times, failure rates, etc.), to calculate the optimum scenario to meet system reliability goals and to obtain maintainability, availability and throughput results through discrete event simulation. BlockSim's blocks can be defined with the reliability characteristics of each component of the process or product. You can then configure these blocks into a reliability block diagram (RBD) that represents the reliability-wise configuration of the system and analyze the diagram in order to determine the reliability function (cumulative density function or *cdf*) of the entire system. This analysis can be used to make statistical calculations and create plots, to perform "what-if" analyses and to determine the optimization of system reliability to meet time and cost goals that you specify. When you define each block's maintenance characteristics, you can also perform maintainability/availability and throughput simulations.

2.2 What's new in Version 7?

BlockSim 7 provides more realistic simulations and better reporting. Specific additions and enhancements include:

- **Additional Distributions** for both analytical and simulation analyses. You can now select from Weibull, mixed Weibull (with two, three and four subpopulations), normal, lognormal, exponential, generalized gamma, gamma, logistic, loglogistic and Gumbel distributions.
- **Phase Diagrams** offer a new capability to model systems that change during the course of a simulation. For example, some airplane components only operate during the take-off and landing phases of a mission, but not during the cruising phase. Likewise, a manufacturing company's production may change during different shifts. **Phase Diagrams** capture changes in system usage and reliability during different time periods, resulting in more accurate simulations.
- **Duty Cycle** allows you to apply a stress factor to one or more components or phases of a system, quickly and easily manipulating the failure distribution parameters of a diagram. For example, a system component that does not work continuously (*e.g.* a CD-ROM drive in a computer) would accumulate less usage than the system accumulates. The **Duty Cycle** allows you to specify such usage as a property of the individual block or phase, creating a more realistic model of the system.
- **Variable Throughput** allows you to specify time-dependent throughput changes. For example, the flow of oil from a well may drop over time as the oil reserves are depleted. BlockSim 7 offers three different models to describe a system's variable throughput.
- **Type I Restoration Factor** allows you to model imperfect maintenance scenarios and define maintenance that reduces a specified portion of damage since the last repair. BlockSim 7 also supports the Kijima Type II model, where the maintenance is assumed to reduce a specified portion of the total damage to the item.
- **Resource Usage Window** provides an at-a-glance view of the diagrams and blocks where resources are used in a project, in either a list or dependency tree view. You can also use this utility to delete all unused resources in a single batch.
- **FRED Reports** have been expanded to include Analytical FRED Reports, which provide graphical representations of a non-repairable system's reliability characteristics to help identify components that may require improvement.

2.3 Fault Tree Analysis

In addition to reliability block diagrams, BlockSim 7 also allows you to perform system reliability analysis using fault tree diagrams. Fault tree diagrams are used for performing fault tree analysis (FTA), which is one of many symbolic analytical logic techniques found in operations research and in system reliability. In BlockSim 7, you can use fault tree diagrams or reliability block diagrams or combinations of both within the same project.

2.4 Intuitive Work Environment

BlockSim's interface is an intelligent, flexible and completely integrated work center. The work environment is designed around the Multiple Document Interface (MDI) and BlockSim's Project Explorer. These tools allow you to display and manage the Diagram Sheets, Fault Tree Sheets, Phase Diagram Sheets, Maintenance Templates, Spreadsheets, Plot Sheets, Templates, Resources and Attachments you will create and use in BlockSim. From within BlockSim's MDI, you can use BlockSim's integrated calculation and plotting tools to analyze your diagrams, make system reliability calculations, create and modify plots and graphics and calculate the optimum reliability scenario. You can also easily interact with other ReliaSoft and Windows applications. This is all included in one comprehensive, easy-to-use package.

2.5 Powerful and Easy to Use

ReliaSoft's BlockSim was designed and built for Microsoft Windows and takes full advantage of the best features Windows has to offer. Using the familiar Windows interface, as well as the examples and help provided, you can be up and running from the moment the application is installed. You can be productive immediately, without the normal downtime you would expect when learning a new software application. But making BlockSim easy does not mean we made it less powerful. BlockSim comes packed with advanced features that you will find indispensable and you will learn and master them as you explore the software. Complete on-line help is also provided.

2.6 Blocks and Templates

BlockSim's blocks are the building blocks with which you will create complex reliability block diagrams and fault tree diagrams. You can start with BlockSim's Templates, which contain pre-defined sets of re-usable blocks. BlockSim provides a gallery of Templates to get you started and provides you with the flexibility to manage these collections of building blocks to meet your specific needs. You can customize individual blocks with the failure, maintenance, reliability optimization, throughput and other characteristics for each component in your system.

2.7 Available Life Distributions

The life distributions available within BlockSim to define the failure, maintenance and other time-dependent characteristics of system components include the Weibull, mixed Weibull (with two, three or four subpopulations), normal, lognormal, exponential, generalized gamma, gamma, logistic, loglogistic and Gumbel distributions. BlockSim also provides the capability to compute the appropriate distribution and parameters for a component using ReliaSoft's Weibull++ life data analysis software and ReliaSoft's ALTA accelerated life testing analysis software.

2.7.1 Integration with Weibull++ and ALTA

The capabilities of ReliaSoft's suite of reliability engineering software products have been designed to complement one another. With BlockSim 7, you can use a new or existing file created in ReliaSoft's Weibull++ or ALTA software to define the failure or maintenance characteristics of a BlockSim block.[1] *Contact ReliaSoft for information on obtaining these powerful life data analysis applications.*

2.8 System Reliability Block Diagrams and Fault Tree Diagrams

Simple drag-and-drop functionality allows you to drag blocks from a Template into a Diagram Sheet or Fault Tree Sheet and configure those blocks to create simple or complex reliability block diagrams (RBDs) or fault tree diagrams. With BlockSim, you can diagram systems with series, parallel and "k-out-of-n" reliability-wise configurations, as well as complex combinations of those configuration types. You can also create standby and load sharing redundancy configurations.

In BlockSim 7 you can also create AND gate, OR gate, voting OR gate, complex gate, load sharing gate and inhibit gate configurations.

BlockSim also allows you to customize the size and shape of component blocks, connecting lines, diagram background, graphics and text.

1. Weibull++ version 6.0.11 or later and/or ALTA version 6.0.10 or later must be installed on your computer in order to use this option. For more powerful analyses and even greater integration, upgrade both Weibull and ALTA to version 7.

2.8.1 Template Blocks

Template blocks are the main building blocks of your reliability block diagrams and fault tree diagrams. You can define these re-usable blocks with the failure, maintenance, reliability, optimization and throughput characteristics of the components they represent. BlockSim's Template blocks allow you to define the characteristics of a component once and use the same block in many diagrams to save time.

2.8.2 Node Blocks

Node blocks are another type of block that can be used in the reliability block diagrams you create. Node blocks act as switches through which RBD paths move. You can specify how many paths leading into a node must be operational in order for the node to function. You can also define the properties of the node itself, including whether it can fail and its failure distribution.

2.8.3 Subdiagram Blocks

In addition to the complex reliability-wise configurations supported by BlockSim's Diagram Sheets and Fault Tree Sheets, you can also link diagrams by using existing RBDs or FTDs as components in other diagrams. BlockSim's Block As Diagram option creates a block that represents the reliability characteristics of an existing BlockSim diagram. This block serves as a subdiagram to the current diagram. This subdiagram block can then be placed into any diagram as a component.

2.8.4 Container and Contained Blocks

Container blocks allow you to identify blocks that operate in a standby or load sharing configuration. The container block has properties that describe the way the container behaves and the configuration of the blocks within the container.

Contained blocks are blocks that exist inside container blocks. Contained blocks describe the characteristics of the items that operate together in the standby or load sharing configuration.

2.8.5 Multi Blocks and Mirrored Blocks

Multi blocks allow you to create a single block that represents more than one component with the same properties. This allows you to save time and space when creating your RBDs. In addition, mirrored blocks allow you to place the exact same component in more than one location, represented by multiple blocks, within the RBD or FTD. This can be useful to simulate bi-directional paths within the diagram.

2.9 Policies

BlockSim allows you to define policies, which are sets of rules that describe various aspects of the maintenance approach for particular blocks. A unique policy is required for each aspect of the maintenance approach (*e.g.* corrective maintenance, work crews, etc.) and for each block or set of blocks that follows a different set of rules to govern maintenance activities.

BlockSim allows you to define the following types of policies:

- **Corrective Maintenance Policies**, which describe the conditions that determine when corrective maintenance will be performed on an item.
- **Preventive Maintenance Policies**, which describe the conditions that determine when preventive maintenance will be performed on an item.
- **Inspection Policies**, which describe the conditions that determine when an inspection will be performed on an item.

- **Crew Policies**, which describe the conditions that determine when a crew will be available to perform specific actions and specifies the logistical time and costs associated when engaging the crew.
- **Spare Parts Pools**, which describe the conditions that determine whether a spare part will be available when needed and specifies the logistical time and costs associated with obtaining the spare part.
- **Feasibility Policies**, which allow you to define a cost function for the difficulty or cost of increasing the reliability of a block.

2.10 Analytical Quick Calculation Pad

ReliaSoft's Analytical Quick Calculation Pad (QCP) provides a quick, easy and accurate way for you to obtain exact results for the most frequently asked reliability questions. From standard probability and mean time calculations, to optimization algorithms, it is all possible using the Analytical QCP. All QCP results can be displayed and manipulated in the Results Panel and BlockSim’s flexible Spreadsheets.

2.10.1 Reliability Metrics

BlockSim's powerful analysis engines analyze the diagrams you create in order to obtain the complete mathematical system reliability function (or cumulative density function, *cdf*). You can use that actual system *cdf* to obtain exact reliability results from the Analytical QCP. Calculations include reliability, probability of failure, conditional reliability, conditional probability of failure, failure rate, warranty time, B(X) information and mean time.

2.10.2 “What-If” Analyses

In addition to providing quick, easy reliability calculations for the system diagrams you create, BlockSim provides you with the flexibility to manipulate a diagram in order to perform “what-if” analyses. BlockSim allows you to mark a component (or components) as inactive (*i.e.* failed, off or absent from the system) and use the Analytical QCP to determine reliability metrics of the system under those hypothetical conditions.

2.10.3 Optimize System Reliability

You can also use BlockSim's Analytical QCP to calculate the best way to optimize system reliability based on time and cost goals that you provide. You can specify system reliability and time goals and select components to be considered when calculating the optimum scenario for meeting those goals. Based on your specification of the feasibility (or cost) of improving the reliability of each individual component, BlockSim calculates the optimum scenario for increasing component reliability in order to achieve a system reliability goal. You can use BlockSim’s feasibility functions or specify your own customized functions to describe the cost feasibility for increasing the reliability of a specific component.

2.11 Maintainability/Availability Simulations

BlockSim’s Maintainability/Availability Simulation window allows you to estimate system maintainability, availability and throughput results via simulation. BlockSim’s simulations are based on the component characteristics and the reliability-wise system configuration of the linked Diagram Sheet or Fault Tree Sheet.

2.11.1 Simulation Results Explorer

The results generated from BlockSim’s Maintainability/Availability Simulation window can be displayed in the Simulation Results Explorer. From the Simulation Results Explorer, you can edit, cut, copy, paste, print and/or transfer the results to a Spreadsheet or to Excel. You can also send the data to Weibull++, ReliaSoft’s life data analysis software, if the software is installed on your computer, for further analysis.

2.11.2 Simulation Quick Calculation Pad

BlockSim's Simulation QCP allows you to perform calculations based on the simulation results. These calculation results include availability, unavailability, reliability, probability of failure, mean availability, mean unavailability, availability time, reliability time and MTTF.

2.12 Sequence Animation

The Sequence Animation utility allows you to animate the sequence of a single iteration of the simulation for the current reliability block diagram or fault tree diagram. You can then save the animation as an Audio Video Interleave (*.avi) file, which can be inserted into a PowerPoint presentation or used for any other video presentation purpose.

2.13 Unparalleled Plots and Graphs

BlockSim offers unparalleled plotting and graphing capabilities. With the click of a button, you can create Unreliability vs. Time, Reliability vs. Time, *pdf*, Failure Rate vs. Time, Reliability Importance vs. Time, Static Reliability Importance and Tableau Reliability Importance plots based on system RBDs or FTDs, as well as plots based on individual block reliabilities.

You also can create plots based on the simulation results. The simulation plot types include ReliaSoft Failure Criticality Index, ReliaSoft Failure Criticality Index Tableau, ReliaSoft Downing Event Criticality Index, ReliaSoft Downing Event Criticality Index Tableau, Point Availability, Point Reliability, Both Point Availability and Reliability, System Up/Down and Block Up/Down plots. BlockSim also allows you to create simulation plots based on the blocks, maintenance crews or spare part pools in the current Diagram Sheet or Fault Tree Sheet.

BlockSim also gives you the flexibility to create a variety of plots and graphs with the Chart Wizard in BlockSim's Spreadsheets. With the Chart Designer, any of these graphs can be extensively customized to meet your particular needs. All BlockSim plots can be saved as Windows metafile (*.wmf) graphics that can be used in other applications.

2.14 Spreadsheets

With BlockSim's Spreadsheets, you can unleash endless possibilities. These Spreadsheets can be used just as you would use an Excel spreadsheet with complete in-cell formula support, cell references and over 140 built-in functions. Use this flexibility, coupled with all of the powerful data analysis capabilities of BlockSim, to perform calculations, create plots and graphs and prepare presentations of your analyses.

2.15 Function Wizard

You can use ReliaSoft's Function Wizard in conjunction with BlockSim's Spreadsheets to generate a variety of calculated results. The Function Wizard returns results based on a linked RBD or FTD. These results include tables of failure rates given a time range, mean times of the system, reliability given time and more. You can also use the Chart Wizard and BlockSim's Spreadsheets to create custom graphs and reports to present your analyses.

2.16 Customize the Application

BlockSim provides a User Setup that allows you to customize the application to meet your particular needs. The User Setup allows you to configure the software to suit the way you and your company work. You can customize the way the software works or use the preferences pre-set by ReliaSoft. You can set the entire look and feel of the software. For example, you can determine the decimal place accuracy you would like to see, for up to fifteen decimal places, and set the displayed math precision to be used for the axis numbers on the plots.

2.17 A Note on BlockSim Calculations

The results generated by BlockSim's analysis tools do not specify the units (*e.g.* hours, miles, etc.) for the values returned. It must be understood that the units for the results are the same as the units for the data inputs on which results are based. For this reason, BlockSim requires a uniformity of units among the property definitions of blocks in Diagram Sheets and Fault Tree Sheets and required inputs for calculations. For example, all time values in a Diagram Sheet or Fault Tree Sheet and in the analysis tools used to generate results based on that diagram must be defined with the same units.

3 First Steps

3.1 Starting BlockSim 7

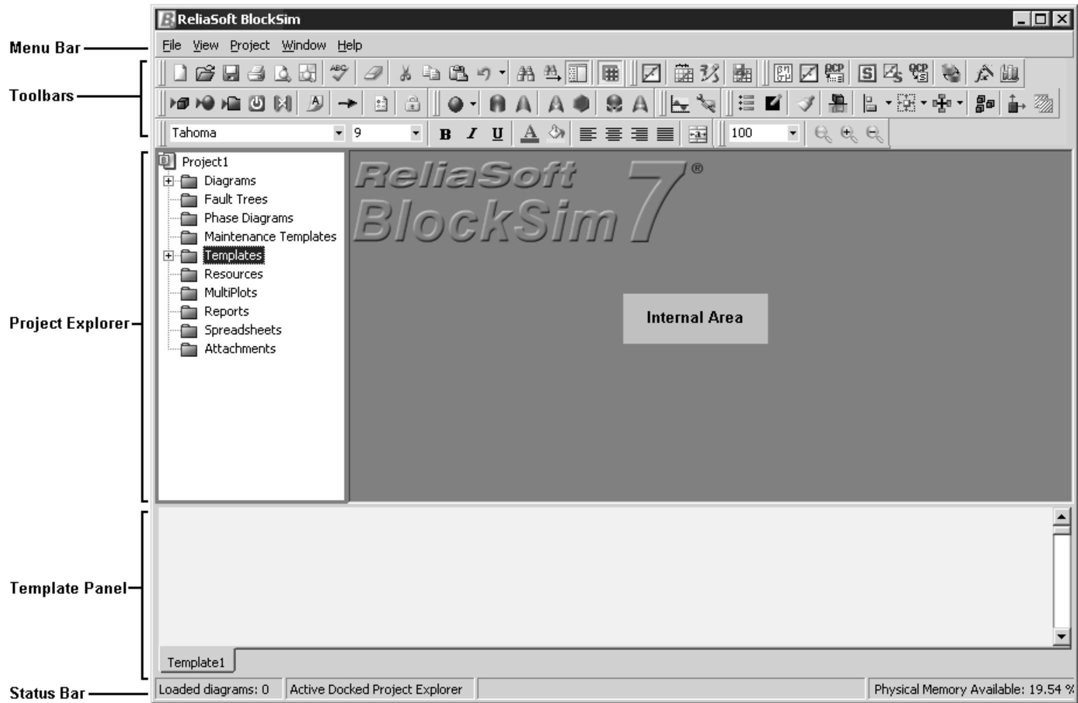
BlockSim is a 32-bit application that has been designed to work with Windows NT, Windows 2000 and Windows XP. To start BlockSim, from **Start** select **Programs**, **ReliaSoft Office**, **BlockSim 7**. The figures used in this manual, as well as the commands required, are all from Windows XP. However, the BlockSim internal screens and commands are identical regardless of which operating system you are using and this manual is equally applicable.

3.2 Multiple Document Interface

The Multiple Document Interface (MDI) is the main window and “manager” for BlockSim. The MDI serves as the container for all the windows you will use in BlockSim.

The menu and toolbar options available within BlockSim's MDI will vary depending on the windows that are currently open. In addition, BlockSim's flexible MDI allows the user to configure the workspace to meet individual needs by hiding or moving the menu bar, toolbars, Project Explorer and Template Panel.

The next figure displays the MDI and its components so that you can familiarize yourself with the options available within the MDI. Your screen may look slightly different from the one shown next, depending on the windows and tools currently open and on the configuration settings that you have established.



3.3 Getting Help in the BlockSim Environment

ReliaSoft's BlockSim 7 includes complete on-line help documentation. This help can be obtained at any time by pressing **F1** or by selecting **Contents** from the **Help** menu.

3.4 BlockSim: A Familiarization

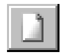
3.4.1 A Quick Overview Example

This section presents you with a very simple example and guides you through the solution. A simple system consists of three resistors configured reliability-wise in series. The failure characteristics of each component are presented in the table shown next. Create a reliability block diagram (RBD) to represent the system, plot the Unreliability vs. Time of the system and calculate the reliability of the system at 50 days of operation.

Component	Failure Distribution	Parameters
Resistor 1	Exponential	Mean Time = 1,000 Gamma = 0
Resistor 2	Exponential	Mean Time = 500 Gamma = 0
Resistor 3	Exponential	Mean Time = 333.33 Gamma = 0

3.4.2 Create a New BlockSim Project

- The first step is to create a new project by selecting **New** from the **File** menu or by clicking the **New** icon.

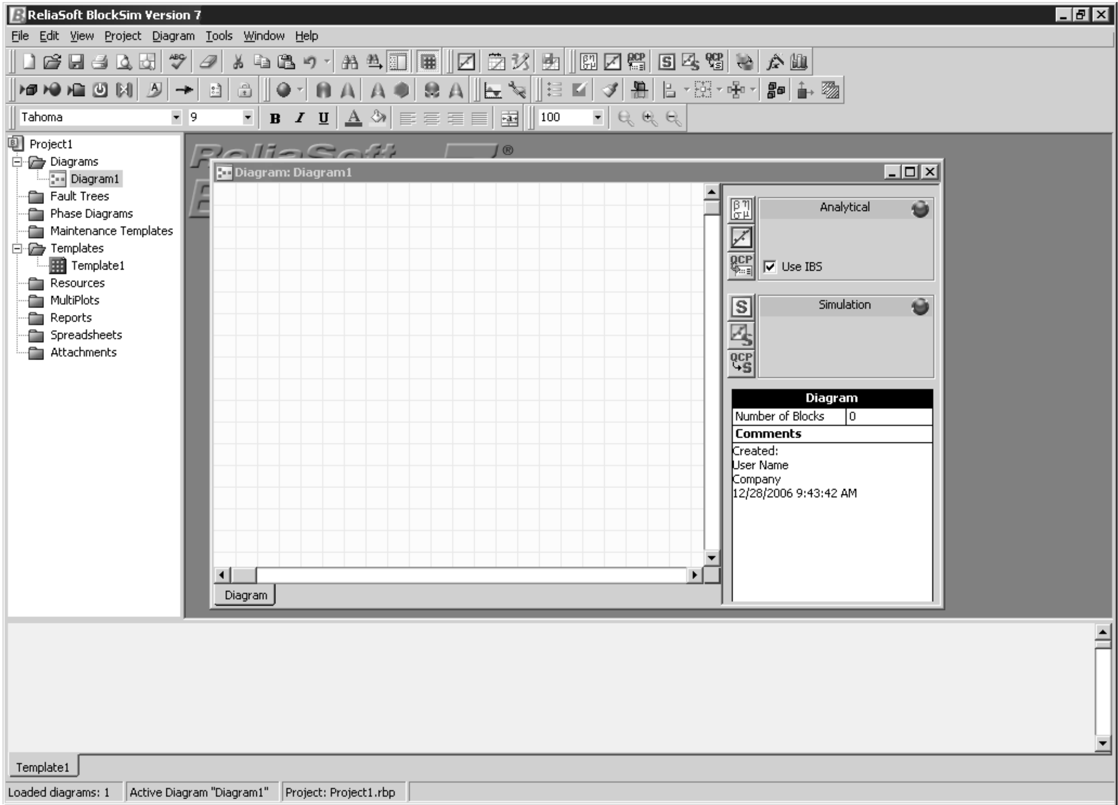


- The New Project Wizard will appear like the one shown next. The Wizard will guide you through the process of creating a new project by asking you a series of questions pertaining to the type of project you want to create.

- The first page of the New Project Wizard allows you to specify whether you will create a new project based on a base project or incorporate items, such as Diagram Sheets, Fault Tree Sheets, Spreadsheets, MultiPlot Sheets, Templates, Resources and Attachments, from an existing project. For this example, you will create a new, blank project. Select the **Blank project** option and click **Next>**.
- The second page of the Project Wizard will appear, which allows you to make selections to determine which items (Diagram Sheets, Fault Tree Sheets, Templates, etc.) will be automatically placed into the new project. The appearance of this page will vary depending on your selection in Step 1. Select to include a new blank Diagram Sheet and a new blank Template and click **Next>**.
- The third page of the New Project Wizard will appear, which allows you to create a new project. Click **Finish**.[1]

1. If the Rename window appears and asks you to enter a name for the new Diagram Sheet in your project, click **OK** to accept the default name.

- The new project will appear, as shown next.



The Project Explorer will appear on the left side of the MDI. You can use the Project Explorer to manage the items within your project. Items include Diagram Sheets, Fault Tree Sheets, Phase Diagram Sheets, Maintenance Templates, Templates, Resources, MultiPlot Sheets, Reports, Spreadsheets and any Attachments. From within the Project Explorer, you can add, import, export, rename and delete items within the current project.

The appearance of the Project Explorer will vary depending on the docking option that is selected from the **Dock Project Explorer** submenu in either the **Project Explorer** shortcut menu or the **View** menu.[2]

If **No Docking** is selected, the Project Explorer will be displayed as a window. If **Dock Left**, **Dock Right**, **Dock Top** or **Dock Bottom** is selected, the Project Explorer will be displayed as a fixed panel on the corresponding side of the MDI. By default, the Project Explorer will be docked to the left side of the MDI, as shown in the previous picture.

The Template Panel will appear at the bottom of the MDI. BlockSim's Templates allow you to store re-usable blocks, which can save you time and effort when building diagrams. Within projects, you can create your own Templates in the Template Panel and then create blocks with pre-defined parameters and other pre-set options in these Templates. You can then drag the Template blocks into a Diagram Sheet or Fault Tree Sheet to build your diagram. The Template Panel always presents all of the Templates and the blocks they contain associated with the current project. Each Template is accessible by clicking its page index tab.

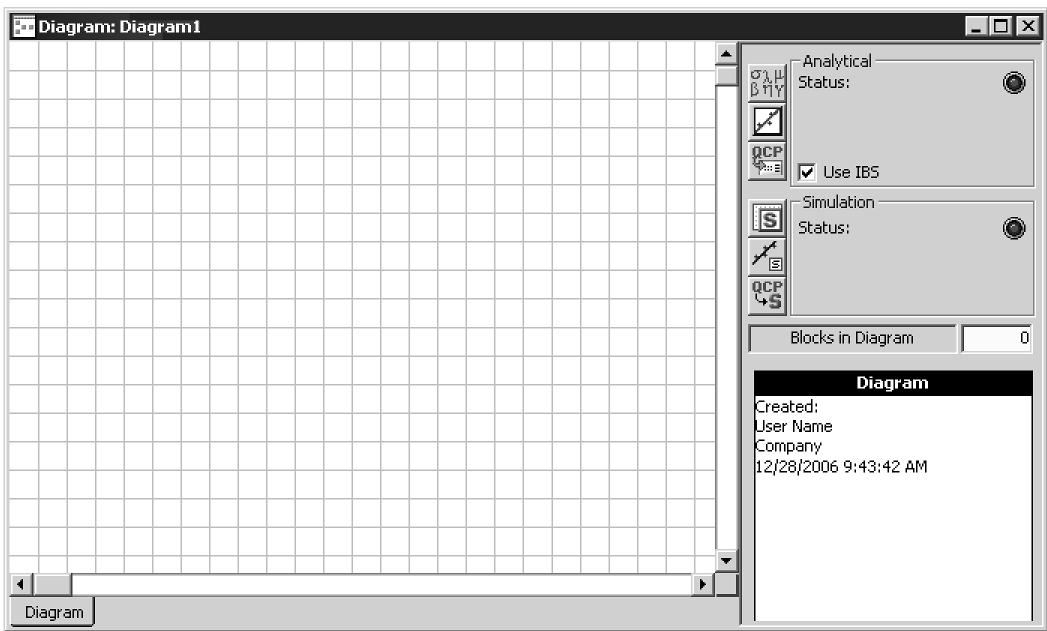
2. Right-click inside the Project Explorer to display the Project Explorer shortcut menu, which provides you with the commands that pertain to BlockSim projects.

The appearance of the Template Panel will vary depending on the docking option that is selected from the **Dock Template Panel** submenu in either the **View** menu or the Template Panel shortcut menu.[3]

If **No Docking** is selected, the Template Panel will be displayed as a window that can be moved freely within the MDI. If **Dock Left, Dock Right, Dock Top** or **Dock Bottom** is selected, the Template Panel will be displayed in a fixed Template Panel on the corresponding side of the MDI. By default, the Template Panel will be docked at the bottom of the MDI, as shown in the previous picture.

The name of the new Template, Template1, appears on its corresponding page index tab.

A new Diagram Sheet will also appear in the MDI. BlockSim's Diagram Sheets provide the canvas on which you will create your reliability block diagrams (RBDs). The Control Panel that appears on the right side of the Diagram Sheet allows you to perform analyses on the RBDs in the Diagram Sheet and displays the status of the analytical analysis and simulation, as well as the number of blocks that exist in the Diagram Sheet. It also displays information for the current Diagram Sheet or for the selected block in the Diagram Sheet, as shown next.



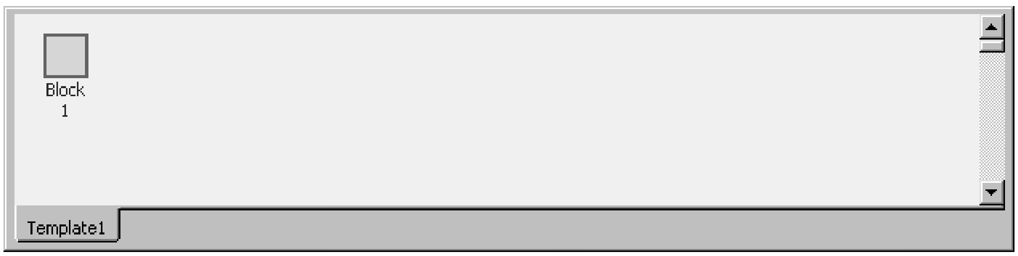
[3] Right-click inside the Template Panel to display the Template Panel shortcut menu, which provides you with the commands that pertain to BlockSim Templates.

3.4.3 Creating a Template Block

BlockSim blocks, defined with the reliability characteristics of system components, are the building blocks you will use to create your diagrams. The next step is to create a new Template block that will be used as the pattern for the Resistor blocks you will use in the diagram.

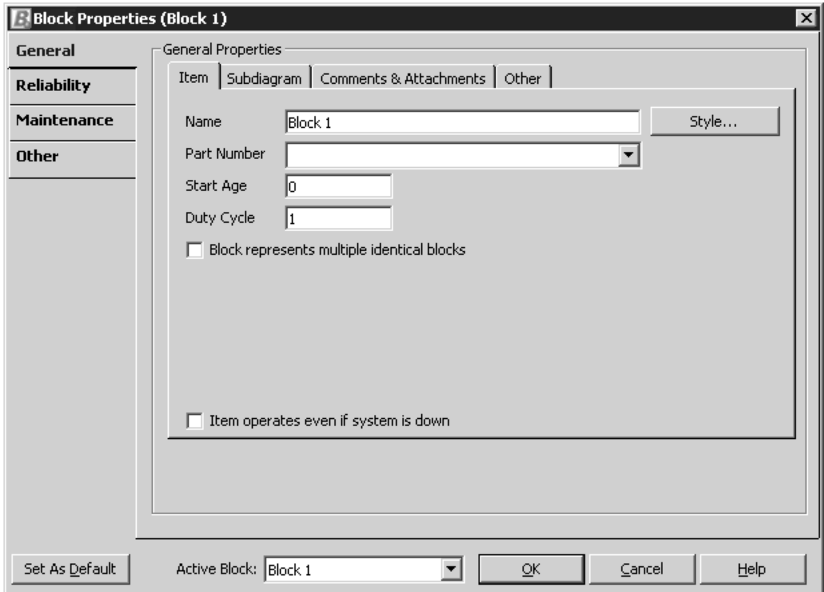
- To add a block to Template1, click the Template Panel or double-click the Template name in the Project Explorer to activate it. Next, select **Add Block** from the **Template** menu or click the **Add New Block** icon in the Diagram Tools toolbar.

- A block will appear in the Template and will be named “Block 1” by default, as shown next.



- To edit the properties of the new block, double-click it or select the block and then select **Edit Block Properties** from the **Block** menu or from the Template Block shortcut menu.

The Block Properties window will appear, as shown next, which allows you to define the new block with the characteristics of the component.



- On the first page in the Block Properties window, the Item page, you can define the block name. Type **Resistor 1** in the Name input box.
- Next, you will define the failure characteristics of the Resistor 1 component. To do this, click the **Reliability** tab and on the Failure Distribution page, verify that the **Block Can Fail** option is selected. In addition, verify that the **Static Reliability** option at the bottom of the window is not selected. [4]
- Select **Exponential** as the failure distribution and notice that the parameter input boxes on the right change to represent the parameter requirements of the selected distribution. Type **1000** for the value of mean time and **0** for the value of gamma.[5]

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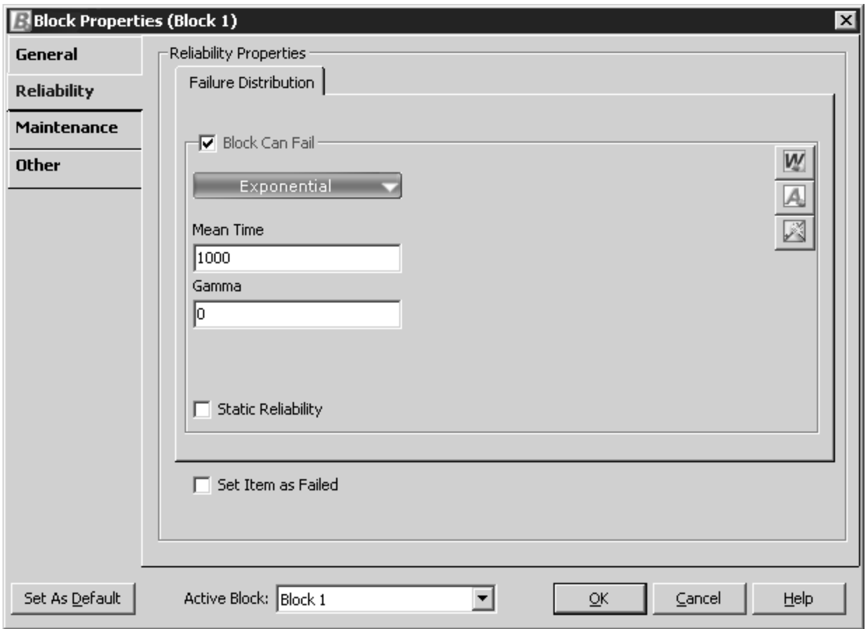
4. If the **Block Can Fail** option is not selected, the reliability of the block at all times is considered to be 1 or 100% and the other options on the Failure Distribution page will be unavailable. The **Static Reliability** option is not selected, indicating that a time-dependent failure distribution will be defined for the component. If the **Static Reliability** option is selected, an input box will appear in which you can type the reliability of the component at a fixed point in time and the other options on the Failure Distribution page will be unavailable.

5. By default in BlockSim, the exponential parameter is defined as mean time. Although the mean time definition is appropriate for this example, you can also define the exponential parameter as lambda by de-selecting the **Use Mean Time for the Exponential distribution** option on the Calculations page of the User Setup.

- The Block Properties window will look like the one shown next. Note that the name change will not take effect until you click **OK** to save the changes.



- Click **OK** to close the Block Properties window and update the Template block's properties.
- The Template block will reflect your name change, as shown next.

- Repeat these steps to create two more Template blocks to represent the Resistor 2 and Resistor 3 components. On the appropriate pages of the Block Properties window for the Resistor 2 block, make the following selections/entries:

  General Tab: Item Page

  Block Name: Resistor 2

  Reliability Tab: Failure Distribution Page

  Block Can Fail: Selected

  Failure Distribution: Exponential

  Mean Time: 500

  Gamma: 0

  Static Reliability: Not Selected

- On the appropriate pages of the Block Properties window for the Resistor 3 block, make the following selections/entries:

  General Tab: Item Page

    Block Name: Resistor 3

  Reliability Tab: Failure Distribution Page

    Block Can Fail: Selected

    Failure Distribution: Exponential

    Mean Time: 333.33

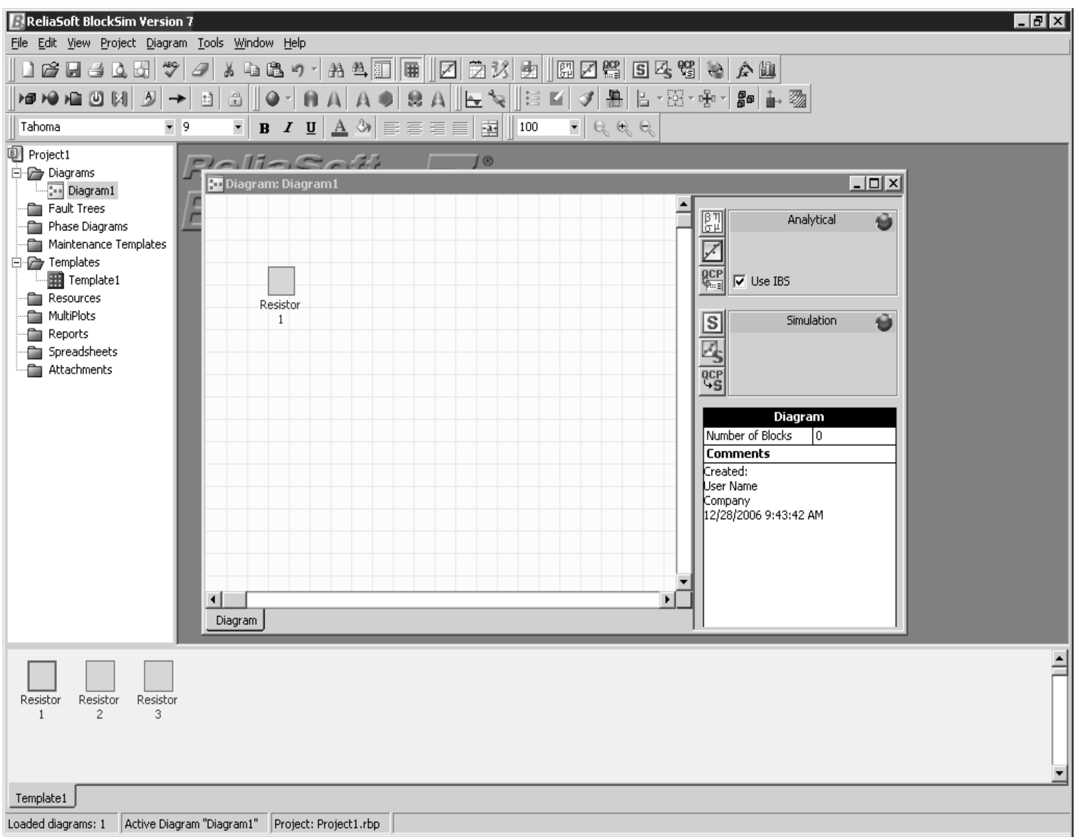
    Gamma: 0

    Static Reliability: Not Selected

3.4.4 Build a Simple Diagram

Now you are ready to build a simple reliability block diagram (RBD) by placing the Template blocks you have created in the Template into the Diagram Sheet. You will do this by dragging the blocks from the Template Panel into the Diagram Sheet.[6]

- First, drag the Resistor 1 block into the Diagram Sheet. To do this, click the block in the Template Panel to select it, hold down the left mouse button, drag the cursor into the desired position on the Diagram Sheet and release the mouse button. Your screen will look like the one shown next.



[6] Please note that this example is meant to demonstrate the use of the Template Panel and Template blocks. However, you can omit the step of adding blocks to the Template Panel and dragging them to the Diagram Sheet, as demonstrated in this example, by adding them directly to the Diagram Sheet.

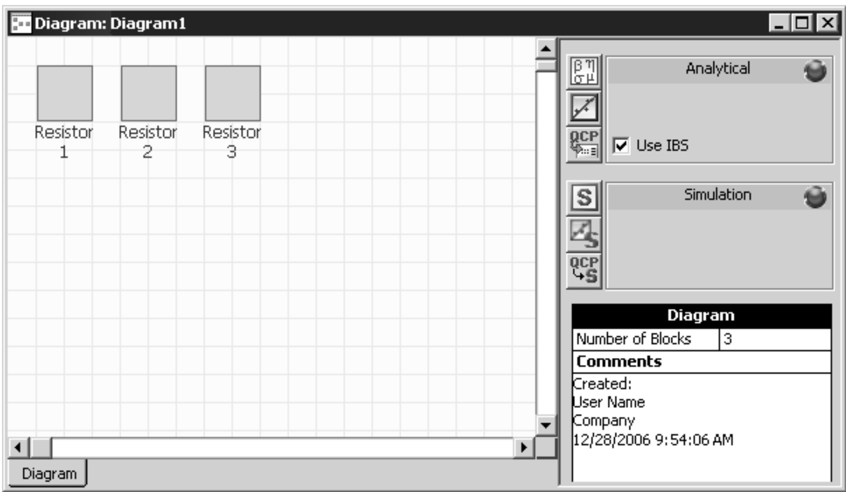
Notice that a copy of the block is placed in the Diagram Sheet and the Template block remains in the Template Panel. Template blocks are like re-usable patterns that you can use to save time and effort. When you drag a Template block into a Diagram Sheet or Fault Tree Sheet, a separate block is created in the Diagram Sheet or Fault Tree Sheet. The new block in the Diagram Sheet or Fault Tree Sheet is independent of the block in the Template and you can modify it to meet the needs of the particular diagram.

- Next, drag the Resistor 2 and Resistor 3 blocks into the Diagram Sheet.

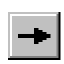
3.4.5 Arrange and Connect the Blocks

You are now ready to arrange and connect the blocks in the Diagram Sheet to create a reliability block diagram (RBD) that will represent the reliability-wise configuration of the system.

- Place the blocks in a horizontal row with Resistor 1 on the left, Resistor 2 in the middle and Resistor 3 on the right. Drag the blocks as before by clicking the block to select it, holding down the left mouse button, moving the cursor into the desired position and releasing the mouse button. Your Diagram Sheet will look like the one shown next.



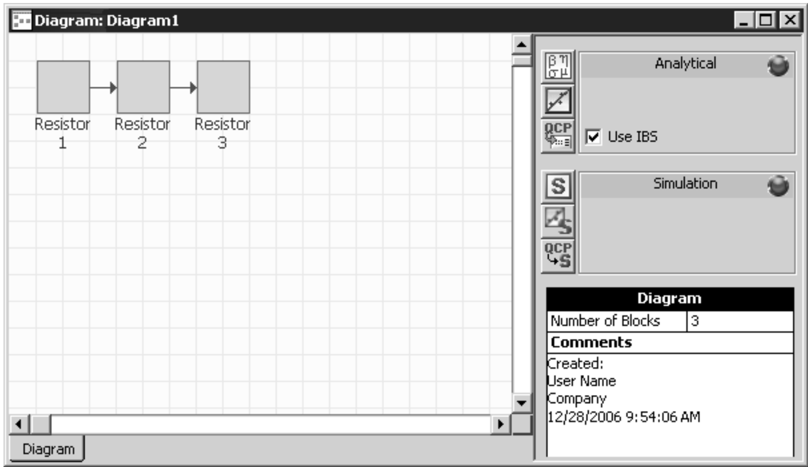
- Now you are ready to connect the blocks to represent the relationships between the components of the system. Select **Join Blocks** from the **Diagram** menu or click the **Join Blocks** icon.



- When you move the cursor over the Resistor 1 block, the cursor will turn into a cross hair. This is the tool that you will use to draw the relationship lines between the blocks. Hold down the left mouse button and drag a line from the Resistor 1 block to the Resistor 2 block with which it will be connected. When the cross hair is located above the second block, release the mouse button. A relationship line will now connect the two blocks.
- Next, connect the Resistor 2 block with the Resistor 3 block. When you have finished adding relationship lines, you must right-click the Diagram Sheet or click the **Join Blocks** icon again to stop adding relationships and return to BlockSim's normal mode.[7]

[7]. If you do not right-click the Diagram Sheet or click the **Join Blocks** icon to return the cursor to its normal mode, you will not be able to perform other activities in BlockSim. If you are experiencing difficulties with the program, make sure that the cursor is in its normal mode.

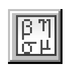
- Your diagram will now look like the one shown next. Notice that the connecting line arrows point from the source blocks to the destination blocks to represent the flow of the system. The specification of source and destination blocks is relevant to BlockSim's analysis of the system configuration.



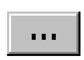
3.4.6 Analyze the Diagram

Now that you have defined the reliability characteristics of each component block and arranged and connected the blocks to represent the system, you are ready to analyze the diagram.

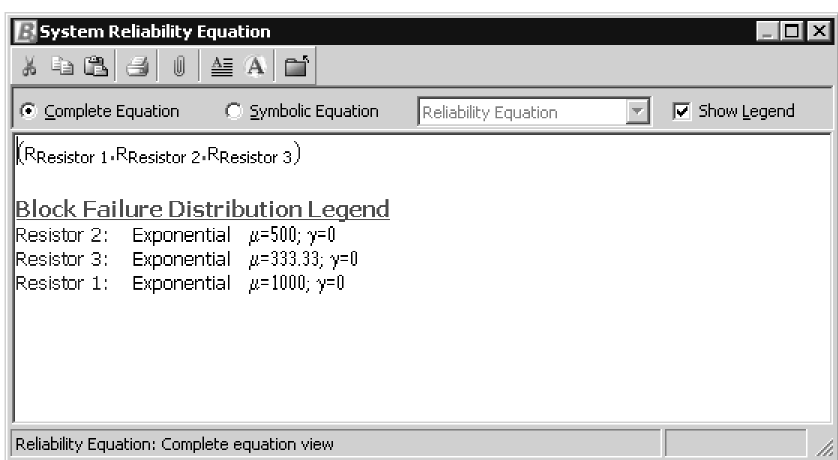
- Select **Analyze** from the **Tools** menu or click the **Analyze** icon.



- Notice that the Analytical Status button on the Diagram Sheet Control Panel has turned from red to green, indicating that the Diagram Sheet has been analyzed.
- You can then view the equation used for the analysis in the System Reliability Equation window by selecting **Show Algebraic Solution** from the **Tools** menu or by clicking the **Show Algebraic Solution** icon on the Diagram Sheet Control Panel.



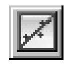
- The exact analytical equation for the system will appear in the window, as shown next.



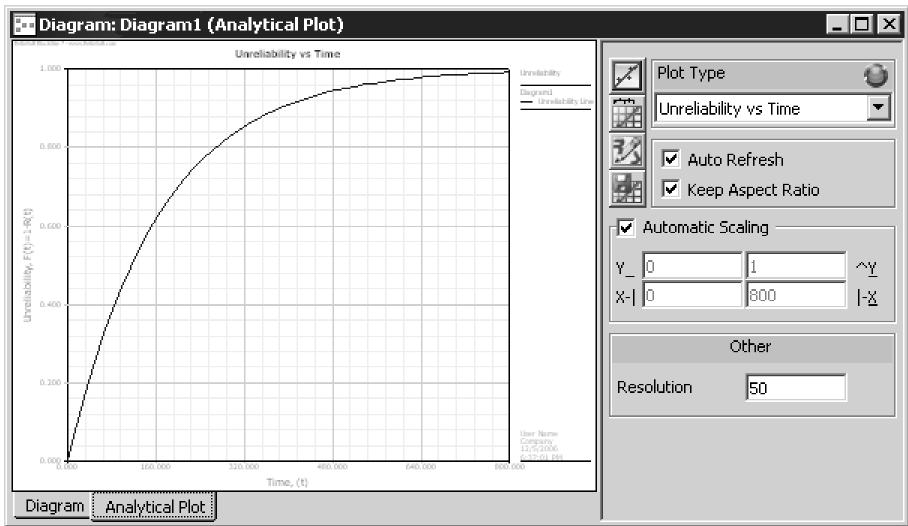
- Click **Close** to close the System Reliability Equation window and return to the Diagram Sheet.

3.4.7 Plot Unreliability vs. Time

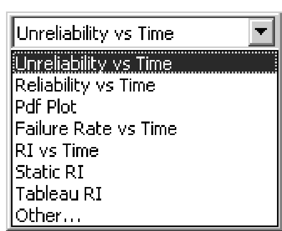
- Now you can generate plots based on the system analysis. Select **Analytical Plot** from the **Tools** menu or click the **Analytical Plot** icon.



- The Unreliability vs. Time plot will appear in the Analytical Plot Sheet that is added to the Diagram Sheet, as shown next. If you have already created a plot in BlockSim, the plot type of the last plot that you created will appear. If a plot other than the Unreliability vs. Time plot appears, select **Unreliability vs. Time** from the Plot Type drop-down menu.



Additional plots are also available in BlockSim's Analytical Plot Sheet, including Reliability vs. Time, *pdf*, Failure Rate vs. Time, Reliability Importance vs. Time, Static Reliability Importance, Tableau Reliability Importance and several block plots. Select a plot type from the Plot Type drop-down menu, as shown next. If Auto Refresh is selected on the Control Panel, the Analytical Plot Sheet will be automatically updated to display the plot type you have selected.



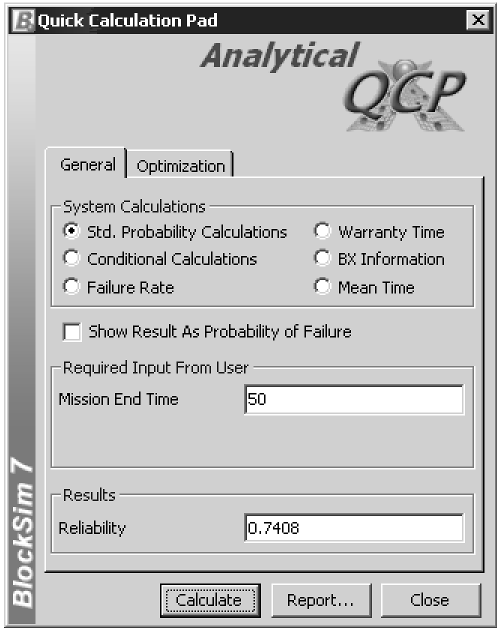
- Now return the focus to the Diagram Sheet by clicking its page index tab at the bottom of the window.

3.4.8 Calculate System Reliability

In addition to generating system reliability plots, BlockSim is also capable of calculating standard system reliability metrics based on the exact system reliability function.

- To calculate the reliability of the system at a specified time, select **Analytical QCP** from the **Tools** menu or click the **Analytical QCP** icon.

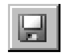
- The Analytical Quick Calculation Pad (QCP) will appear. You can use the first page of the QCP, the General page, to obtain standard reliability calculations. To determine the reliability of the system at 50 days, select **Std. Probability Calculations** under System Calculations. Type a Mission End Time of **50** under Required Input from User. Finally, click **Calculate** and the estimated system reliability at the given time will appear under Results, as shown next.



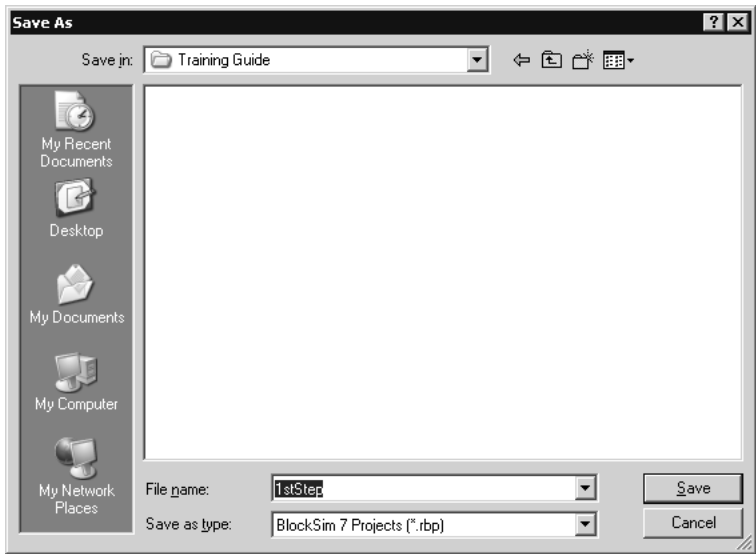
- You can see that the reliability of the system at 50 days is 0.7408 or about 74.08%. Click **Close** to close the Analytical Quick Calculation Pad and return to the Diagram Sheet.

3.4.9 Save and Close the Project

- Now save the project. To do this, select **Save** from the **File** menu or click the **Save** icon.



- The Save As window will appear. Select to save the file in the BlockSim7/Examples/Training Guide folder and type **1stStep** as the file name. Accept the default file type, ReliaSoft BlockSim 7 files (*.rbp), as shown next.



- Click **Save** to save the file. If you are working with an evaluation copy of BlockSim, you will not be able to save the project. In this case, simply close the project and proceed with the rest of the examples in the training guide.
- After saving the file, close the project by selecting **Close** from the **File** menu. You will now be looking at the MDI without any projects open.

4 Step-by-Step Examples

4.1 Detailed Examples

4.1.1 Example 1

A computer consists of two Hard Drives and a Circuit Board. The two Hard Drives operate reliability-wise in parallel within the system. The reliability and optimization characteristics of each component are presented in the table shown next.

Component	Failure Distribution	Parameters	Max Achievable Reliability	Feasibility of Increasing Reliability
Hard Drive 1	Weibull	Beta = 2.5 Eta = 3,000 days Gamma = 0	.999	Moderate
Hard Drive 2	Exponential	Mean Time = 10,000 Gamma = 0	.999	Easy
Circuit Board	Weibull	Beta = 1.5 Eta = 5,000 days Gamma = 0	.999	Hard

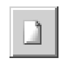
Do the following:

- Create a reliability block diagram (RBD) of the system.
- Calculate the reliability of the system at 730 days (2 years) of operation.
- Calculate the reliability of the system at 730 days if the Hard Drive 1 component is removed from the system.

- Determine the optimum scenario for increasing the reliability of each component in order to achieve a system reliability of 0.98 (or 98%) at 730 days of operation.

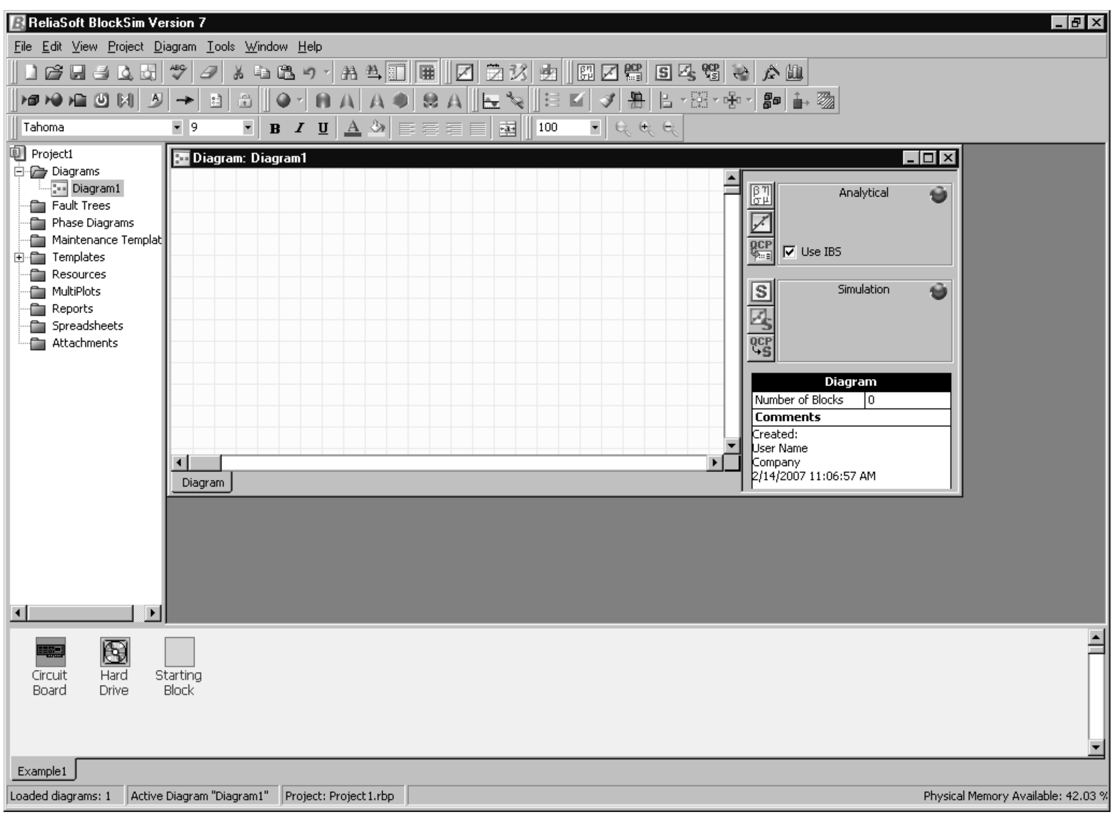
Solution

- Create a new project by selecting **New** from the **File** menu or by clicking the **New** icon.

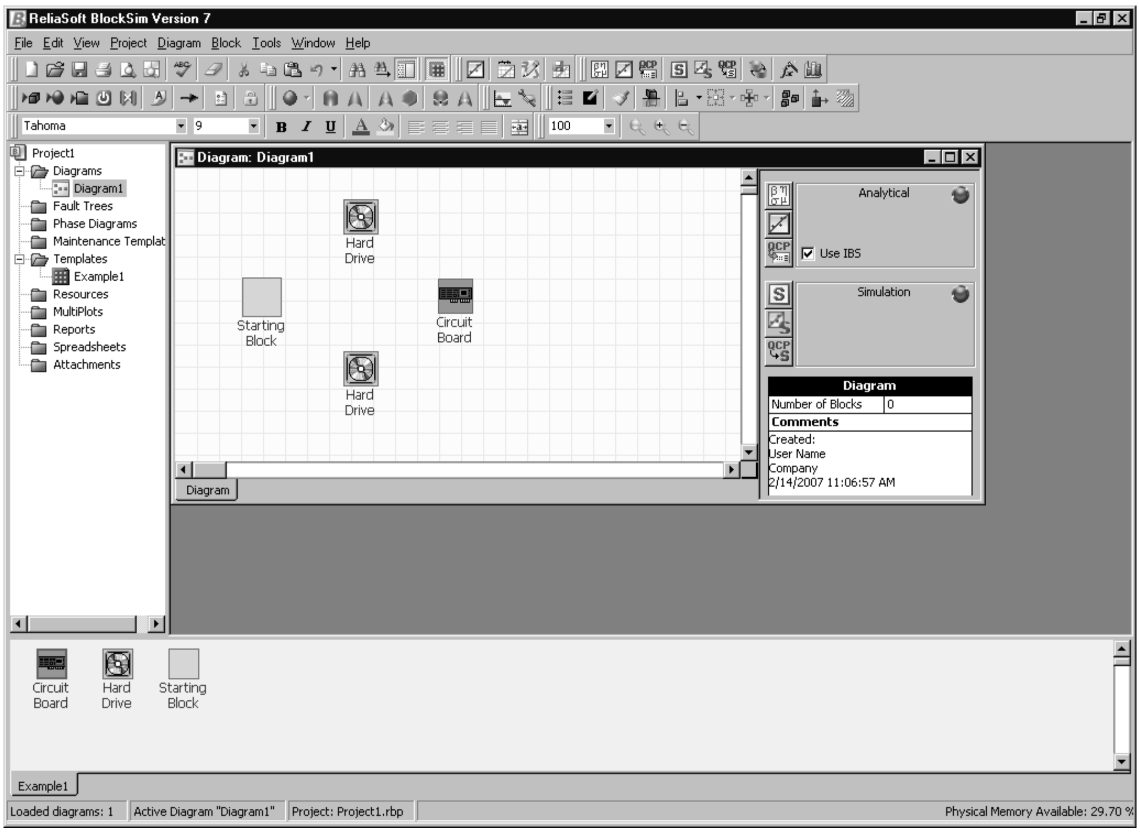


- The New Project Wizard will appear. For this example, you will create a new project using an existing base project. A base project contains pre-defined Templates and Resources, such as maintenance, crew and spare pool policies, that will be placed automatically into the new project.
- In Step 1 of the New Project Wizard, select to create a new project using an existing base project and click **Next>**.
- In Step 2 of the New Project Wizard, click the **Open** icon.

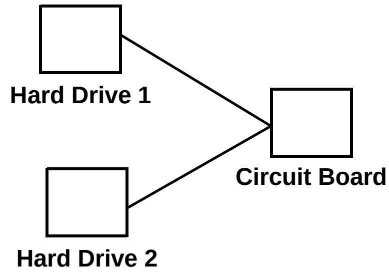
- In the window that appears, browse through the “BlockSim7\Examples\Training Guide” folder to locate the **Example1.rbb** base project. Once you have selected the base project, click **Open**.
- Select the Example1 base project and select to include a new blank diagram. Click **Next>**.
- In the last step of the New Project Wizard, click **Finish**.
- The Project Explorer, Template Panel and a blank Diagram Sheet will appear. Your screen will look like the one shown next.



- As mentioned in the First Steps example, the Diagram Sheet is the workspace in which you will create simple or complex diagrams that represent the reliability characteristics of systems or processes. The Project Explorer appears on the left side of the MDI and the Template from the base project, Example1, appears in the Template Panel at the bottom of the MDI.
- You are now ready to build a simple reliability block diagram (RBD) by dragging blocks from the Example1 Template into the Diagram Sheet.
- Drag the Starting block from the Template into the Diagram Sheet. To do this, click the block in the Template Panel to select it, hold down the left mouse button, drag the cursor into the desired position on the Diagram Sheet and release the mouse button. The Starting block will represent the starting point of the computer system in this example.
- Now drag the Hard Drive and Circuit Board blocks from the Template Panel into the Diagram Sheet. Drag a second Hard Drive block into the diagram to represent the second Hard Drive component in the system. The Diagram Sheet will now contain four blocks and the Example1 Template will be unchanged, as shown next.

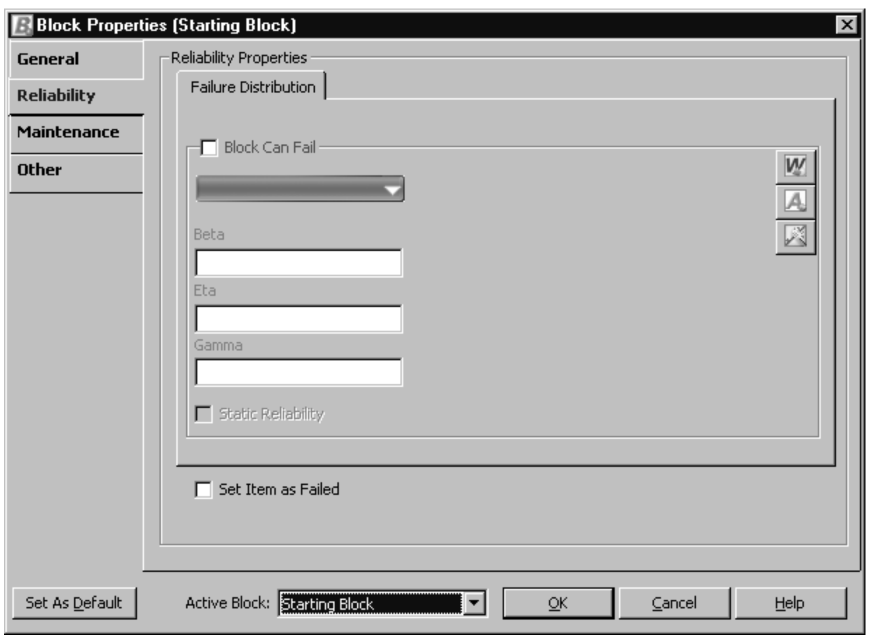


The system in this example contains only three components: two Hard Drives and a Circuit Board. The Hard Drives are connected in parallel. Therefore, the original system would look like the figure shown next.



However, a BlockSim diagram must have exactly one starting point and one ending point. Therefore, a single starting point that does not possess failure characteristics (represented by the Starting block) was introduced to close the system without impacting reliability calculations.

- To set the properties for the Starting block, double-click the block in the Diagram Sheet to open the Block Properties window.
- Click the **Reliability** tab to view the Failure Distribution page, as shown next.



- On the Failure Distribution page, you can define the reliability characteristics of the component. Because this block does not represent a component of the system with failure characteristics to be taken into account, the **Block Can Fail** option must be de-selected to indicate that the component cannot fail. Because the component cannot fail, the other options on the Failure page are unavailable.
- Now, select the first **Hard Drive** block that appears in the Active Block drop-down menu at the bottom of the window to define the characteristics for the Hard Drive 1 block. If you made any changes to the properties of the Starting block, a window will appear asking if you want to apply the changes to the Starting block. Click **Yes**. The properties will be saved for the Starting block and the Hard Drive block will become the active block.

- For the Hard Drive block, make sure that the following options and properties have been defined in the Block Properties window:
  - **General Tab: Item Page**

    Block Name: Hard Drive 1
  - **Reliability Tab: Failure Distribution Page**

    Block Can Fail: Selected

    Failure Distribution: Weibull

    Beta: 2.5

    Eta: 3000 days

    Gamma: 0

    Static Reliability: Not Selected
- Select the other Hard Drive block as the active block to define the Hard Drive 2 block properties. Be sure that the following options and properties have been defined in the Block Properties window:
  - **General Tab: Item Page**

    Block Name: Hard Drive 2
  - **Reliability Tab: Failure Distribution Page**

    Block Can Fail: Selected

    Failure Distribution: Exponential

    Mean Time: 10000

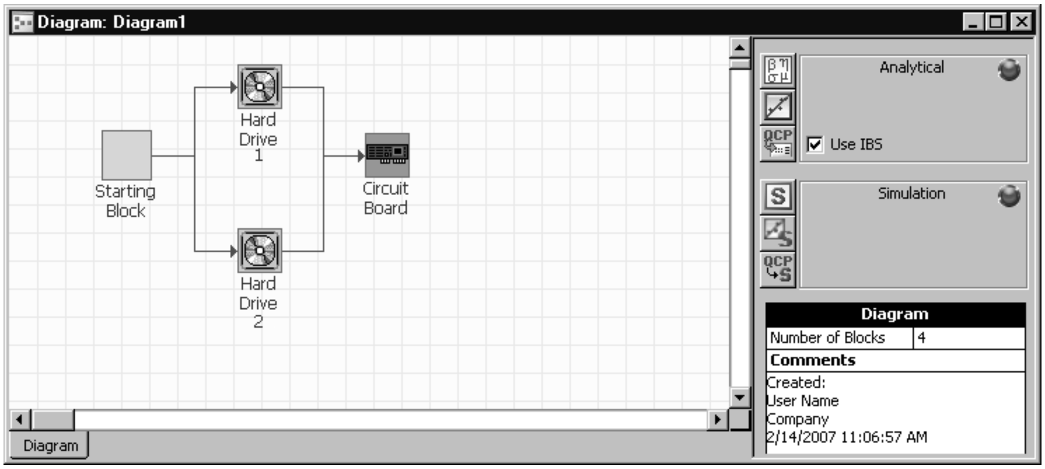
    Gamma: 0

    Static Reliability: Not Selected
- Close the Block Properties window.

The Circuit Board block has already been defined with the failure characteristics of the Circuit Board component. To verify this, you can select the block within the Diagram Sheet to view its failure distribution in the Information area on the Diagram Sheet Control Panel that appears on the right side of the Diagram Sheet or double-click the block to open the Block Properties window.

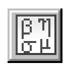
At any point, you can change the properties of a block within the Diagram Sheet or within the Template Panel. If you change the properties of a block within the Template Panel, then each time the block is dragged into the Diagram Sheet, the block's properties will reflect the values specified in the Template. Changing the properties of a block within the Template Panel will not, however, change the properties of blocks already positioned in the Diagram Sheet, nor will changing the properties of blocks within the Diagram Sheet alter the properties of blocks within the Template Panel.

- Now you are ready to connect the blocks to represent the relationships between the components of the system. Use the Join Blocks tool to connect the Starting block to the Hard Drive 1 block, the Starting block to the Hard Drive 2 block, the Hard Drive 1 block to the Circuit Board block and the Hard Drive 2 block to the Circuit Board block. When you use the Join Blocks tool to add relationship lines, be sure to right-click the Diagram Sheet or click the **Join Blocks** icon once the relationships have been made in order to return to BlockSim's normal mode. Your screen will look like the one shown next.

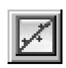


Notice that the Hard Drive blocks are diagrammed in parallel to show that if one Hard Drive component fails, the system will continue to operate with the other Hard Drive component.

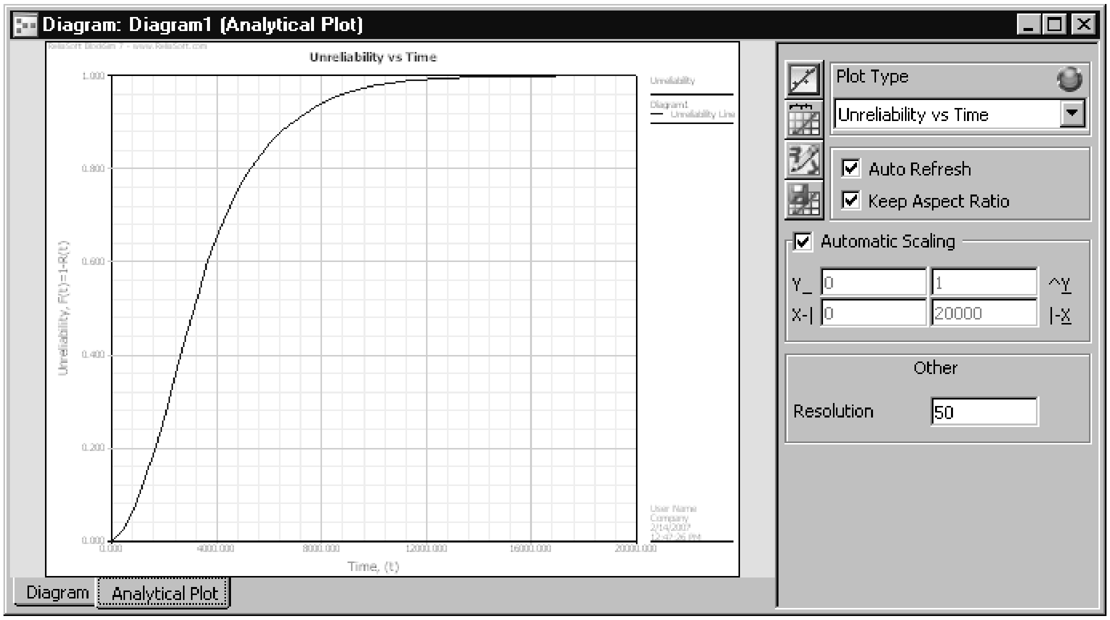
- Now that you have defined the reliability characteristics of each component block and arranged and connected the blocks to represent the system, you are ready to analyze the system. To analyze the system, select **Analyze** from the **Tools** menu or click the **Analyze** icon.



- Now you can generate plots based on the reliability characteristics of the entire system. Select **Analytical Plot** from the **Tools** menu or click the **Analytical Plot** icon.



- If the Unreliability vs. Time plot is not displayed in the Analytical Plot Sheet by default, select Unreliability vs. Time from the Plot Type drop-down menu on the Control Panel. The Unreliability vs. Time plot will appear, as shown next.



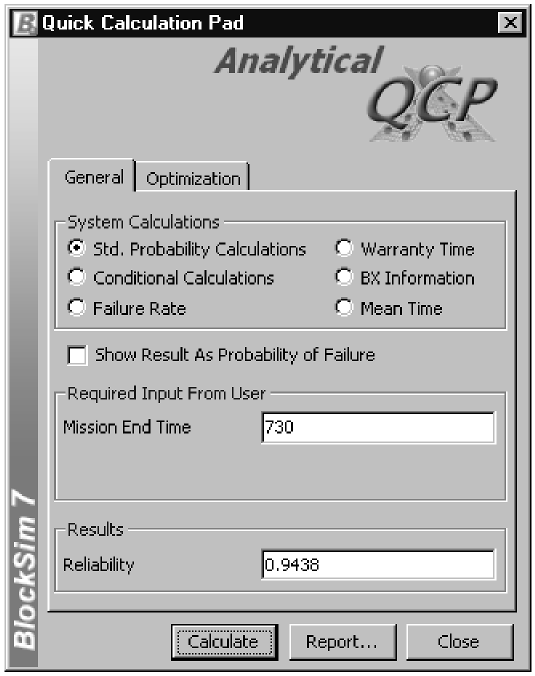
- Return to the Diagram Sheet by clicking its page index tab.

As demonstrated in the First Steps example, BlockSim also allows you to obtain standard reliability results based on the exact system reliability function. To calculate the reliability of the system at 730 days, the Analytical Quick Calculation Pad (QCP) will be used.

- Select **Analytical QCP** from the **Tools** menu or click the **Analytical QCP** icon.

- The Analytical QCP will appear. The QCP contains two pages, the General page and the Optimization page. On the General page, select **Std. Probability Calculations** under System Calculations to determine the reliability of the system.

- Type a Mission End Time of **730** under Required Input from User. Finally, click **Calculate** and the results of the calculation will appear under Results, as shown next.



You can see that the reliability of the system at 730 days is 0.9438 or 94.38%. Click **Close** to close the Analytical Quick Calculation Pad and return to the Diagram Sheet.

BlockSim allows you to perform "what-if" calculations based on the RBDs you create. You can toggle the status of individual blocks on or off to indicate whether the component is active or inactive and then obtain reliability results for the system under those hypothetical conditions.

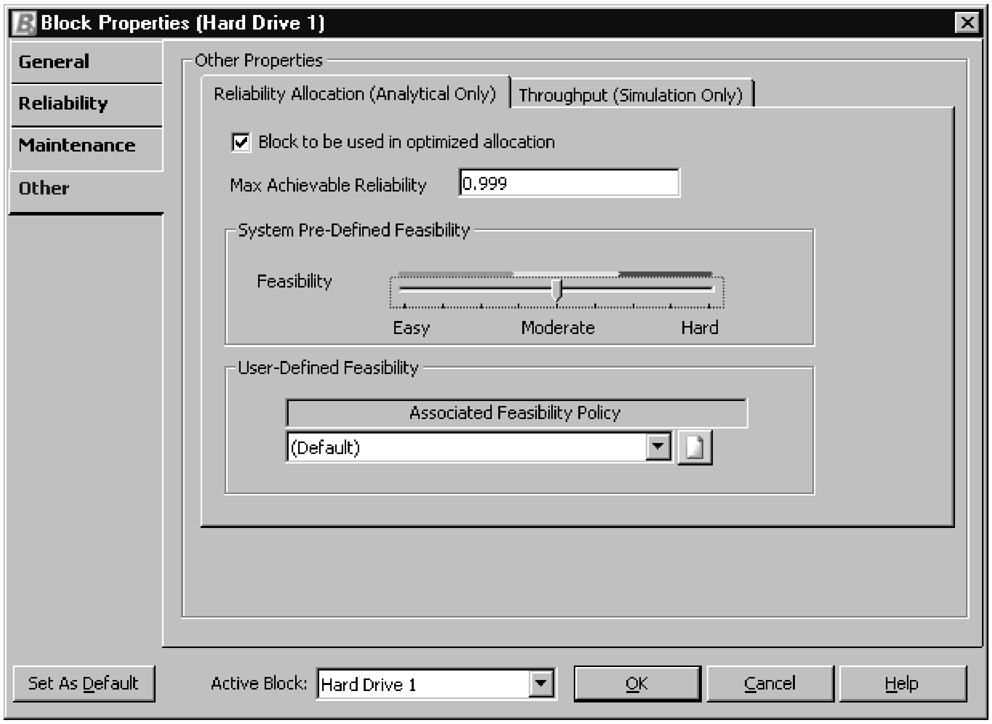
- Next, you will determine the reliability of the system if Hard Drive 1 is turned off or absent from the system. To toggle the status of Hard Drive 1 to "off," right-click the block and select **Set Block to Off** from the shortcut menu that appears.[1] A red **X** will appear on the block to indicate that the component is inactive, as shown next.

- Now re-open the Analytical QCP. Select the **Std. Probability Calculations** option and specify **730** as the Mission End Time. Click **Calculate** and the results will be displayed under Results.
- You can see that with Hard Drive 1 inactive, the reliability of the system at 730 days decreases from 0.9438 (94.38%) to 0.8792 (87.92%). Close the Analytical QCP.
- Now toggle the status of the Hard Drive 1 block back to "on" by de-selecting the **Set Block to Off** option from the shortcut menu. The red **X** will disappear, indicating that the component is active.

BlockSim also provides the capability of reliability allocation calculations to determine the best way to achieve a system reliability goal by improving the reliability of individual components.

1. You can also click the block to select it and then select **Set Block to Off** from the **Block** menu.

- Double-click the Hard Drive 1 block to open the Block Properties window. Click the **Other** tab to display the Reliability Allocation page. On this page, you can define the optimization characteristics of the selected component. Select the **Block to be used in optimized allocation** option and enter **0.999** (default) into the Max Achievable Reliability input box. This option indicates the highest reliability value that can reasonably be achieved for the component.
- Drag the marker on the Feasibility scale to **Moderate** to indicate that it is moderately difficult (or costly) to increase the reliability of the component.[2] The window will look like the next figure.

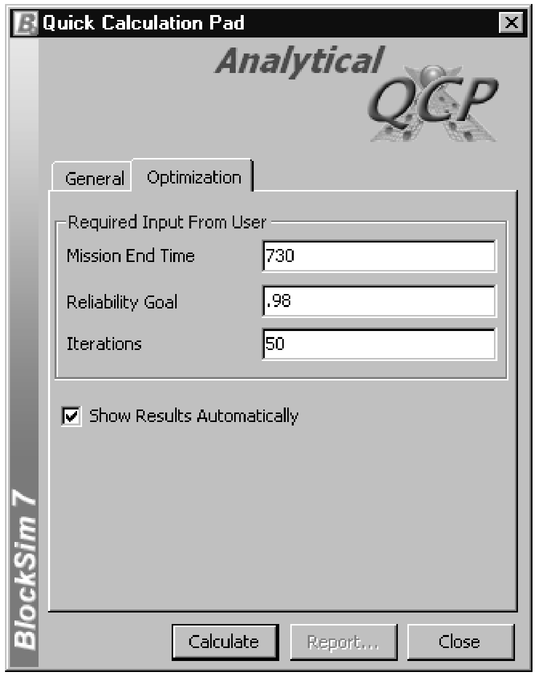


- Click **OK** to return to the Diagram Sheet. A green box will appear at the bottom right corner of the block, as shown next, to indicate that the reliability of this component is to be considered in the optimization algorithm.

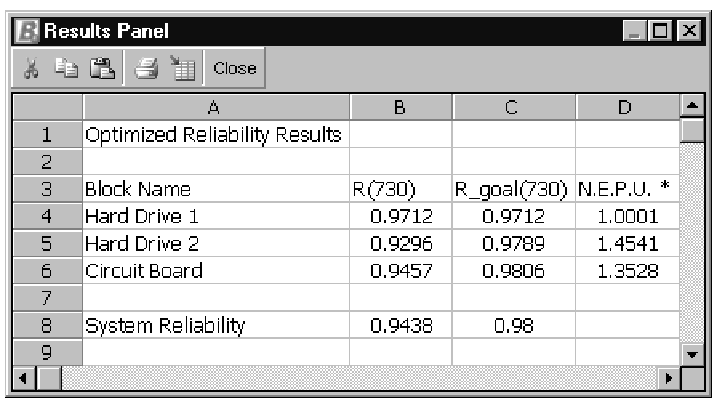
- Repeat these steps to define the optimization characteristics of the Hard Drive 2 and Circuit Board blocks. For the Hard Drive 2 block, the Max Achievable Reliability is 0.999 and the Feasibility is **Easy**. For the Circuit Board block, the Max Achievable Reliability is 0.999 and the Feasibility is **Hard**. Be sure to select the **Block to be used in optimized allocation** option for both blocks.

2. You can also define your own cost function for the difficulty or cost of increasing the reliability of the block instead of using the pre-defined Feasibility Scale by creating a feasibility policy.

- Re-open the Analytical QCP and click the **Optimization** tab. The Optimization page allows you to set up and run the allocation optimization algorithm for the system. For Mission End Time, type **730**; for Reliability Goal, type **0.98**; for Iterations, accept the default value of **50**.[3] Select the **Show Results Automatically** option, as shown next.



- Click **Calculate** to begin the optimization process.
- Because the **Show Results Automatically** option was selected in the Analytical QCP, when the optimization calculations are complete, the results will appear in the Results Panel, as shown next.[4]



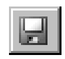
	A	B	C	D
1	Optimized Reliability Results			
2				
3	Block Name	R(730)	R_goal(730)	N.E.P.U. *
4	Hard Drive 1	0.9712	0.9712	1.0001
5	Hard Drive 2	0.9296	0.9789	1.4541
6	Circuit Board	0.9457	0.9806	1.3528
7				
8	System Reliability	0.9438	0.98	
9				

3. The Iterations input box allows you to enter the maximum number of iterations of the optimization algorithm to be calculated in order to obtain a solution. As the complexity and number of units in the system increases, a greater number of iterations may be required.

4. If the **Show Results Automatically** option is not selected, you can click the **Report** button to display the results in ReliaSoft's Results Panel.

The reliability goals for each optimized component, displayed in the R_goal(730) column, represent the optimum scenario for increasing component reliability in order to achieve the system reliability goal of 0.98 (or 98%) while minimizing the system cost. The number of equivalent units that would have to be placed in parallel to achieve this reliability is shown in the N.E.P.U. column, which stands for Number of Equivalent Parallel Units.

- Click **Close** in the Results Panel and again in the Analytical Quick Calculation Pad.
- If you are using a fully functional copy of the software (*i.e.* not a demonstration version), save the project as **Example1.rbp**. To do this, click the **Save** icon or select **Save** from the **File** menu.



- In the Save As window, enter **Example1** as the file name and click **Save**. After saving the file, leave the project open, as it will be used in the next example.

4.1.2 Example 2

The Circuit Board from Example 1 was examined further to determine the major failure modes so that its reliability could be improved. It was found that most of the failures were due to the failure of the Processor and the Fan. The properties for the Processor and Fan are shown in the table below.

Component	Failure Distribution	Parameters	Max Achievable Reliability	Feasibility of Increasing Reliability
Processor	Weibull	Beta = 2.3 Eta = 7,655.19 days Gamma = 0	.999	Moderate
Fan	Exponential	Mean Time = 14,231.83 Gamma = 0	.999	Easy

The Processor and Fan are connected reliability-wise in series.

Do the following:

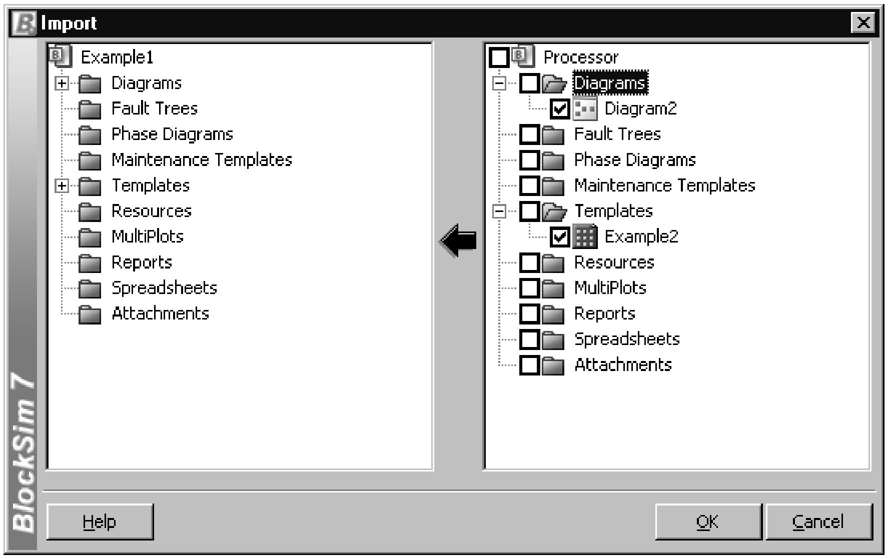
- Create an RBD for this subsystem.
- In the previous example, it was found that the reliability of the Circuit Board would need to be increased from 0.9457 to 0.9806 for the system to reach a reliability goal of 0.98. Find the optimized reliabilities for the Processor and Fan in order to achieve this goal.

Solution

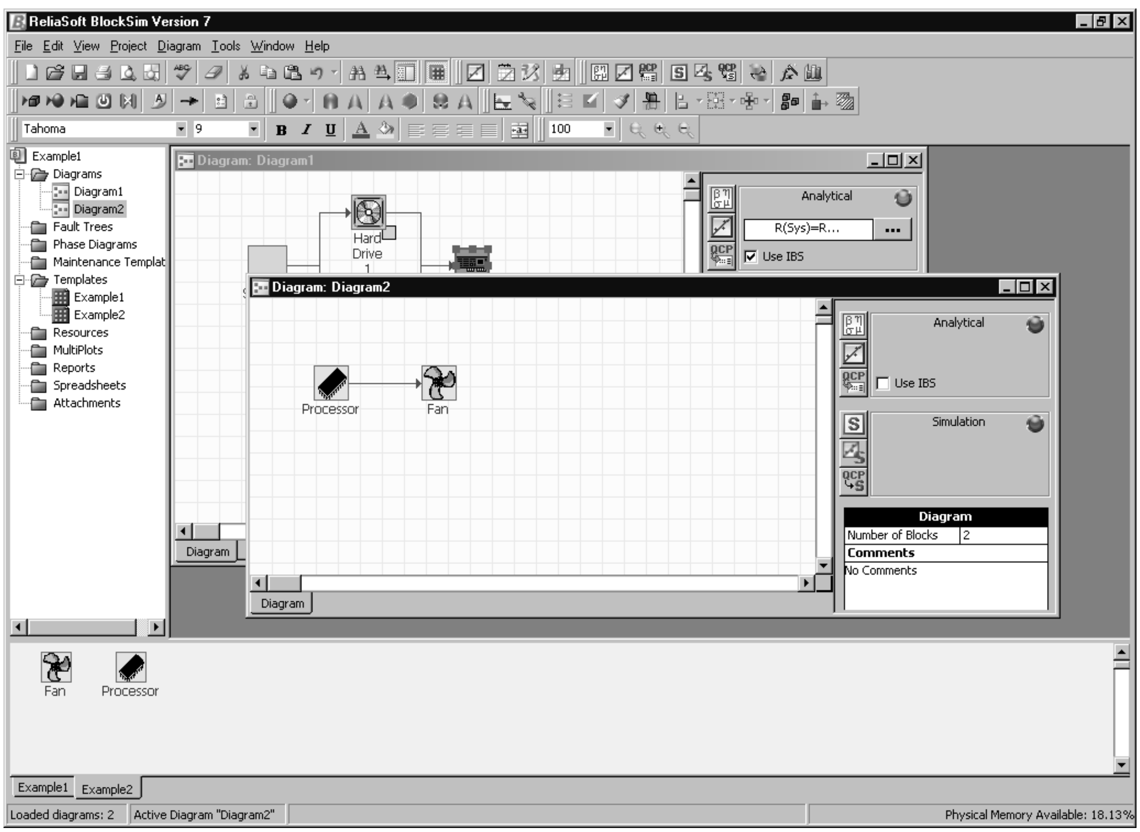
- First, import an existing Diagram Sheet and Template from the Processor project.[5] To do this, select **Import Items** from the **Project** menu or right-click inside the Project Explorer and select **Import Items** from the Project Explorer shortcut menu.
- The Select Project to Import from window will open. Select the **Processor.rbp** file from the list of files (in the BlockSim7\Examples\Training Guide directory) and click **Open**.
- The Import window will appear.

[5]. If you are using a restricted demo version of the software (*i.e.* one that cannot save files), you will not be able to import items. For this example, you can manually create the RBD for the subsystem. Select **Add Diagram** from the **Project** menu to create a new diagram, then add blocks, connect them and assign their properties based on the table and instructions given in this example.

- On the right side of the window, select the **Diagram2** diagram that appears under the Diagrams folder and also select the **Example2** Template that appears under the Templates folder, as shown next.[6]



- Click **OK**. The Diagram Sheet and Template will be imported into the project and your screen will look like the one shown next.

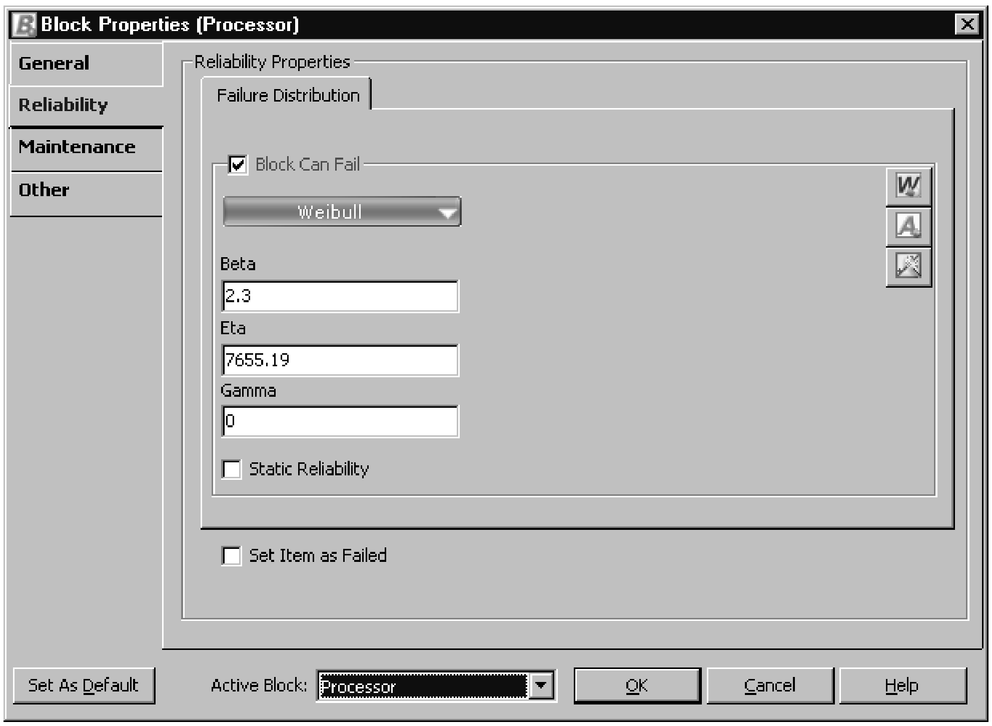


6. You can also select the box that appears next to the project file name at the top of the right side of the window to indicate that you want to import all items that exist in the project.

You can now see that two Diagram Sheets appear in the MDI and in the Project Explorer under the Diagrams folder.[7]

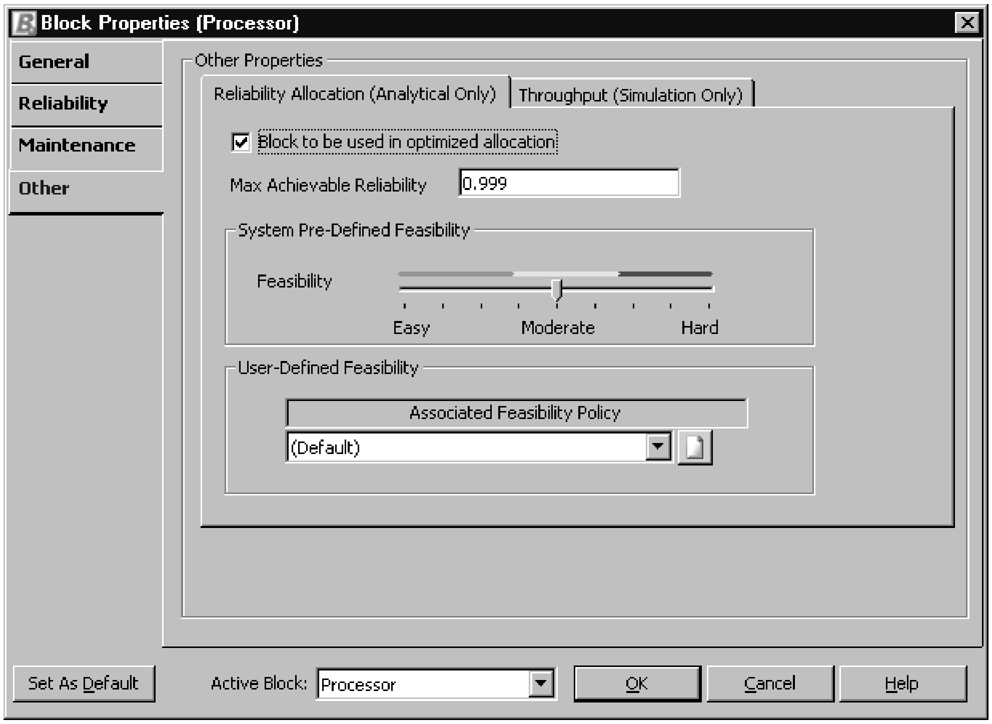
You can also see that two Templates appear in the Template Panel and in the Project Explorer under the Templates folder. You can switch between Templates by clicking the corresponding page index tab in the Template Panel or by double-clicking the Template name that appears in Templates folder in the Project Explorer.

- Double-click the Processor block in the Diagram2 Diagram Sheet to open the Block Properties window. Be sure that the **Block Can Fail** option is selected on the Failure Distribution page of the Reliability tab.
- Next, select **Weibull** as the failure distribution and enter the known parameter values from the table on page 36. The window will look like the one shown next.



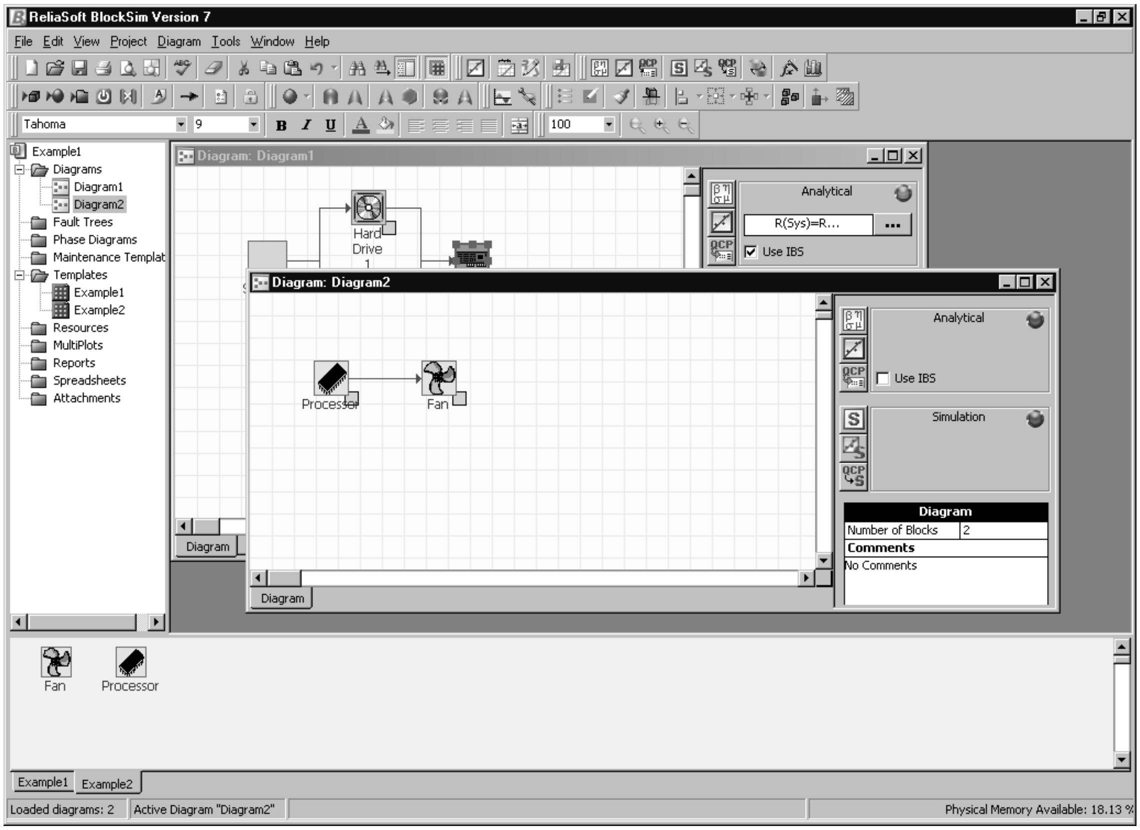
[7] If the Diagram2 Diagram Sheet does not appear in the MDI, double-click its name in the Project Explorer to activate it.

- Now click the **Other** tab to display the Reliability Allocation page of the Block Properties window. Select the **Block to be used in optimized allocation** option and type the proper values for the Max Achievable Reliability (*i.e.* 0.999). Select the correct Feasibility option (*i.e.* Moderate), as shown next.

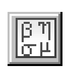


- Select the Fan block as the active block. A window will appear asking if you want to apply the changes to the Processor block. Click **Yes**.
- The Fan block will become the active block. Enter the appropriate block properties for the Fan using the same process described for the Processor (*i.e.* 0.999, Easy). After you have entered all of the properties, click **OK**.

- A green box will appear in the bottom right corner of the blocks in the Diagram Sheet to indicate that the reliability of these components is to be optimized. Your screen will look like the one shown next.

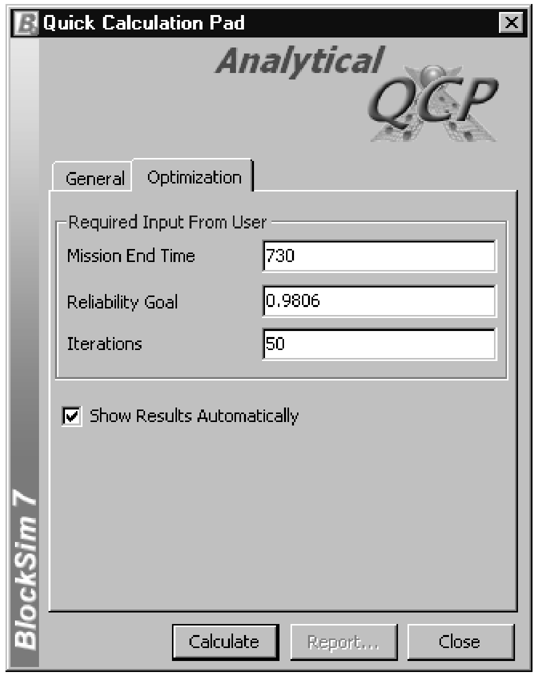


- Analyze the system by selecting **Analyze** from the **Tools** menu or by clicking the **Analyze** icon.

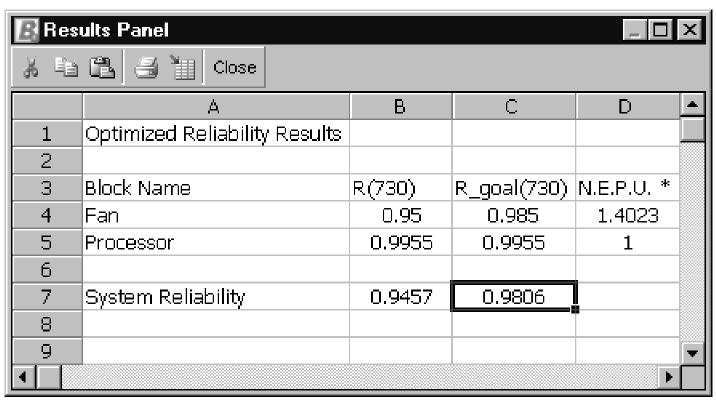


- Next, optimize the reliabilities of the Processor and Fan so that the system reliability meets the reliability goal of 0.9806.

- To do this, open the Analytical Quick Calculation Pad (QCP) and click the **Optimization** tab. Make sure that **730** is entered for the Mission End Time, the Reliability Goal is set at **0.9806** and the number of Iterations is **50** (default). In addition, make sure the **Show Results Automatically** option is selected. The Analytical QCP will look like the next figure.



- Click **Calculate** to conduct the optimization calculations. The results are shown next.



	A	B	C	D
1	Optimized Reliability Results			
2				
3	Block Name	R(730)	R_goal(730)	N.E.P.U. *
4	Fan	0.95	0.985	1.4023
5	Processor	0.9955	0.9955	1
6				
7	System Reliability	0.9457	0.9806	
8				
9				

As the results indicate, to achieve a reliability goal of 0.9806, the reliability of the processor must be at least 0.9955 and the reliability of the fan must be at least 0.985.

- Click **Close** to close the Results Panel and click **Close** to close the Analytical QCP. If you are using a fully functional copy of the software, save the project as **Example2.rbp.** Leave the project open, as it will be used in the next example.

4.1.3 Example 3

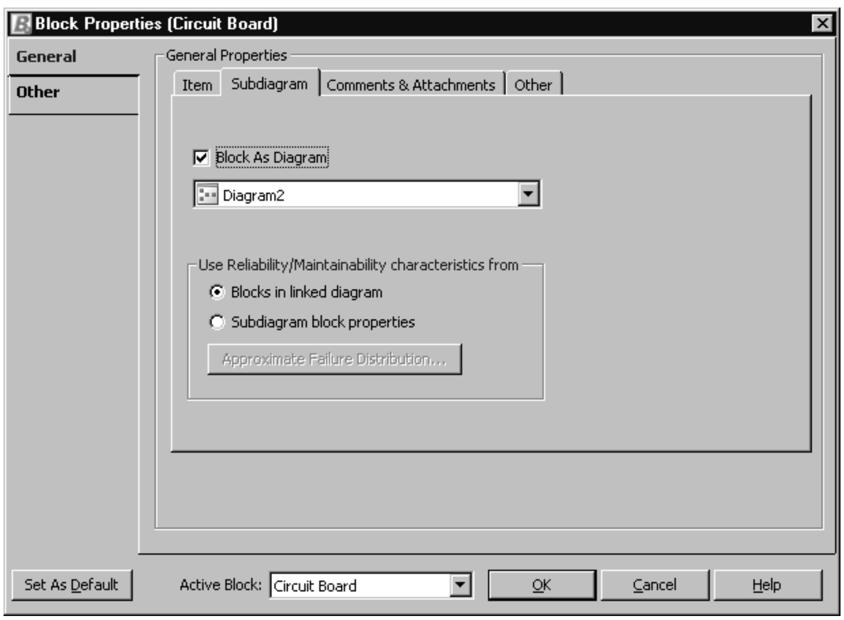
In BlockSim, you have the ability to include subsystems within selected blocks. This allows you to drill down or view the subsystems within a particular component. This example will demonstrate this aspect of BlockSim. At this point, you will still be working with the data and diagrams used in Examples 1 and 2.

Do the following:

- Include the Fan and Processor as a subsystem within the Circuit Board block.
- Calculate the reliability of the system at 730 days.

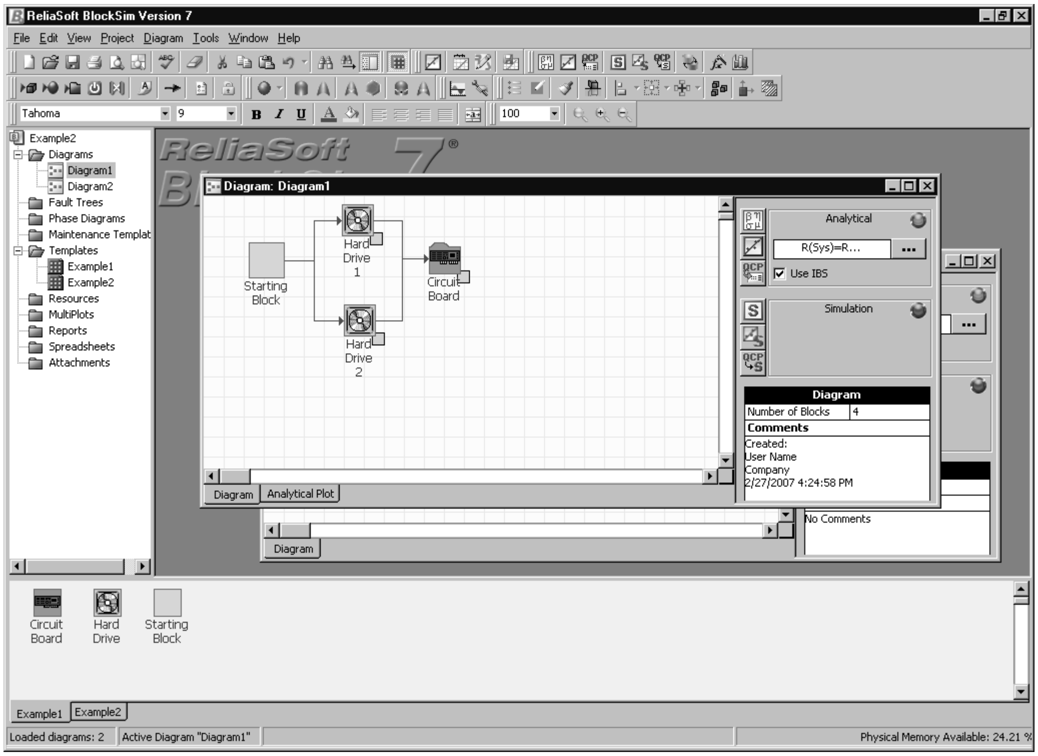
Solution

- To begin, return the focus to Diagram 1. This is the diagram with two Hard Drives and a Circuit Board. Double-click the Circuit Board block to open the Block Properties window.
- On the Subdiagram page of the General tab, select the **Block As Diagram** option. Below the Block As Diagram option, a drop-down menu will appear. This menu contains a list of all available diagrams in the current project. Select **Diagram2** from this list. This is the diagram with the Processor and the Fan that you were working with in Example 2. The window will look like the one shown next.



- Click **OK** to apply the current settings to the Circuit Board block and close the Block Properties window.

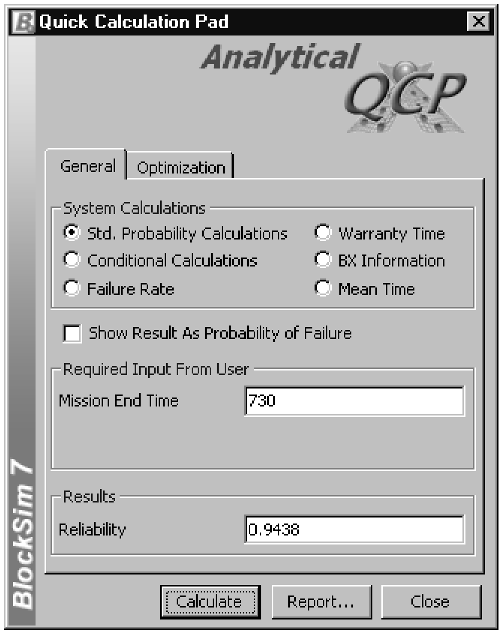
- The appearance of the Circuit Board block has now been modified. It still contains the original picture, but it is now in the shape of a folder. This is the way that BlockSim identifies subdiagram blocks (blocks that represent other diagrams).



The Circuit Board is now defined by the subsystem containing the Fan and Processor. In other words, the block definition indicates that the Circuit Board is composed of one Fan and one Processor. This is obviously an oversimplification; however, this example simply shows you how one block can represent another diagram in BlockSim.

- To calculate the reliability of the system at 730 days, the QCP will be used. Select **Analytical QCP** from the **Tools** menu or click the **Analytical QCP** icon.

- Select **Std. Probability Calculations** under System Calculations. Type **730** for the Mission End Time and click **Calculate**. The results are shown next.

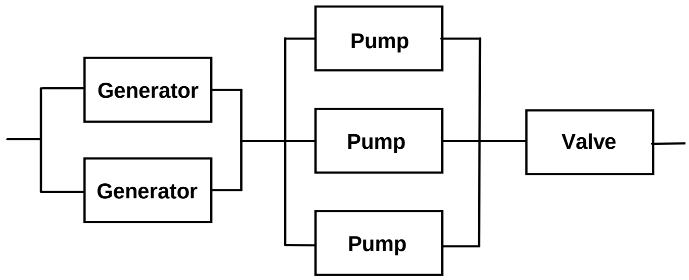


The reliability of the system at 730 days is 0.9438 (94.38%), which is the same as the result returned in Example 1.

- Close the Analytical QCP.
- If you are using a fully functional copy of the software, save the project.
- Close the project by selecting **Close** from the **File** menu.

4.1.4 Example 4

ACME Company manufactures subsystems for oil refinery plants. One of the subsystems that ACME manufactures consists of two power generators, three pumps and one valve. The two generators are identical to each other, as are the pumps. The pumps are in a 2-out-of-3 configuration. The system configuration is shown next.



The following table presents the failure data for the generators.

Number in State	State	Time-to-Failure, hr
1	F	1,150
1	F	1,660
1	S	1,660
5	S	1,850
2	F	3,000
4	S	3,000
1	S	3,200
4	S	4,150
1	F	4,330
1	F	4,800
4	S	4,850
1	F	5,600
1	F	6,100
1	F	7,800
3	S	8,500
1	F	8,750
2	S	8,750
3	S	10,100
1	S	11,500
3	S	12,000

The table shown next presents the failure distribution data and parameter values for the pumps and the valve.

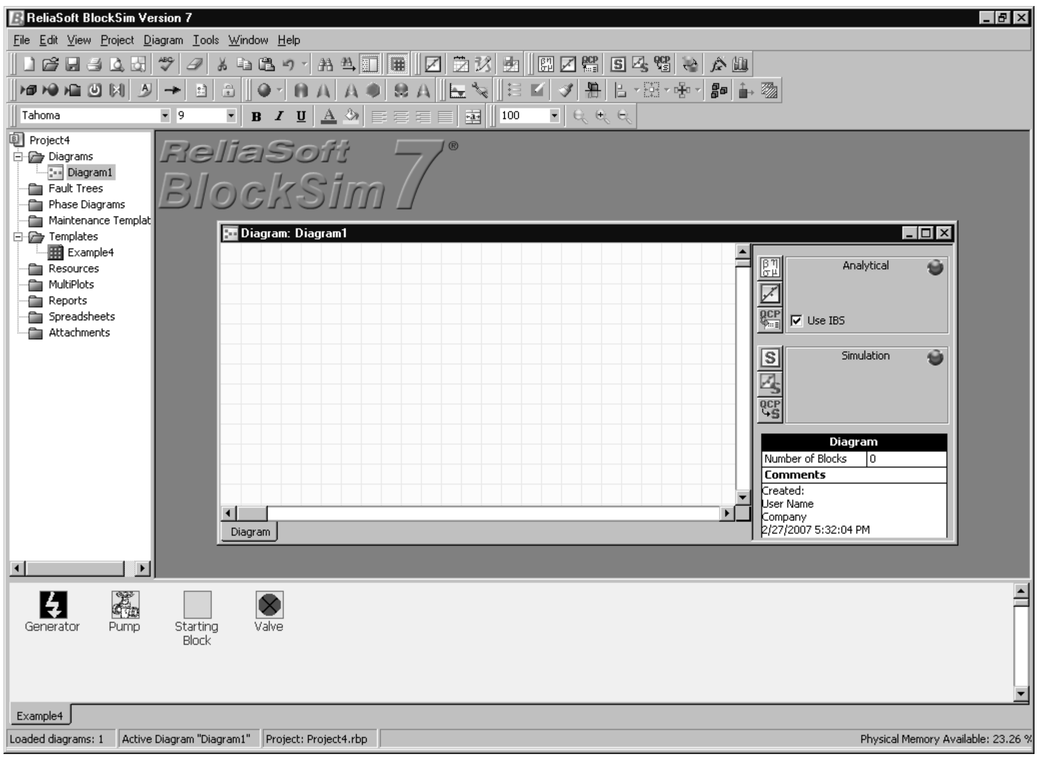
Component	Failure Distribution	Parameter Values
Pumps	Mixed Weibull (2 subpopulations)	β 1 = 0.589, η_1 = 6,343.390 hr, Portion[1] = 0.2695 β 2 = 2.394, η_1 = 20,301.856 hr, Portion[2] = 0.7305
Valve	Exponential	Mean Time = 830,288.94

Do the following:

- Using the Weibull++ software, determine an appropriate failure distribution for the generators based on the given data.
- Estimate the parameters of the selected distribution using maximum likelihood estimation (MLE).
- Generate a table of system reliabilities given a start time of 1,000 hr and an end time of 5,000 hr with a time increment of 1,000 hr.

Solution

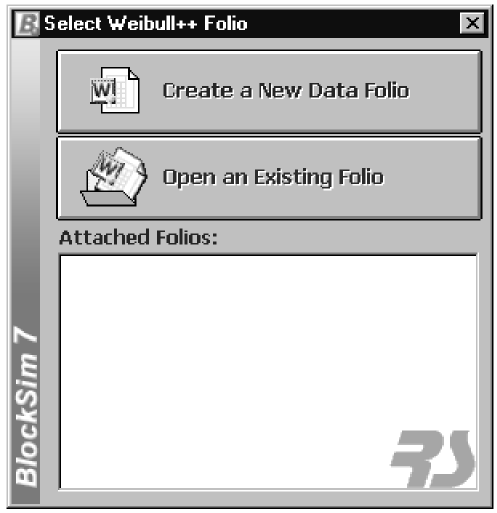
- Create a new project. In the New Project Wizard, select to create the project based on the **Example4.rbb** base project (in the BlockSim7\Examples\Training Guide directory) and include a new blank Diagram Sheet.
- The Project Explorer and a blank Diagram Sheet, along with the Template from the selected base project, will open in the new project. Your screen will look like the one shown next.



- Double-click the Generator block inside the Template Panel. The Block Properties window will appear. The properties for the Generator block have not been set. Although the parameter values are currently unknown, life data has been obtained based on life tests conducted on the generator. This data, given in the table on page 45, can be used to calculate the parameters of the failure distribution for the Generator block.

- Be sure that you are on the Failure Distribution page of the Reliability tab of the Block Properties window. Click the **Compute parameters using Weibull++** button in the lower right corner.

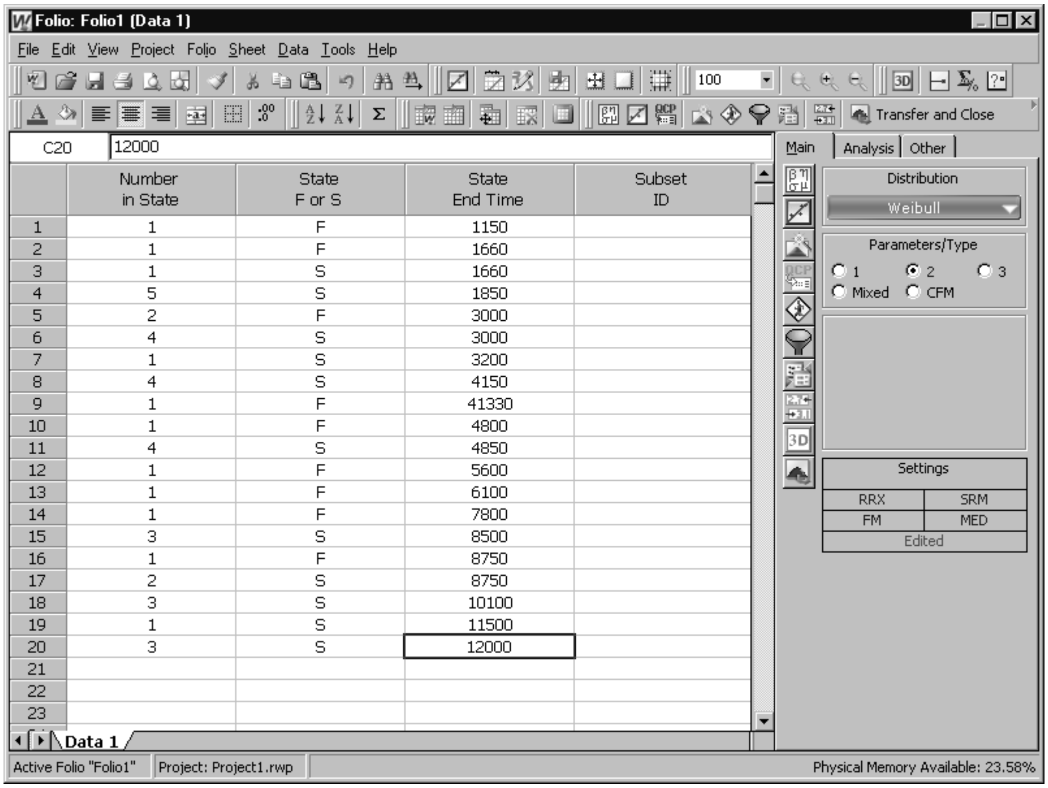
- This will open the Select Weibull++ Folio window, which allows you to launch ReliaSoft's life data analysis software, Weibull++.[8]



- In the Select Weibull++ Folio window, click **Create a New Data Folio**.
- Once Weibull++ has been activated, the Weibull++ New Data Sheet Setup will appear. You will use the New Data Sheet Setup to create the appropriate Data Entry Spreadsheet for the generator component's life data. In the New Data Sheet Setup, select **Times-to-failure**, **My data set contains suspensions (right-censored data)** and **I want to enter data in groups**. Click **OK**. A Data Entry Spreadsheet will be created for you based on your selections.

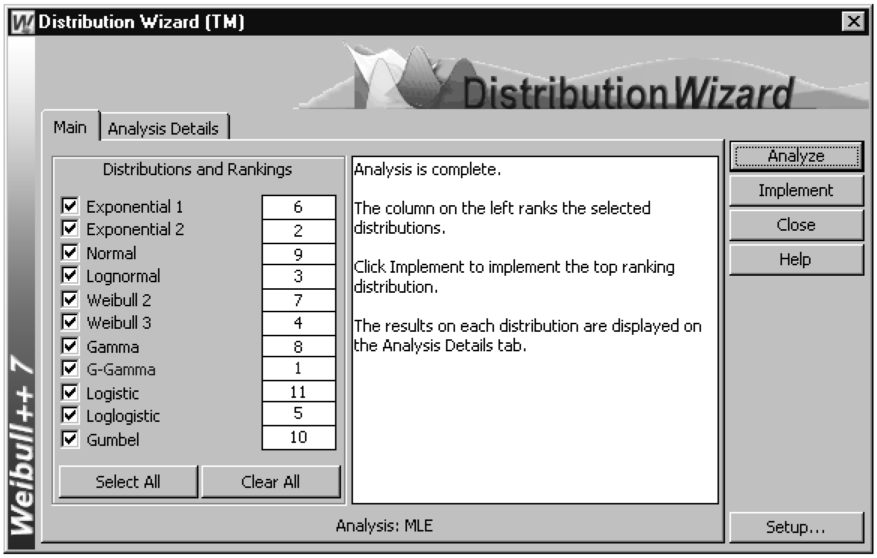
8. Weibull++ must be installed on your computer in order for you to use the **Compute parameters using Weibull++** option.

- Enter the data given for the Generator into the Data Entry Spreadsheet, as shown next.

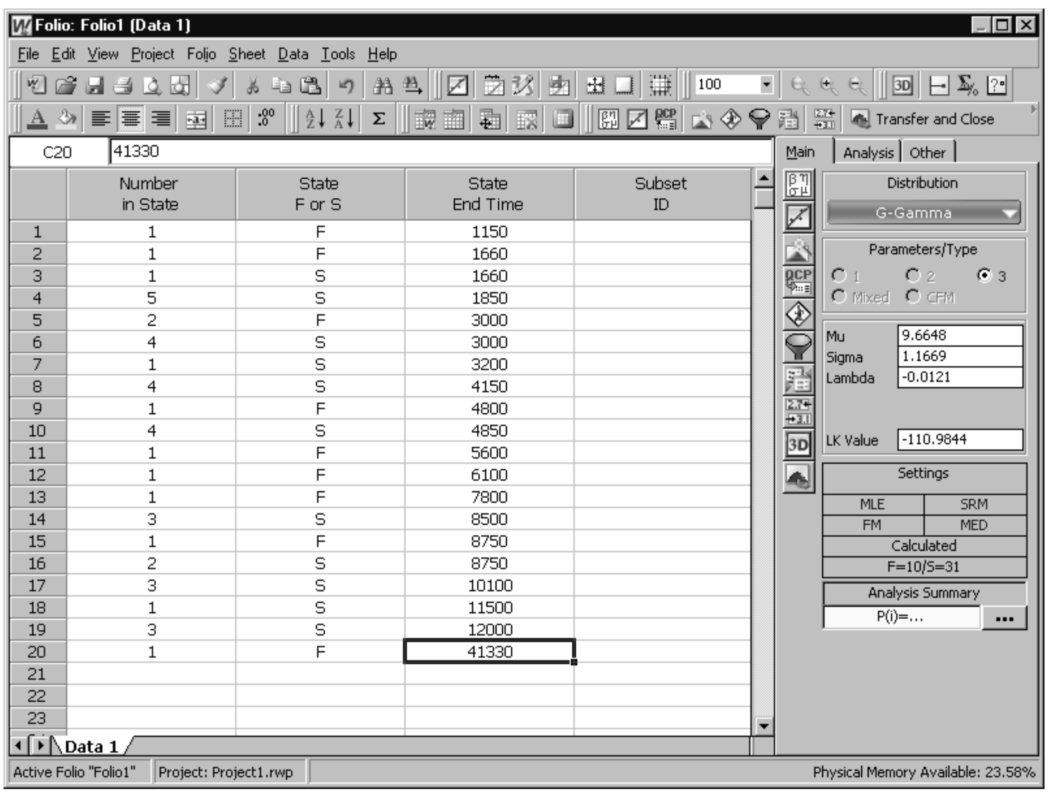


- Maximum likelihood estimation (MLE) will be used for the parameter estimation. You can specify this by clicking the **Analysis** tab on the Data Folio Control Panel. Select the **Maximum Likelihood (MLE)** option from the Analysis Method area. Return to the Main page of the Control Panel by clicking the **Main** tab.
- The Distribution Wizard utility in Weibull++ conducts a variety of goodness-of-fit tests designed to suggest the best distribution for your data. Select **Distribution Wizard** from the **Data** menu or click the **Distribution Wizard** icon.

- The Distribution Wizard will appear. Click **Analyze** so that the Distribution Wizard can go through the process of suggesting a distribution. After the Distribution Wizard has finished conducting the tests, the generalized gamma distribution will be suggested (indicated by the 1 in the Ranking column next to G-Gamma), as shown next.

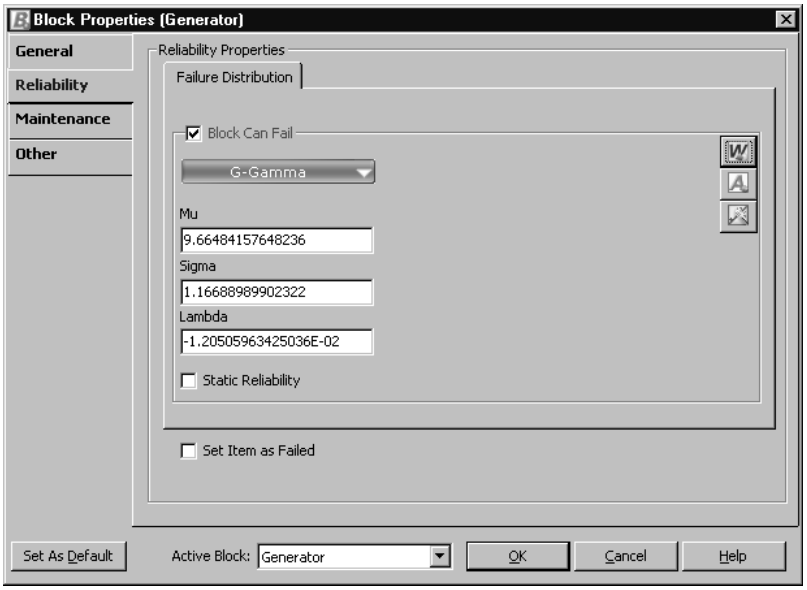


- Click **Implement** to indicate that you would like to calculate the parameters using the generalized gamma distribution. The Distribution Wizard will close and you will now be viewing the Data Entry Spreadsheet with the entered data and the parameters calculated, as shown next.

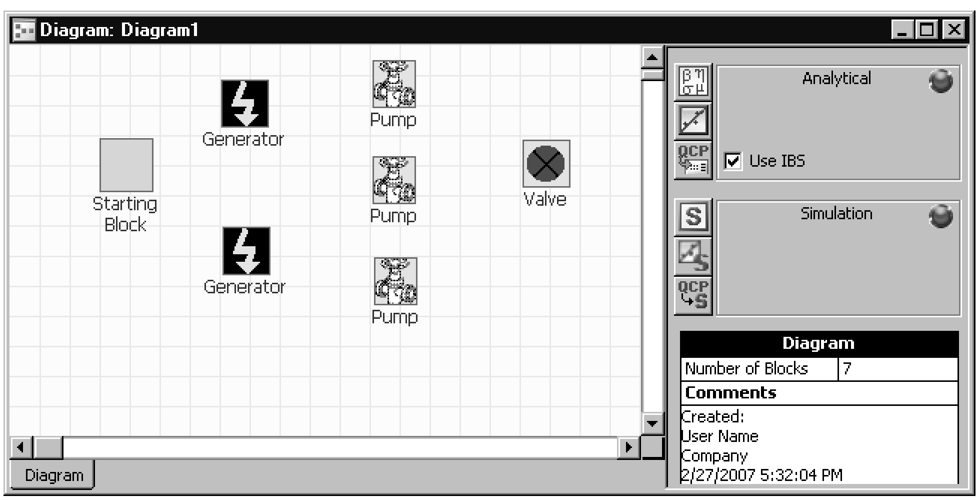


- Click the **Transfer and Close** button to transfer the calculated data to BlockSim and close Weibull++.. A message box will appear to ask if you would like to save the changes made to the Weibull++ project. Click **Yes** and save the Data Folio as **Example4.rwp**.

- Notice that the parameter values that were calculated using Weibull++ have been inserted as the parameter values of the failure distribution of the Generator block, as shown next. Click **OK** to accept the current block properties.



- Now you will arrange the blocks in the diagram. Because BlockSim's diagrams must have only one starting point, you will use the Starting block as the starting point of the diagram. Place the Starting block on the left side of the diagram. Drag one Generator block into the diagram and place it above and to the right of the Starting block. Drag another Generator block into the diagram and place it below and to the right of the Starting block. Drag the Pump block into the diagram three times, placing each of them in a vertical line to the right of the Generator blocks. Drag the Valve block into the diagram and place it on the far right side.
- Your diagram will look like the one shown next.



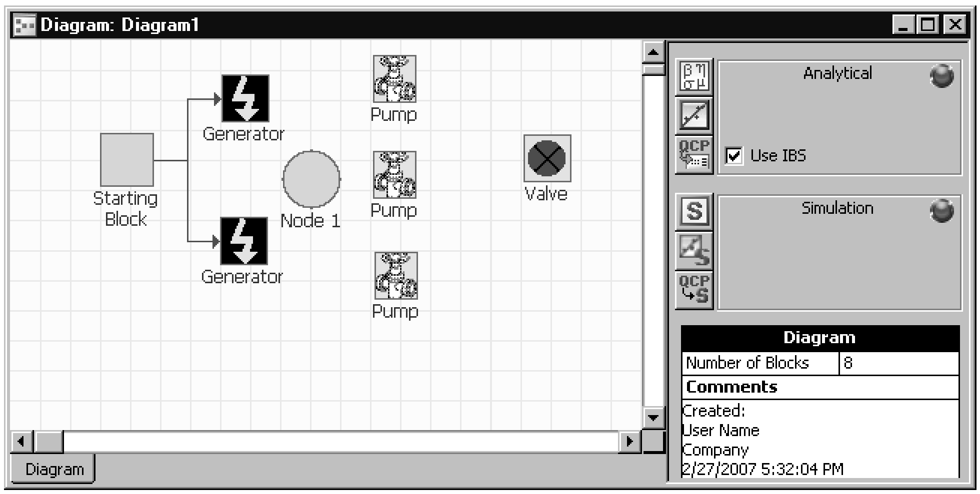
Now you will connect the blocks by dragging relationship lines between them. Connect the Starting block to each of the Generator blocks.[9] The Generator blocks will be connected to each of the Pump blocks through a

[9] Remember to right-click the Diagram Sheet or click the **Join Blocks** icon again once the relationships have been made in order to return to BlockSim's normal mode.

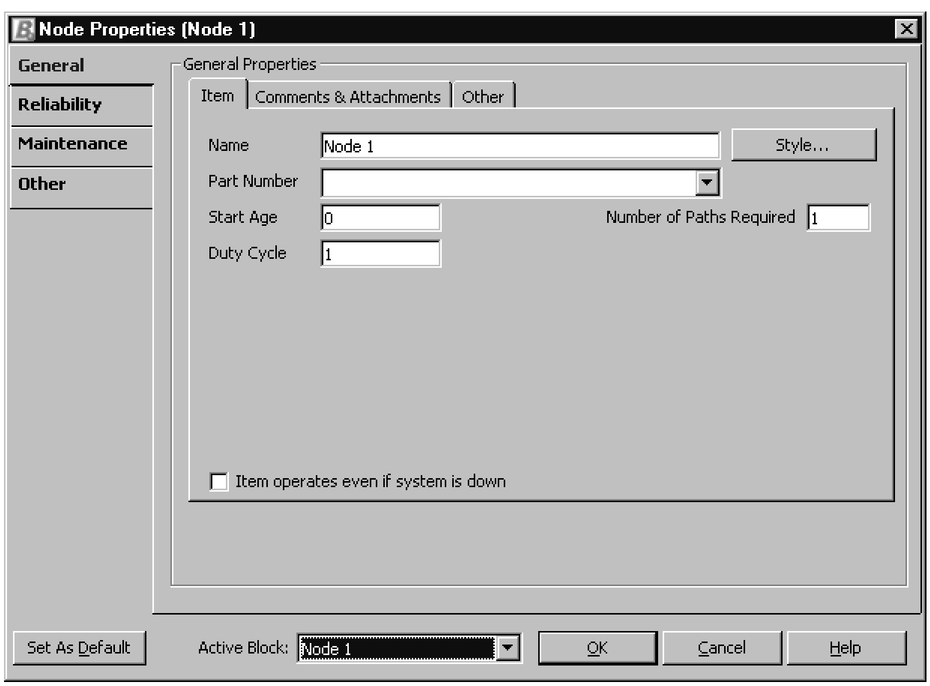
Node block. A Node block is a different type of block that can be defined to indicate the number of paths that must successfully pass through the block in order for the system to succeed (k-out-of-n).

- To place a node into the diagram, select **Add Node to Diagram** from the **Diagram** menu or click the **Add New Node** icon.

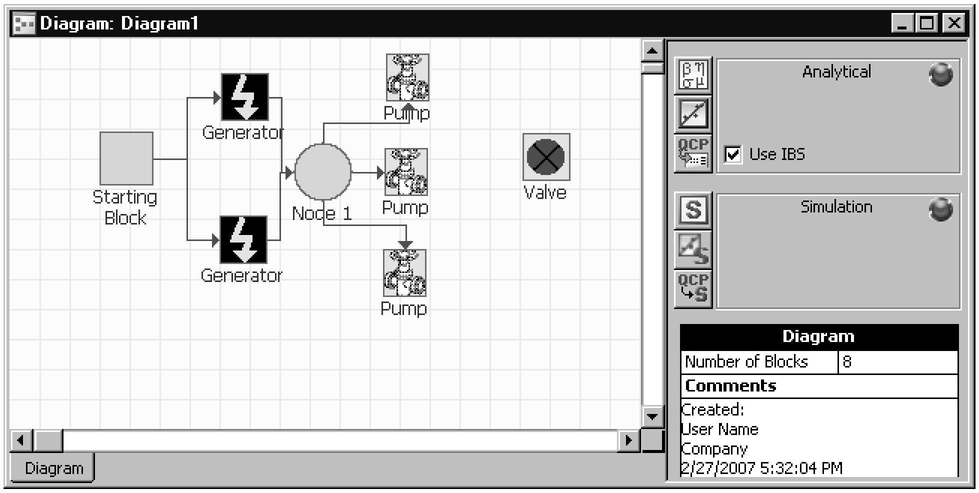
- A Node block will appear in the Diagram Sheet. Place the Node block between the Generator blocks and the Pump blocks. Your screen will look like the one shown next.



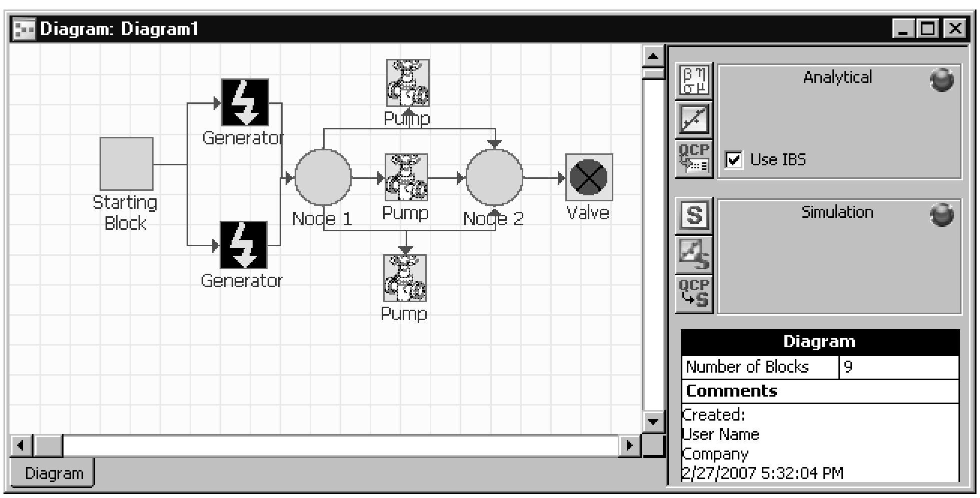
- Double-click the Node block to open the Node Properties window.
- On the Item page of the General tab, in the Number of Paths Required input box, type **1**, to indicate that one working generator is required in order for the system to succeed, as shown next.



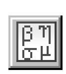
- Make sure the **Block Can Fail** option is not selected on the Failure Distribution page of the Reliability tab.[10] Click **OK** to close the Node Properties window.
- Connect each Generator block to the Node block and then connect the Node block to each Pump block. Your screen will look like the one shown next.



- You will also use a Node block to represent the k-out-of-n configuration of the Pump blocks in relation to the Valve block. Place a Node block between the Pump blocks and the Valve block. Double-click the Node block to open the Node Properties window. In the Number of Paths Required box, type **2** to indicate that two working pumps are required in order for the system to operate. Make sure the **Block Can Fail** option is not selected on the Failure Distribution page of the Reliability tab. Click **OK** to close the Node Properties window.
- Now connect each Pump block to the Node 2 block and connect the Node 2 block to the Valve block. Your diagram will look like the one shown next.



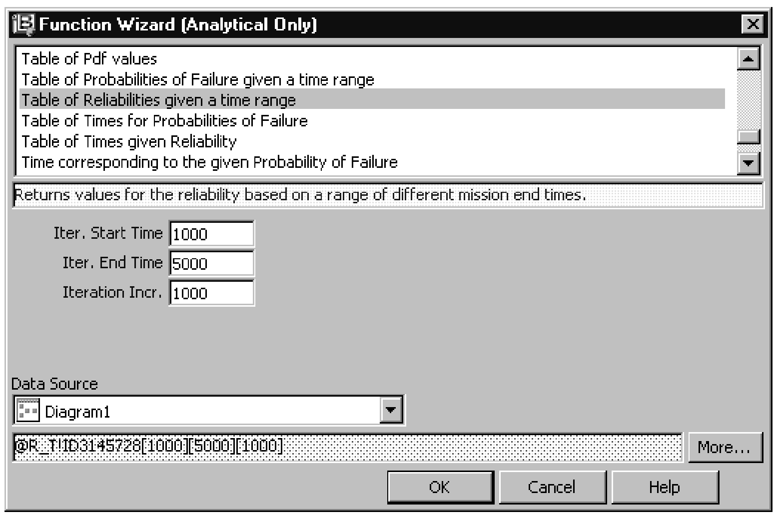
- Analyze the system by selecting **Analyze** from the **Tools** menu or by clicking the **Analyze** icon.



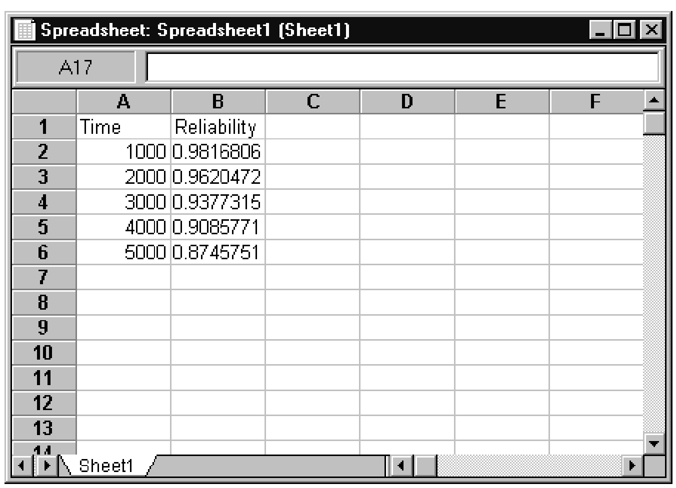
[10] If the **Block Can Fail** option is selected, you can define the failure properties for the Node block.

- Insert a new Spreadsheet into the project by selecting **Add Spreadsheet** from the **Project** menu or from the Project Explorer shortcut menu. A Spreadsheet will appear in the MDI. You can also see that the Spreadsheet has been added to the Project Explorer under the Spreadsheets folder.
- From the Spreadsheet, you will use the Function Wizard to generate a table of system reliabilities. Open the Function Wizard by selecting **Function Wizard** from the **Spreadsheet** menu or by clicking the **Function Wizard** icon.

- Scroll through the list of available functions and select **Table of Reliabilities given a time range**. Type **1000** for the Iter. Start Time, **5000** for the Iter. End Time and **1000** for the Iteration Incr. in the input boxes. Make sure that **Diagram 1** is selected from the Data Source drop-down menu. The Function Wizard should look like the one shown next.



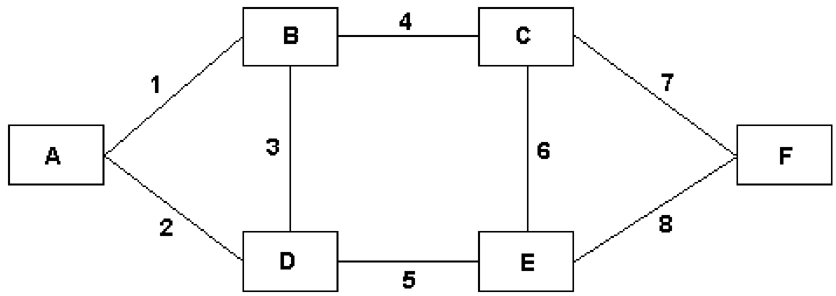
- Click **OK** to generate the table in the Spreadsheet, as shown next.



- If you are using a fully functional copy of the software, save the project as **Example4.rbp**.
- Close the project.

4.1.5 Example 5

Consider the following telecommunications network:



The letters A-E represent the Communication Centers, where A is the main Center. F is a City to which service is being supplied. The numbers 1-8 represent the Communication Lines. Communication Lines 3 and 6 can operate in two directions (*e.g.* from B to D and from D to B). The Communication Centers cannot fail, while the failure rate (λ) for the Communication Lines is 1.3E-4 failures/hour. The repair distribution for the Communication Lines is normal with a mean time of 101.35 hr and a standard deviation of 62.1 hr. The cost of each Communication Line is $1,000 and the labor cost for replacing a line is $75/hr.

Do the following:

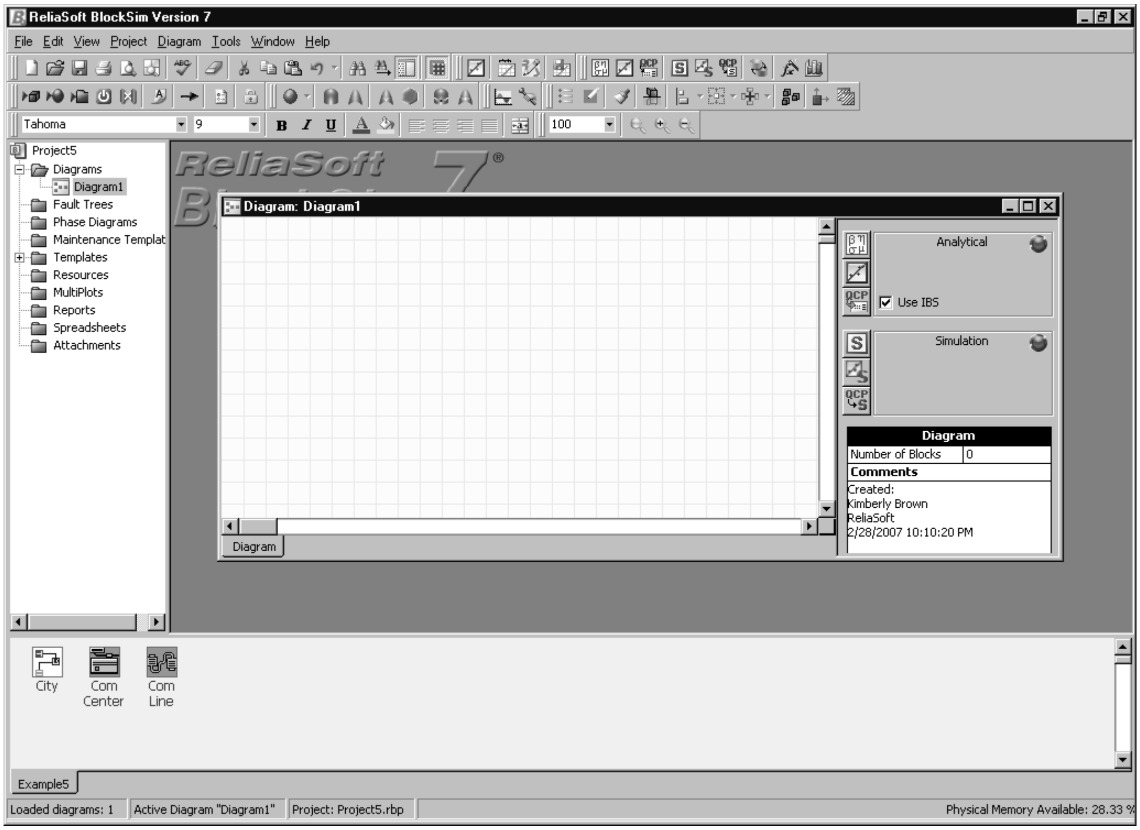
- Create the RBD and use mirrored blocks for the Communication Lines that operate in two directions.
- Find the reliability of the system at 6 months.
- Find the estimated time at which 25% of the Communication Systems that are in operation will have failed.
- Using simulation, estimate the total downtime for the system for one year (8,766 hr) and the maintenance costs.

Solution

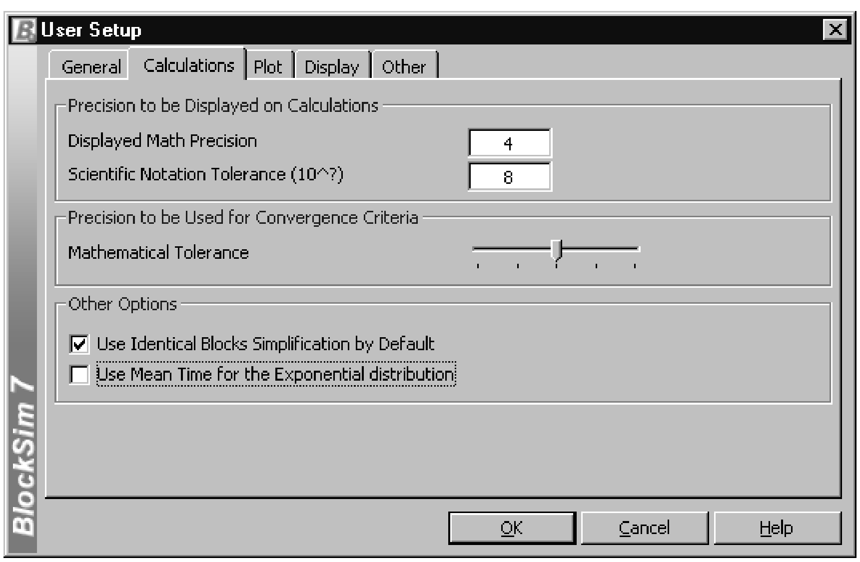
- Create a new project by selecting **New** from the **File** menu or by clicking the **New** icon.

- In the New Project Wizard, select to create a new project based on the existing base project **Example5.rbb** (located in the BlockSim7\Examples\Training Guide folder) and select to add a new blank Diagram Sheet.
- The selected base project will open in the new project and the Example5 Template will appear in the Template Panel.

- The Project Explorer and a blank Diagram Sheet will also appear. Your screen will look like the one shown next.

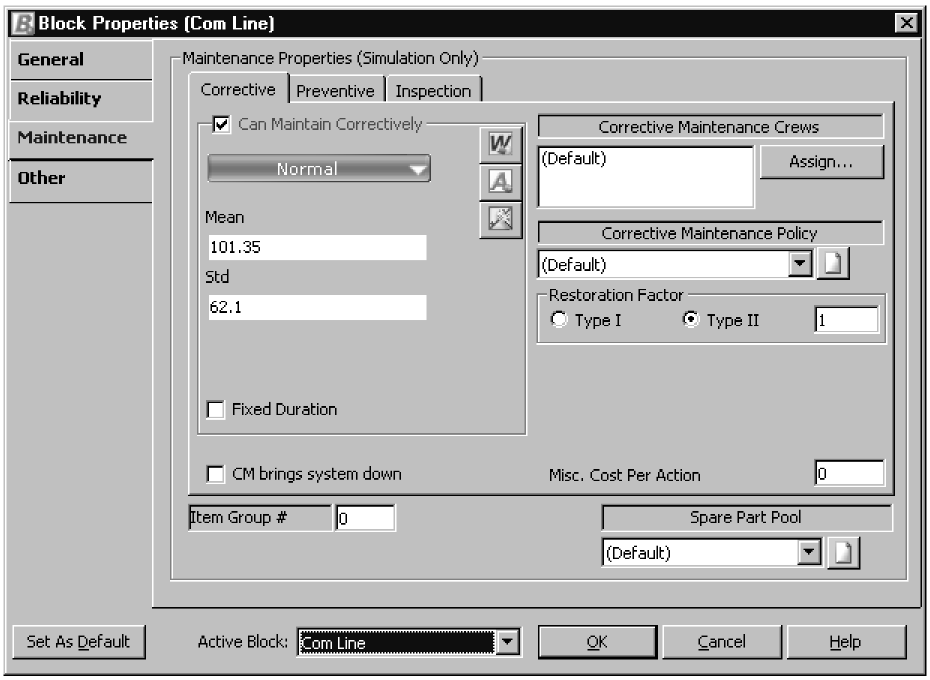


- For this example, the exponential parameter will be defined as “lambda” instead of “mean time.” To define the exponential parameter as lambda, select **User Setup** from the **File** menu to open the User Setup window.
- Click the **Calculations** tab to display the Calculations page of the User Setup and de-select the **Use Mean Time for the Exponential distribution** option at the bottom of the window, as shown next.



When the **Use Mean Time for the Exponential distribution** option is not selected, you will be prompted to enter a value for lambda each time you define a block with the exponential distribution.

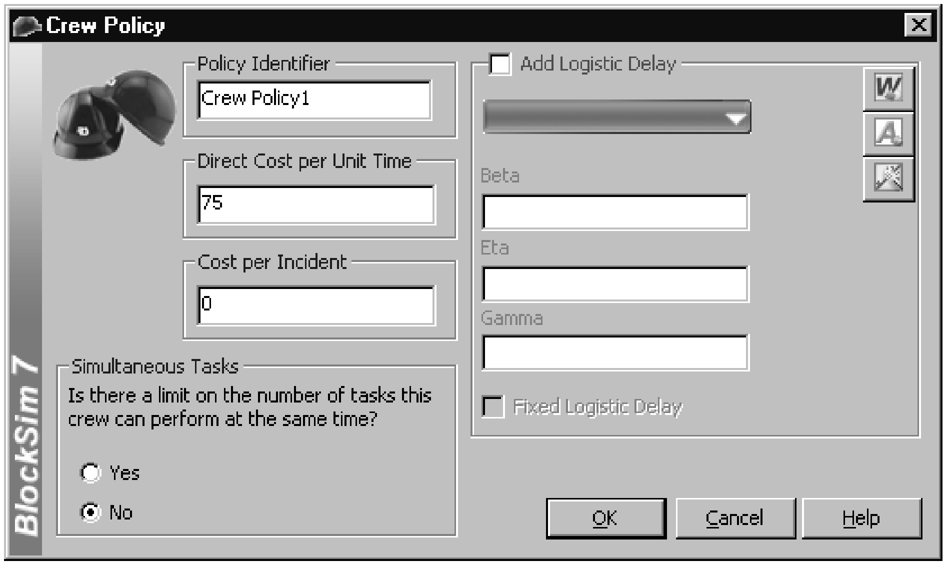
- Click **OK** to close the User Setup window.
- Double-click the Com Center block in the Template to open the Block Properties window. The Com Centers designated by the letters A-E cannot fail. Therefore, make sure the **Block Can Fail** option is not selected on the Failure Distribution page of the Reliability tab and click **OK**.
- Now double-click the Com Line block. The failure distribution associated with each Communication Line is the exponential distribution. On the Failure Distribution page, select **Exponential** under Failure Distribution. Enter **1.3E-4** for the value of lambda and **0** for the value of gamma.
- Click the **Maintenance** tab to open the Corrective page of the Block Properties window. Click to select the **Can Maintain Correctively** option. The corrective maintenance distribution options will become available. Select **Normal** as the corrective maintenance distribution and enter **101.35** for the mean value and **62.1** for the Std value, as shown next.



- Next, assign a crew to perform corrective maintenance on the block by clicking the **Assign** button in the Corrective Maintenance Crews area in the upper right corner of the window.
- The Select Crew window will appear.[11] Click **New** to create a new crew.

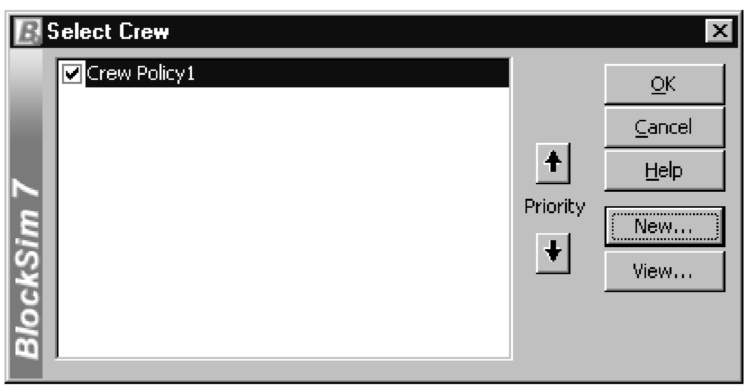
[11] At this time, the Select Crew window will not display any crews to be selected since no crews have been defined in the current project. Once you have defined crews in a project, the crews will appear in this window and you can select the crews that you want to assign to perform the maintenance.

- In the Crew Policy window that appears, type **Crew Policy1** for the Policy Identifier and type **75** for the Direct Cost per Unit Time, as shown next. This indicates that it costs $75 per hour for the crew to perform maintenance.



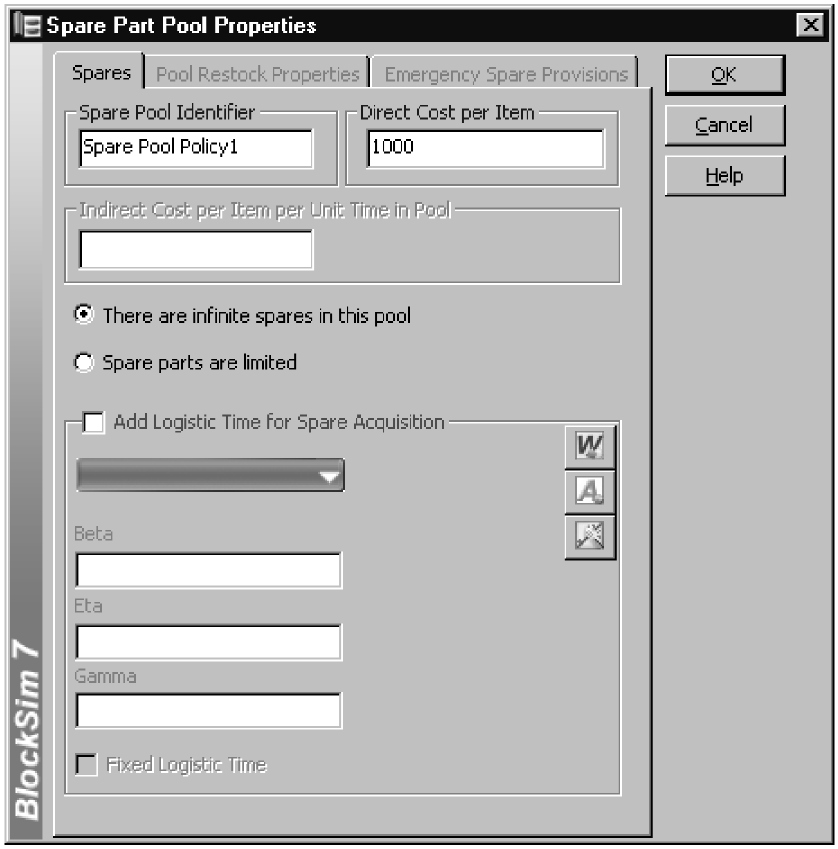
The Simultaneous Tasks area of this window allows you to specify how many simultaneous tasks the crew can perform and the Logistic Delays area allows you to indicate that there is a delay time before the crew can start the task. For this example, accept the default selections for both areas (*i.e*. **No** should be selected for Simultaneous Tasks and the **Add Logistic Delay** option should not be selected).

- Click **OK** in the Crew Policy window.
- The Select Crew window will reappear. Verify that **Crew Policy1** is selected, as shown next.



- Click **OK**. Notice that the crew policy appears in the Corrective Maintenance Crews area of the Block Properties window.
- Next, assign a spare part pool for the block by clicking the **Create New Spare Part Pool** button in the Spare Part Pool area in bottom right corner of the Block Properties window.

- The Spare Part Pool Properties window will appear. Type **Spare Pool Policy1** for the Policy Identifier and type **1000** for the Direct Cost per Item, as shown next. This indicates that it costs $1,000 per spare part.

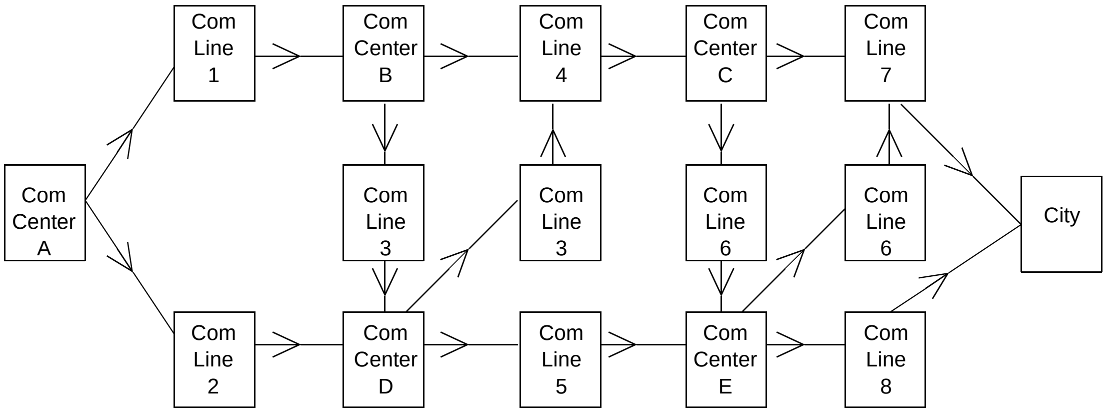


Accept the default selections for the rest of the options in this window. The **Indirect Cost per Item per Unit Time in Pool** input box allows you to specify the indirect costs of maintaining the spare part in the pool over time. This should be set to 0. The **There are infinite spares in this pool** option allows you to specify if there is an unlimited number of spare parts in the pool. This option should be selected. The **Spare parts are limited** option allows you to specify if there is a limited number of spare parts in the pool. This option should not be selected. The **Add Logistic Time for Spare Acquisition** area allows you to specify the amount of time required to obtain the part when it is required for maintenance. This option should not be selected.

- Click **OK** in the Spare Part Pool Properties window. Notice that the policy appears in the Spare Part Pool area of the Block Properties window.
- Next, select the City block as the active block. As is the case for the Com Centers, the City cannot fail. De-select the **Block Can Fail** option on the Failure Distribution page of the Reliability tab and click **OK**.

The Communication Lines are the most important blocks in this example. The Communication Centers cannot fail and will be used as Node blocks within the RBD. They will be used to direct the Communication Lines. When constructing the RBD, be sure to change the name of each Com Line and Com Center block within the diagram to represent the proper Communication Line and Communication Center. You can change the name of the block by double-clicking it to open the Block Properties window. Designate each Communication Center as Center A, Center B, etc. Designate each Communication Line as Com 1, Com 2, etc.

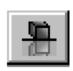
A representation of the RBD to be constructed is shown next.



Because Communication Lines 3 and 6 flow in two directions, multiple representations of Communication Lines 3 and 6 must be included in your RBD, as shown above. A relationship line within BlockSim cannot flow in two directions at the same time. In other words, there can be no circular paths.

You can use mirror blocks to represent these blocks. Mirror blocks can be used to represent a single item with more than one block placed in multiple locations within the diagram. Mirror blocks can be used to simulate bi-directional paths within a diagram. When simulation is performed on a Diagram Sheet with mirror blocks, every event associated with the "source" block will be exactly the same for every event associated with the "mirror" block(s).

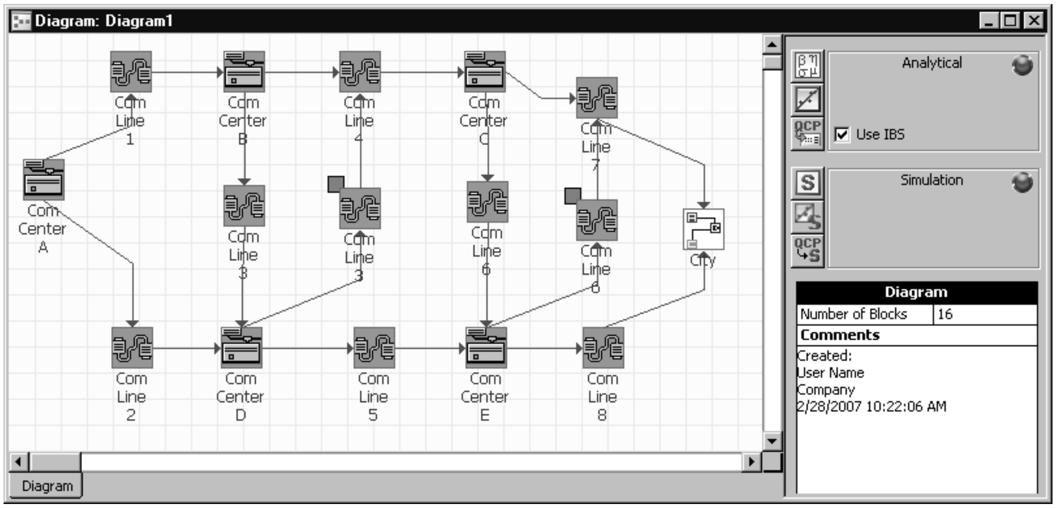
- To create a mirror block for Communication Line 3, select the Communication Line 3 that flows to Communication Center D in the Diagram Sheet and select **Mirror Block** from the **Block** menu or click its icon.



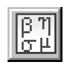
- The mouse pointer will turn into a mirror when it is above a block. Next, click the Communication Line 3 block in the Diagram Sheet that flows to Communication Line 4. The properties of the "source" Communication Line 3 block will be mirrored in the "target" Communication Line 3 block. A grey box will appear at the top left corner of the "target" block, as shown next, to indicate that the block is a mirror block.

- Repeat these steps to create a mirror block for Communication Line 6.

- The RBD constructed using mirror blocks is shown next.

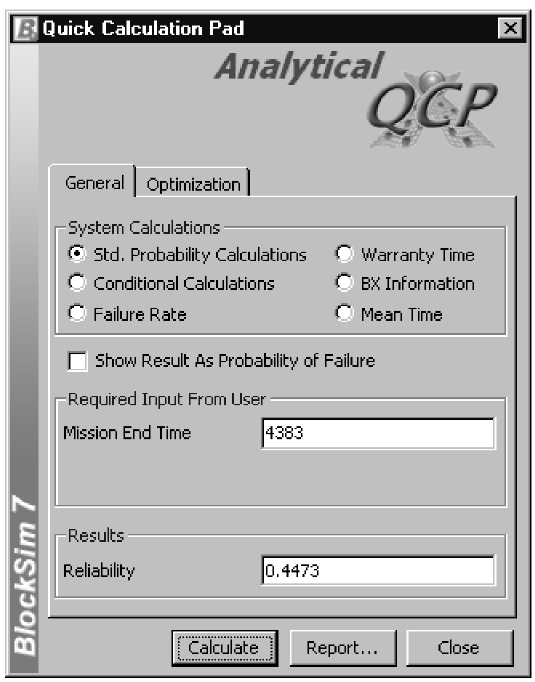


- Analyze the system by selecting **Analyze** from the **Tools** menu or by clicking the **Analyze** icon.



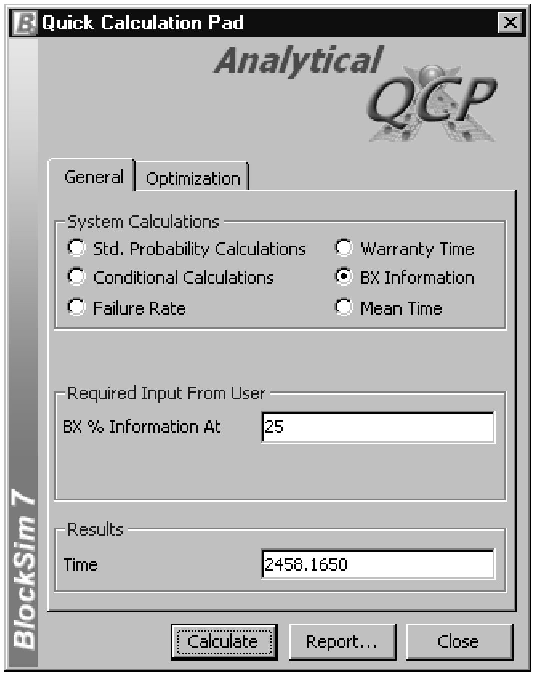
- The Analytical Quick Calculation Pad (QCP) will be used to calculate the reliability of the system. To access the Analytical QCP, select **Analytical QCP** from the **Tools** menu or click the **Analytical QCP** icon.

- Select **Std. Probability Calculations** under System Calculations. Type **4383** for the Mission End Time and click **Calculate** to return the system reliability, as shown next.



The reliability of the system at 4,383 hr is 0.4473 (44.73%).

- The second question requires the time at which 25% of the Communication Systems in operation will have failed. Select **BX Information** under System Calculations. Type **25** in the BX% Information At input box and click **Calculate** to return the result, as shown next.



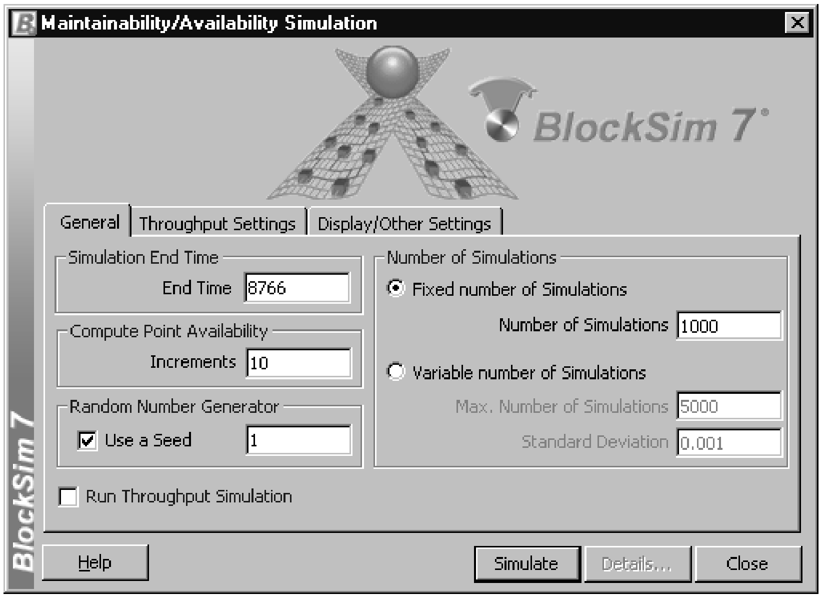
The time at which 25% of the Communication Systems will fail is approximately 2,458.165 hr.

- Close the Analytical QCP by clicking **Close**.
- You will now use BlockSim's Maintainability/Availability Simulation utility to analyze the system for one year of operation and to estimate the system costs.[12] Select **Simulate** from the **Tools** menu or click the **Simulate** icon.

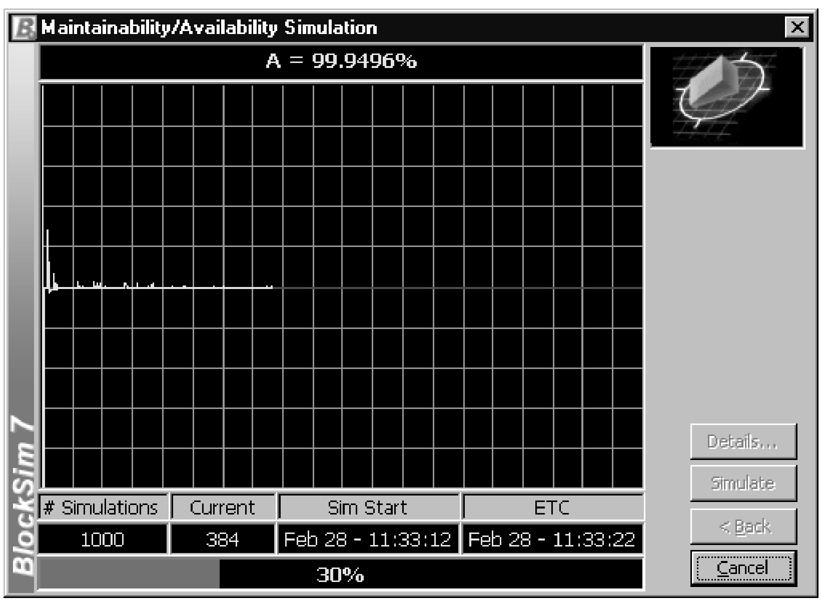
- The Maintainability/Availability Simulation window will open.
- On the General page, type **8766** for the End Time. Type **10** for the Increments, which allows you to specify the intervals at which point availability results will be calculated. The application will divide 8766 by 10 and report the point results at 10 equal increments (*i.e.* at 876.6, 1,753.2, etc.).
- Select the **Use a Seed** option and type **1** for the seed value. Using a seed for the simulation allows you to replicate these results.

12. The calculations performed in the Analytical QCP are based only on the failure information of the components. The Maintainability/Availability Simulation utility uses the failure and maintenance information of the components in order to obtain such results as point availability, mean availability, etc.

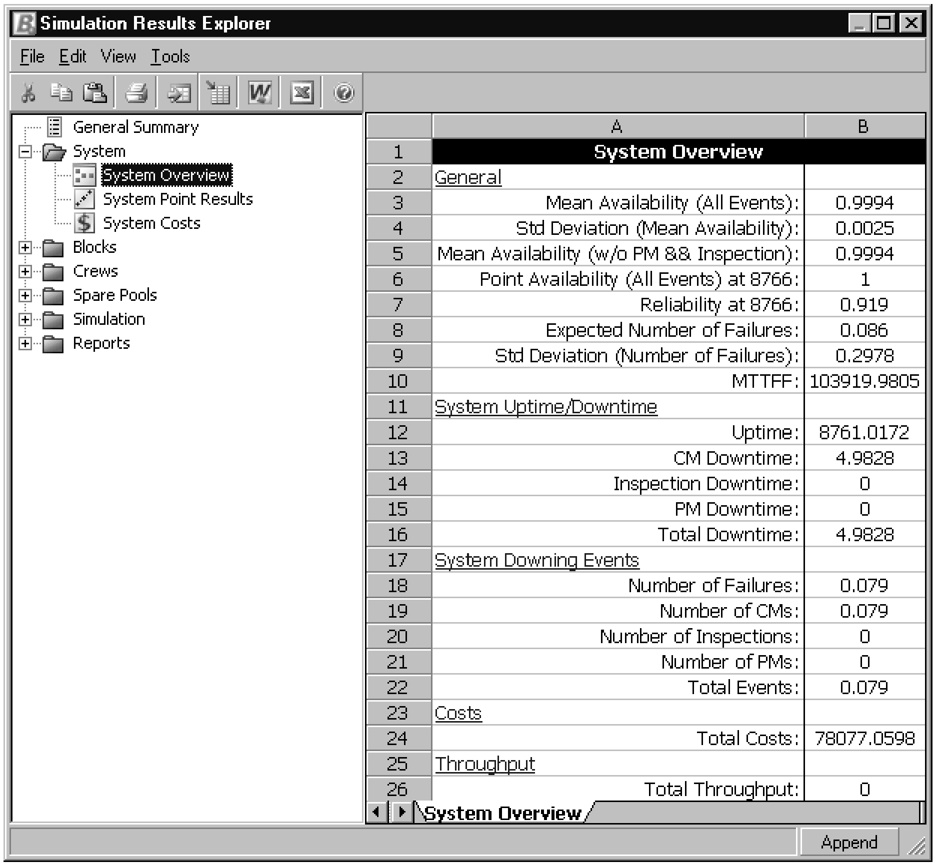
- Select the **Fixed number of Simulations** option and type **1000** in the Number of Simulations input box, which allows you to specify the number of simulations to be performed to obtain a solution. The window should look like the one shown next.



- Click **Simulate** to begin the simulation. While the simulation is being performed, the appearance of the Maintainability/Availability Simulation window will change to show the status of the simulation, as shown next.



- When the simulation is complete, you can click the **Details** button in the Maintainability/Availability Simulation window to view the simulation results in the Simulation Results Explorer, as shown next.



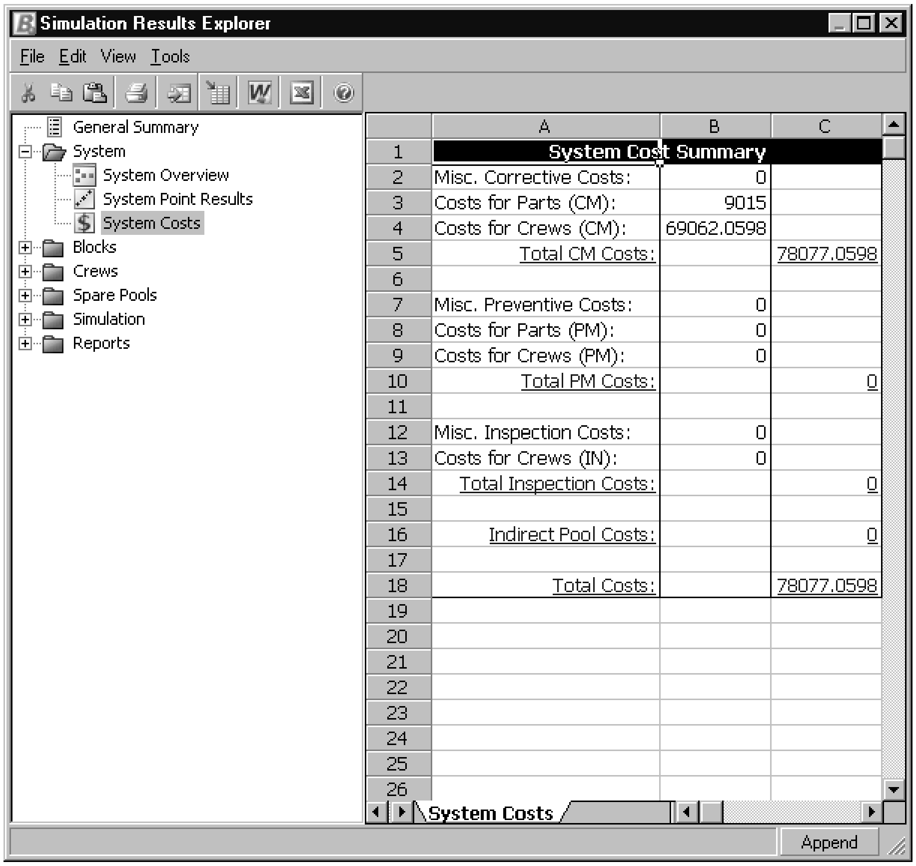
	A	B
1	System Overview	
2	General	
3	Mean Availability (All Events):	0.9994
4	Std Deviation (Mean Availability):	0.0025
5	Mean Availability (w/o PM && Inspection):	0.9994
6	Point Availability (All Events) at 8766:	1
7	Reliability at 8766:	0.919
8	Expected Number of Failures:	0.086
9	Std Deviation (Number of Failures):	0.2978
10	MTTFF:	103919.9805
11	System Uptime/Downtime	
12	Uptime:	8761.0172
13	CM Downtime:	4.9828
14	Inspection Downtime:	0
15	PM Downtime:	0
16	Total Downtime:	4.9828
17	System Downing Events	
18	Number of Failures:	0.079
19	Number of CMs:	0.079
20	Number of Inspections:	0
21	Number of PMs:	0
22	Total Events:	0.079
23	Costs	
24	Total Costs:	78077.0598
25	Throughput	
26	Total Throughput:	0

The Simulation Results Explorer contains a Control Panel on the left side of the window, which allows you to view the simulation results for the entire system, for each block, for the crews and spare pool policies and for the simulation settings on separate worksheets. Click an element in the Control Panel to view its simulation results in a worksheet.

- For this example, you can see from the second worksheet in the Results Explorer, the System Overview worksheet, that the downtime for the system is 4.9828 hr of the 8,766 total hours.[13]

13. Please note that these results may vary since they are based on simulation.

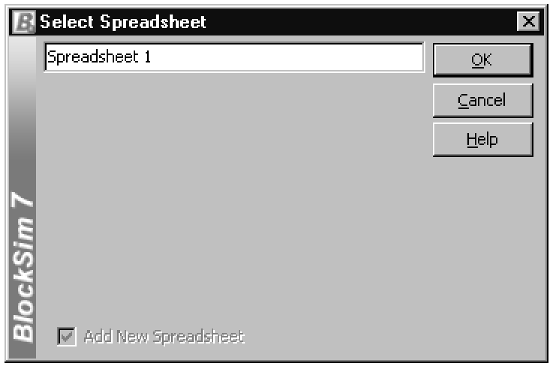
- Next, click the **System Costs** worksheet in the Control Panel to view the maintenance costs for the system, as shown next.



The total system cost for corrective maintenance is estimated to be $78,077.06.

- Return to the System Overview worksheet. These results can be transferred to a Spreadsheet by clicking the **Transfer to Spreadsheet** icon.

- The Select Spreadsheet window will appear, which allows you to select the Spreadsheet you want to transfer the results to or to create a new Spreadsheet.[14] For this example, type “Spreadsheet 1” for the Spreadsheet name in the input box at the top of the window, as shown next.



- Click **OK**.
- Close the Simulation Results Explorer and the Maintainability/Availability Simulation window. You can see that Spreadsheet 1 has been added to the project and appears in the Project Explorer under the Spreadsheets folder.
- If you are using a fully functional copy of the software, save the project as **Example5.rbp**.
- Close the project.

[14] For this example, you must create a new Spreadsheet since the current project does not contain any existing Spreadsheets to transfer the results to.

4.1.6 Example 6

This example demonstrates the integrated fault tree analysis capabilities available in BlockSim 7.

There are five independent events (sub-modes) associated with a particular failure mode, Mode A. It is assumed that events S1, S2 and Y each have a constant rate of occurrence (exponential distribution). Events T1 and T2 are more likely to occur in an older component than in a newer one. Specifically, the following probabilities are assumed:

Event	Failure Distribution	Parameter Values
S1	Exponential	Mean Time = 87,595,619
S2	Exponential	Mean Time = 175,195,619
T1	Weibull	$\beta = 3.32$, $\eta = 140081$
T2	Weibull	$\beta = 2.74$, $\eta = 326469$
Y	Exponential	Mean Time = 8,755,619

There are three possible ways for Mode A to manifest:

- Events S1 and S2 both occur.
- Event T1 or event T2 occurs.
- Event Y and either event S1 or S2 occur (*i.e.* Y and S1 or Y and S2)

Do the following:

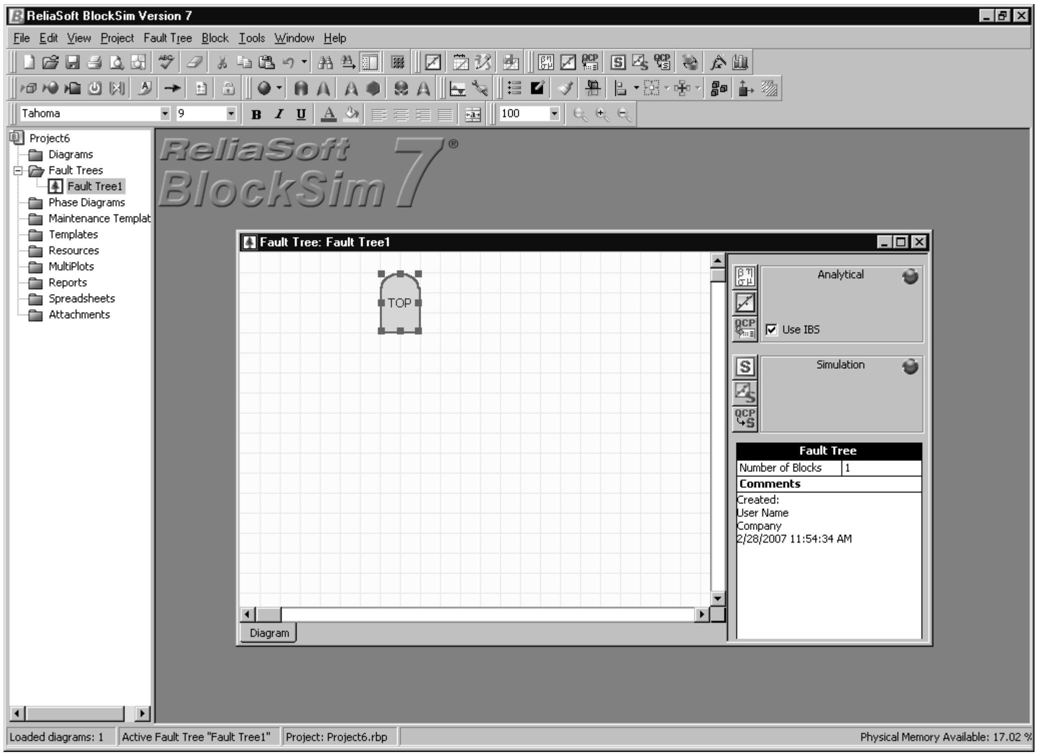
- Create a fault tree diagram for Mode A.
- Create a reliability block diagram for Mode A.
- Use the QCP to estimate the reliability at five years (43,800 hr).

Solution:

- Create a new project by selecting **New** from the **File** menu or by clicking the **New** icon.

- In the New Project Wizard, select to create a new blank project and select to add a new blank Fault Tree.

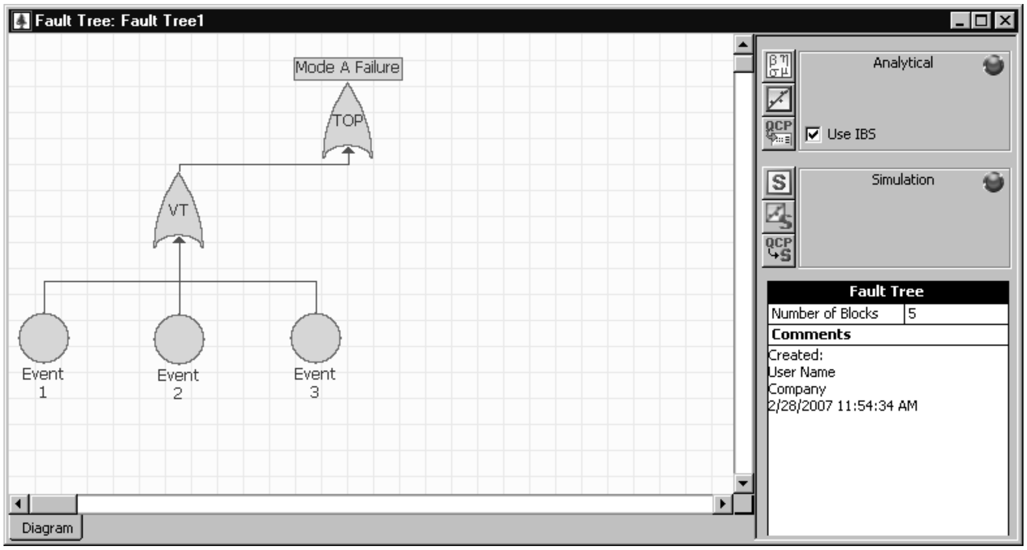
- The new project will appear, as shown next.



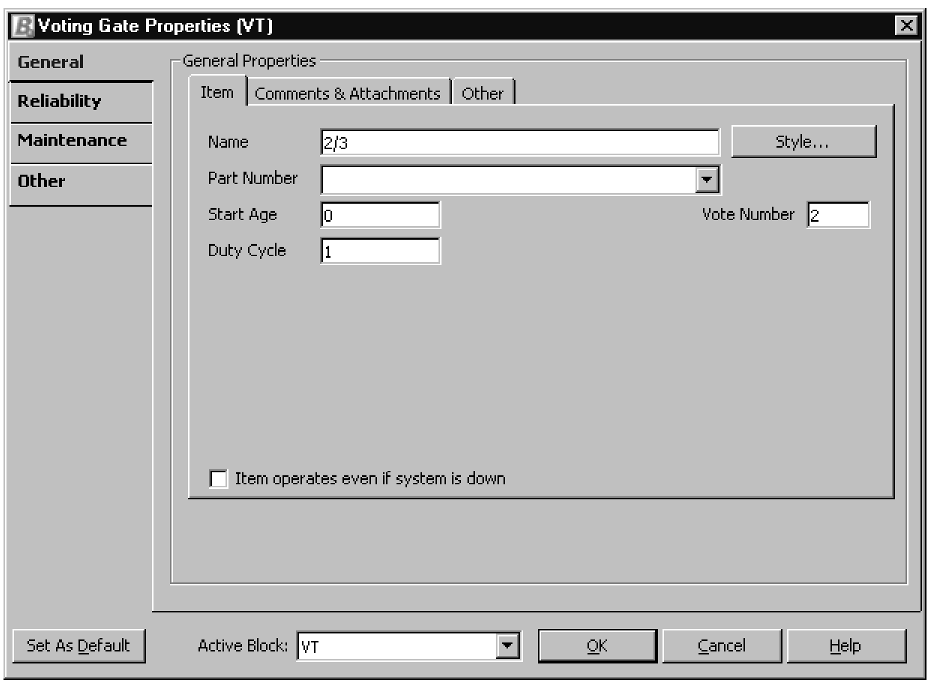
- By default, the top gate is an AND gate. Since Mode A can manifest in any of three ways, the top gate in your fault tree will be an OR gate. You can change the gate by right-clicking on it and choosing **Convert Block To** then **OR Gate** from the menu that appears.
- Double-click the gate, or right-click it and select **Edit Block Properties**, to open the Gate Properties window. On the Comments and Attachments page, type **Mode A Failure** in the Comments area and click **OK** to close the window.
- It is possible to represent the information in this example in more than one way. To create the simplest fault tree, notice that events S1, S2, and Y must always occur in some combination to cause Mode A failure. This is a two-out-of-three configuration, and can be represented by a Voting Gate. Make sure the top gate is selected, then add a Voting Gate to the fault tree, either by selecting **Add Gate** then **Voting Gate** from the **Fault Tree** menu or by clicking on the Voting Gate icon.

- The Voting Gate will automatically be connected to the top gate. (If the top gate had not been selected when you added the Voting Gate, there would be no connection.) You can drag the new gate to reposition it where you want it.
- With the Voting Gate selected, add three Basic Events, either by selecting **Add Event** then **Basic Event** from the **Fault Tree** menu or by clicking on the Event icon. This icon has a drop-down menu, from which you can select event types, but if you click the circle itself, a Basic Event will be added.

- Your fault tree will now look like the one shown next.

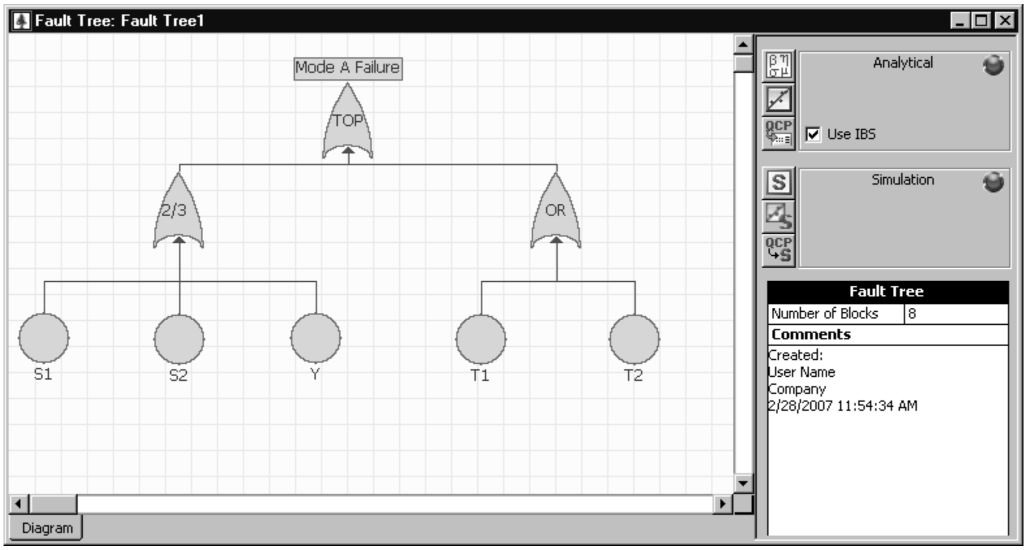


- For each event, define its properties using the the Event Properties window, opened by double-clicking on the event. You will need to name the event on the Item page of the General Properties tab and to specify the reliability parameters on the Reliability tab.[15]
- Double-click on the Voting Gate to open the Gate Properties window. On the Item page of the General Tab, rename the gate to **2/3**. Input **2** for the Vote Number, to indicate that two of the three events under the gate must occur.

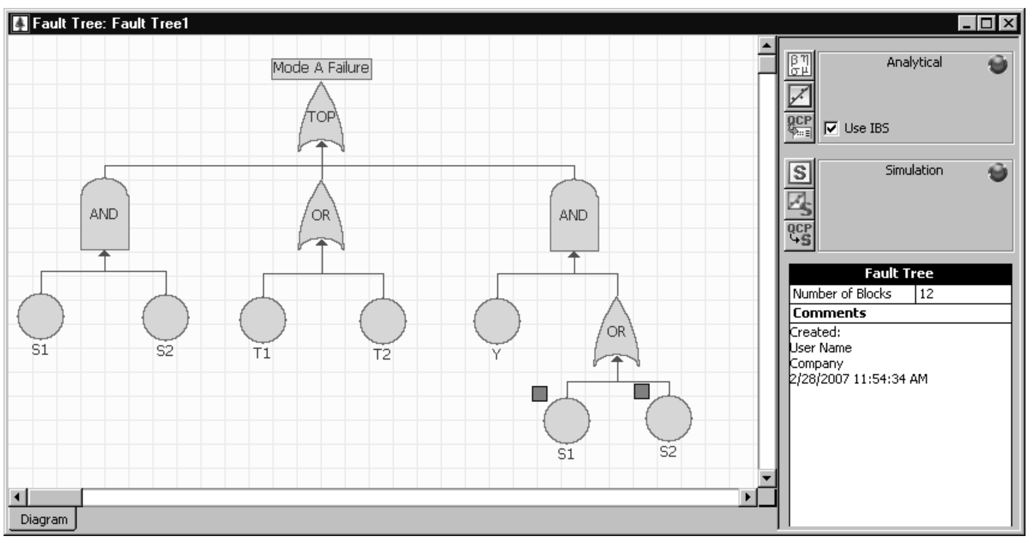


15. If the exponential parameter is still defined as “lambda” instead of “mean time,” you will need to go back into User Setup to change this.

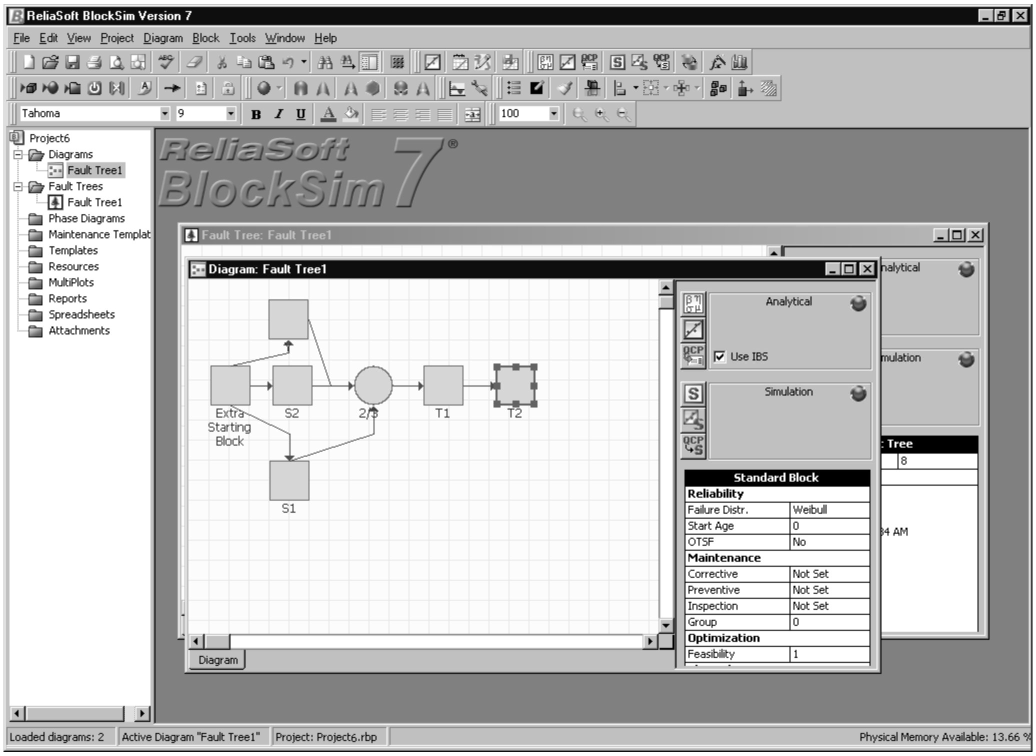
- Using the same procedures, add an OR Gate and events T1 and T2. Your final fault tree will look like the one shown next.



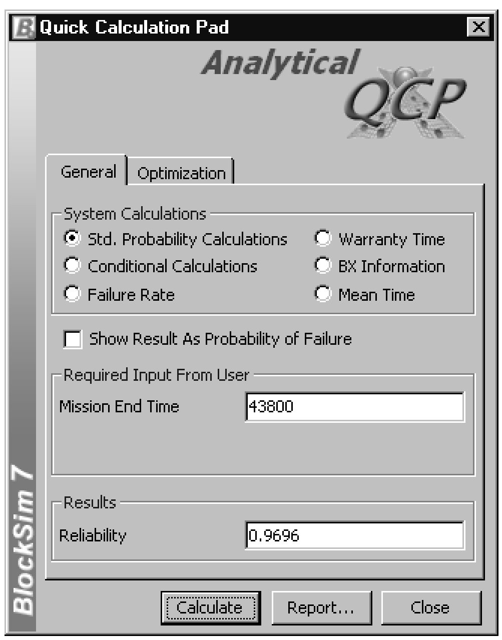
- As noted earlier, this information can be represented with a different fault tree, with a separate gate for each of the three possible ways for Mode A to manifest. This fault tree, involving the use of mirrored events, looks like the one shown next. You do not need to create this fault tree.



- It is possible to create a reliability block diagram directly from your fault tree diagram. To do this, select **Create RBD** from the **Fault Tree** menu. BlockSim will automatically create the RBD, using all of the parameters you supplied. Your screen will look like the one shown next.



- Return to the fault tree diagram and open the analytical QCP. Note that when you do this, BlockSim automatically analyzes the system.
- Select **Std. Probability Calculations** under System Calculations. Type **43800** for the Mission End Time and click **Calculate** to return the system reliability, as shown next.



The reliability of the system at 43,800 hr is 0.9696 (96.96%).

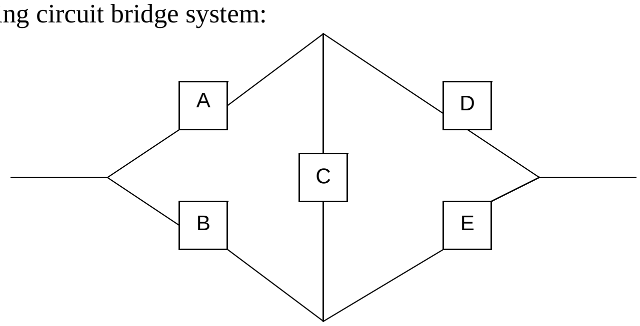
- If you are using a fully functional copy of the software, save the project as **Example6.rbp**.
- Close the project.

5 Practice Questions

The following practice questions can be performed using BlockSim[1]. The answers to these practice questions can be found in Chapter 6 of this training guide.

5.1 Practice Question 1

Consider the following circuit bridge system:



All components are identical, following an exponential life distribution with $\lambda = 8.126E-4$ failures/ day.

1. Create a Template with the blocks you need to create the RBD and customize the Template blocks to your liking.
2. Create the reliability block diagram for this system.
3. Estimate the reliability at 200 days using the Analytical QCP.

---

1. If you have a demonstration version of BlockSim, you will not be able to enter your own data or perform analyses for these examples. However, example files are available for the examples in Chapter 4.

4. Create the Reliability vs. Time plot.
5. Rename the Diagram Sheet to “Bridge System.”
6. Save your project as **Quest1.rbp** and leave it open.

5.2 Practice Question 2

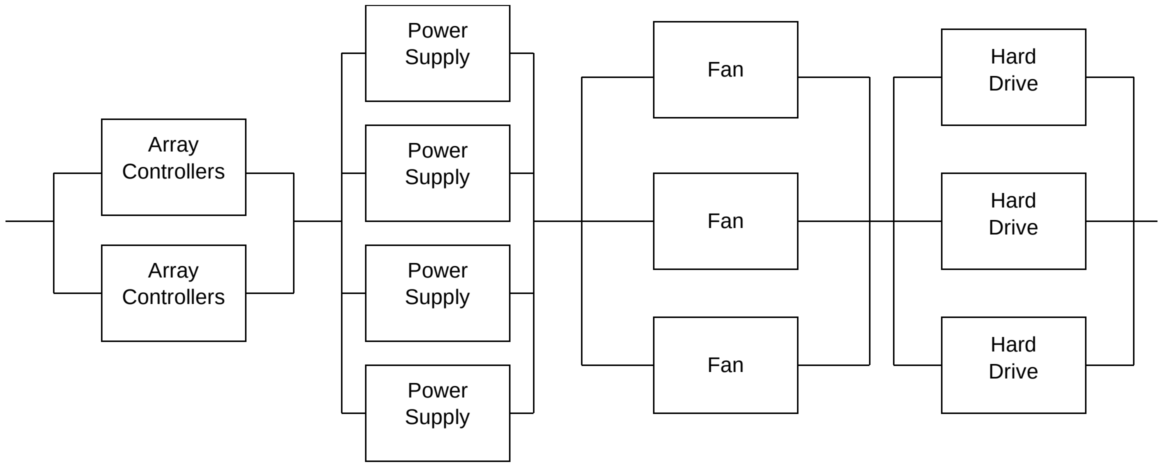
The reliability predictions of Practice Question 1 can also be performed using simulation. However, the results are dependent on the number of simulations. This example will take you through such a scenario.

1. Quest1.rbp will already be open.
2. Open the Maintainability/Availability Simulation window by clicking its icon.

3. On the General page, enter an End Time of **200** and an Increments value of **100**. Select **Fixed number of Simulations** and type **100** for the Number of Simulations. Click **Simulate** to perform the simulation.
4. What is the reliability of the system at 200 days? How does this value compare with the reliability obtained in Practice Question 1?
5. Repeat step 4 with 1,000, 5,000 and 10,000 simulations. When is the reliability estimate closer to the analytical value obtained in Practice Question 1?
6. Save and close the project.

5.3 Practice Question 3

Consider the following disk array subsystem:



The failure distributions and parameters for each component are:

Component	Distribution	Parameters
Array Controllers	Weibull	β = 1.2 η = 1,953 days
Power Supply	Lognormal	μ = 7.0102 (log-mean) σ = 1.2124 (log-std)
Fan	Exponential	λ = 0.000070265 failures/day
Hard Drive	Weibull	β = 2.5 η = 3,000 days

The Power Supply subsystem is in a 2-out-of-4 configuration. The Fans are in a 2-out-of-3 configuration. The Hard Drives are also in a 2-out-of-3 configuration.

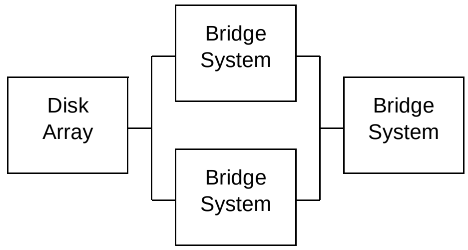
Do the following:

1. Create a block for each type of component within a Template and customize the Template blocks to your liking.
2. Create the RBD and rename the Diagram Sheet to “Disk Array.”
3. Obtain the Reliability vs. Time plot.
4. From the plot, determine:
   i. The reliability of these units for a mission of 182 days, R(182days).
   ii. The mission duration for the system if a 90% reliability is required.
   (Hint: Use the Position Indicator in the bottom right corner of RS Draw.)
5. Using the Analytical Quick Calculation Pad, determine:
   i. The reliability of the system for a mission of 182 days, R(182days).
   ii. The reliability for each subsystem/component.
   iii. The mission duration for the system if a 90% reliability is required.

   iv. Knowing that the system has successfully operated for 182 days, what is the probability that it will operate successfully for another 182 days?
   v. What is the MTTF for the system?
6. Obtain the *pdf* plot for the system.
7. Obtain the Failure Rate vs. Time plot for these units. From the plot, what is the failure rate of the system at 182 days?
8. Add a Spreadsheet into the project. Using the Function Wizard, obtain:
   i. The failure rate at 182 days.
   ii. A table of times given reliability, starting from 0.9 to 0.99 with a 0.01 increment.
9. Save the project as **Quest3.rbp**.
10. Close the project.

5.4 Practice Question 4

This example shows how you can import previously created diagrams and use them as components in a new diagram. Consider the following system in which the Disk Array of Practice Question 3 is connected with the Bridge System of Practice Question 1, as shown next:



1. Create a new project.
2. Import the previously created diagrams, Bridge System and Disk Array, from the **Quest1.rbp** and **Quest3.rbp** projects, respectively.
3. Create the RBD for the system shown above where the blocks represent the corresponding Disk Array and Bridge System diagrams that were imported.
4. Estimate the reliability of the system at 200 days.
5. Save the project as **Quest4.rbp** and close it.

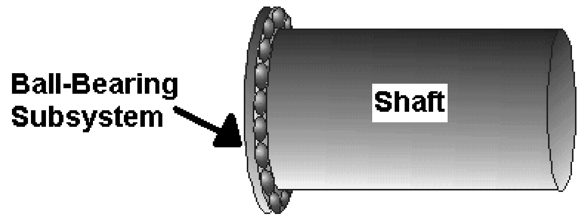
5.5 Practice Question 5

A four-engine airplane has two engines on each wing. It requires at least one engine to be operating on each wing for a successful mission. Assume that the reliability of each engine is 90% for a specified mission duration.

1. Create a new project.
2. Create the RBD.
3. Obtain the reliability of the system.
4. Add a new diagram and repeat the example, but this time consider a 2-out-of-4 engine configuration.
5. When is the reliability of the system higher? Why?
6. What would the reliability of each engine be in the first design in order to achieve the system reliability of the second design? Since the units are identical, you can assume the same feasibility of increasing the reliability and maximum achievable reliability for each engine.
7. Save the project as **Quest5.rbp** and close it.

5.6 Practice Question 6

A subsystem of a machine is composed of a Ball-Bearing subsystem and a Shaft, as shown below:



The inspection times (in hours) for the Ball-Bearing subsystem are given in the table below.

Number in State	Last Inspected	State	State End Time
5	0	F	600
16	600	F	1,900
12	1,900	F	2,900
18	2,900	F	3,500
18	3,500	F	3,900
2	3,900	F	4,500
6	4,500	F	5,200
17	5,200	F	6,300
73	6,300	S	6,300

The life data set for the Shaft is given in the table below.

Number in State	State	State End Time
1	F	1,226
1	F	1,943
1	F	2,362
1	F	2,518
1	F	5,462
1	F	6,404
1	F	10,388
5	S	11,772

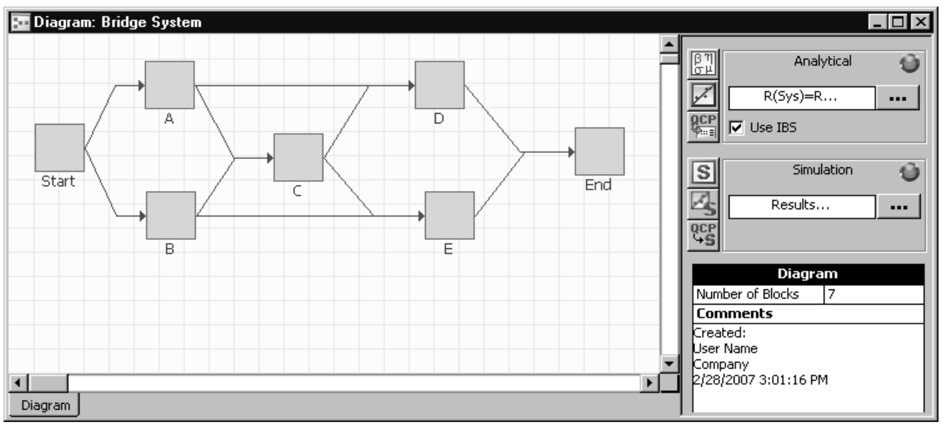
1. Using the 2-parameter Weibull distribution with RRX for the Ball-Bearing data and the lognormal distribution with RRX for the Shaft data, estimate the reliability of the system at 1,000 hrs.
2. What is the reliability of each component at 1,000 hrs?
3. Save the project as **Quest6.rbp** and close it.

6 Answers to Practice Questions

The purpose of this section is to provide answers to the Practice Questions in Chapter 5 of this training guide.

6.1 Practice Question 1

2.



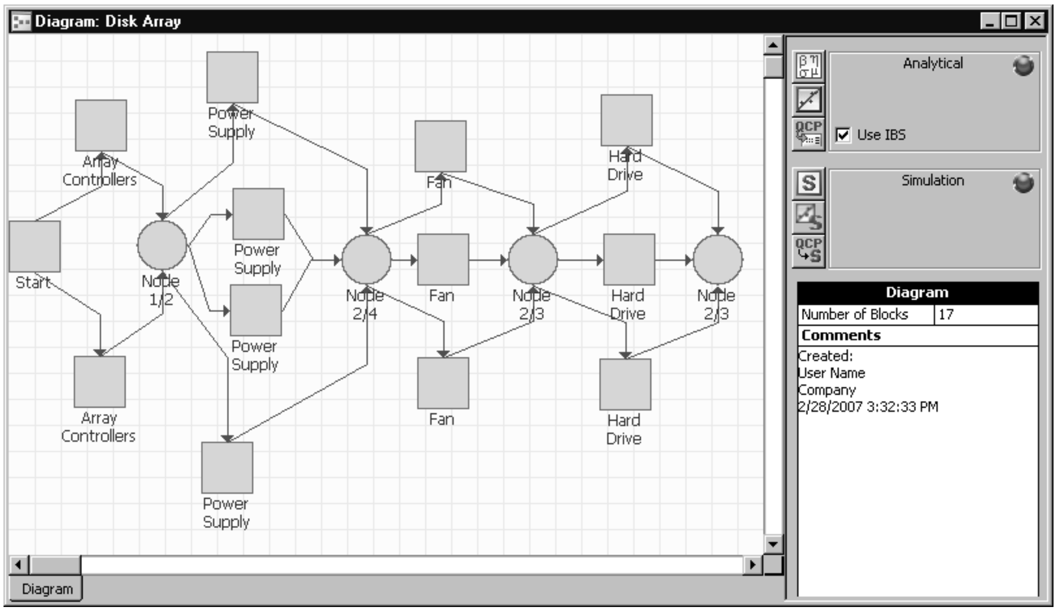
3. R(200days) = 0.9506

6.2 Practice Question 2

4. R(200days) = 0.98. Not very accurate.[1]
5. The reliability estimated using 10,000 simulations is closer to the analytical value.

6.3 Practice Question 3

2.



4. From the Reliability vs. Time plot:
   i. R(182days) $\cong$ 0.99
   ii. T $\cong$ 517 days
5. Using the Analytical QCP:
   i. R(182days) = 0.9951
   ii. Array Controller: 0.9437
       Power Supply: 0.9319
       Fan: 0.9873
       Hard Drive: 0.9991
   iii. T = 527.6891
   iv. R(182,182) = 0.9676
   v. MTTF = 1,316.1014 days
7. $\lambda \approx 0.00008$ failures/day
8. Using the Function Wizard:
   i. λ = 7.7E-005 failures/day

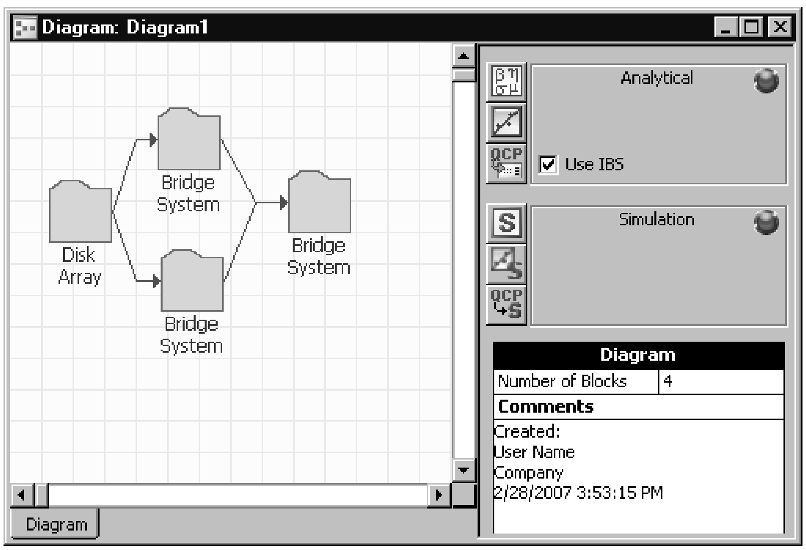
1. Please note that these results may vary since they are based on simulation.

ii.

Reliability	Time
0.9	527.68907
0.91	505.9283
0.92	483.10633
0.93	458.96273
0.94	433.12952
0.95	405.05836
0.96	373.87145
0.97	338.00912
0.98	294.19751
0.99	232.94363

6.4 Practice Question 4

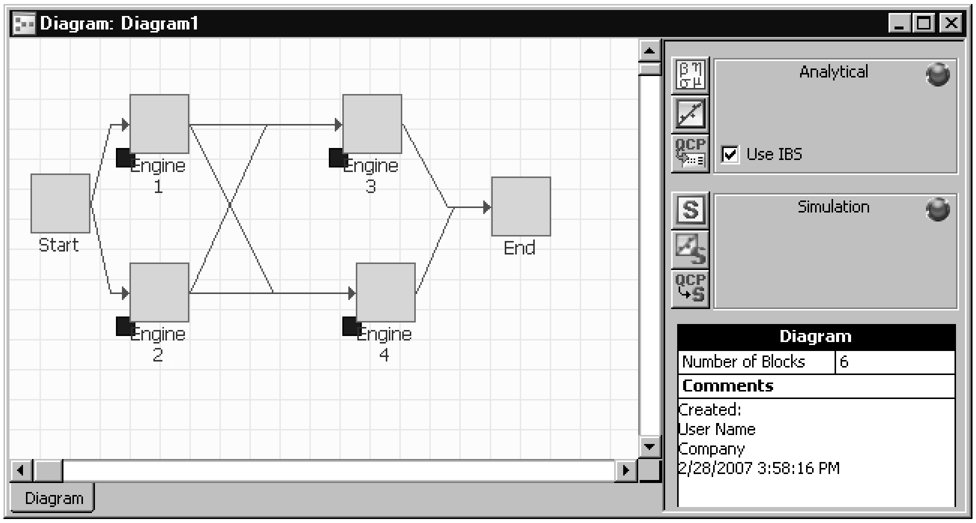
3.



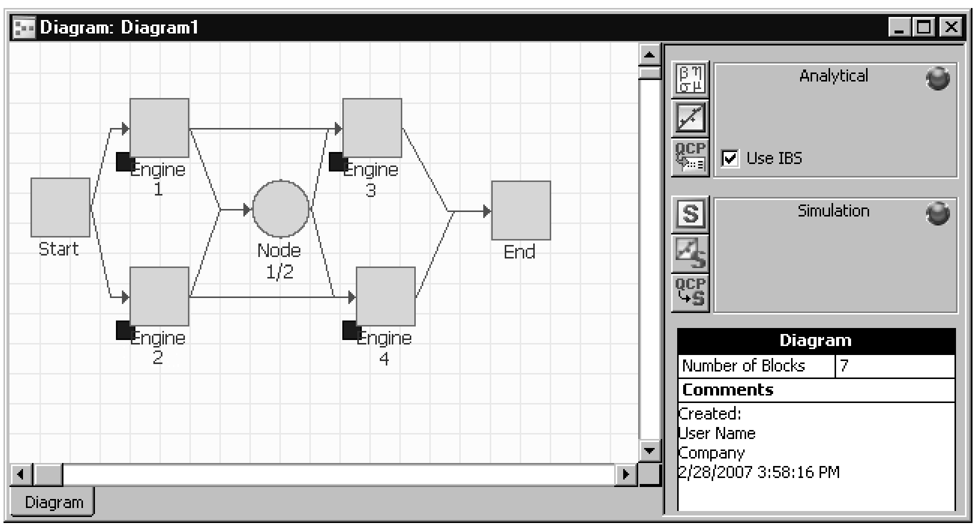
4. R(200days) = 0.9423

6.5 Practice Question 5

2.

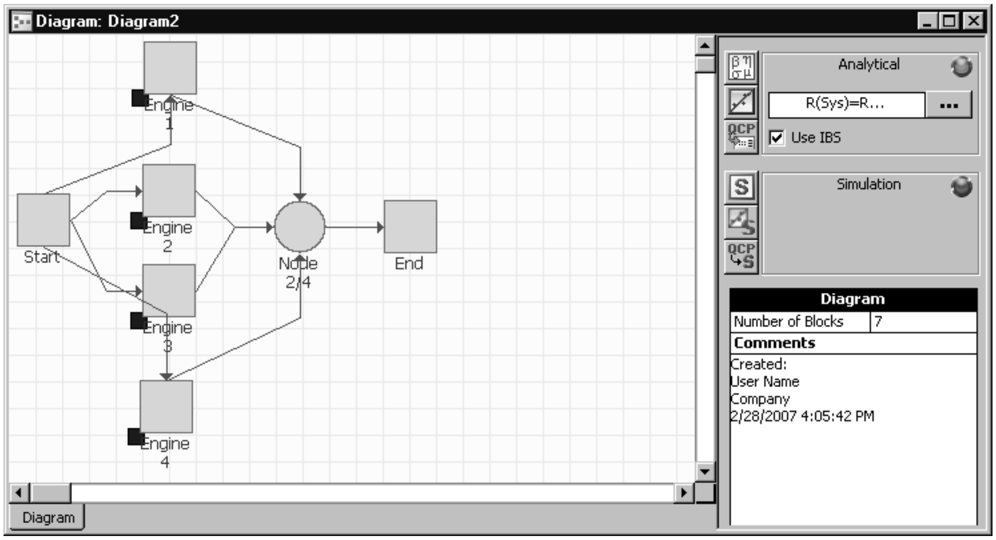


Or



3. R = 0.9801

4.



5. For the 2-out-of-4 engine configuration: R = 0.9963. The reliability is higher because there is more redundancy in the 2-out-of-4 configuration.
6. The reliability for each engine is: R = 0.957

6.6 Practice Question 6

1. R(1,000hrs) = 0.8691
2. Bearings: 0.9187

   Shaft: 0.946