User's Guide

GoldSim

Probabilistic Simulation Environment

GoldSim
TECHNOLOGY GROUP

Version 14.0 (October 2021)

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Chapter 1: Welcome to GoldSim!

> If a man will begin with certainties, he shall end in doubts, but if he will be content to begin with doubts, he shall end in certainties.
>
> Francis Bacon, *The Advancement of Learning*

Chapter Overview

GoldSim is a user-friendly, highly graphical program for carrying out dynamic, probabilistic simulations to support management and decision-making in business, engineering and science.

This User's Guide provides a complete description of the features and capabilities of GoldSim.

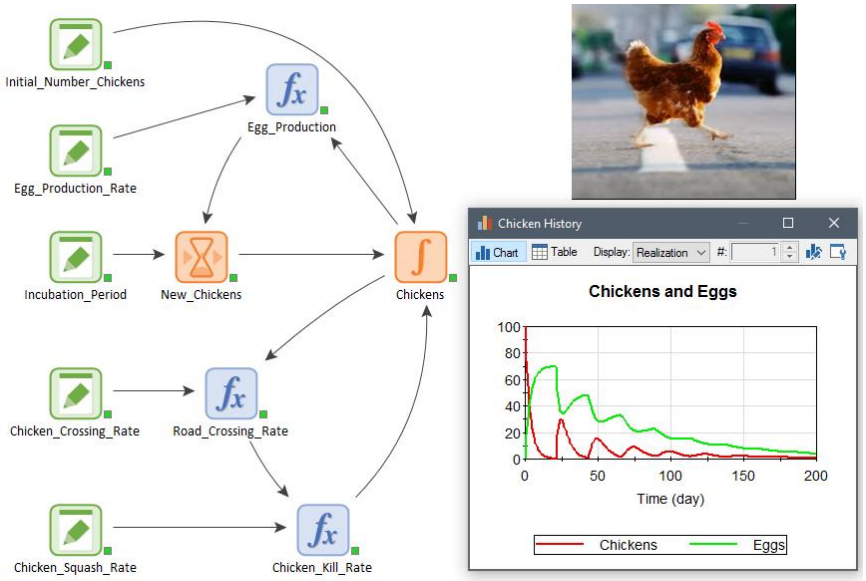
In this Chapter

This introductory chapter discusses the following topics:

- What is GoldSim?
- How to Use this Manual
- Conventions Used in this Manual
- Installing and Activating GoldSim
- Learning to Use GoldSim
- Using Help and the GoldSim Tutorial
- Getting Technical Support

What is GoldSim?

GoldSim is a highly graphical, object-oriented computer program for carrying out dynamic, probabilistic simulations. In a sense, GoldSim is like a "visual spreadsheet" allowing you to *visually* create and manipulate data and equations.



What Can I Do With GoldSim?

GoldSim is a simulation program. As used here, *simulation* is defined as the process of creating a model (i.e., an abstract representation or facsimile) of an existing or proposed *system* (e.g., a business, a mine, a watershed, a forest, the organs in your body, the atmosphere) in order to identify and understand those factors which control the system and/or to predict (forecast) the future behavior of the system. Almost any system which can be quantitatively described using equations and/or rules can be simulated.

Simulation is an important tool because it provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment on a real system, which may be prohibitively costly, time-consuming, or simply impractical to do. That is, simulation allows you to ask "What if?" questions about a system without having to experiment on the actual system itself (and hence incur the costs and delays associated with field tests, prototypes, etc.).

What Kind of Problems Can I Apply It To?

Because GoldSim was designed with flexibility in mind, you can use it to simulate almost any kind of system. Illustrative examples from the fields of business, science and engineering include the following:

Strategic Planning: You could simulate the implementation of a complex undertaking (e.g., design, manufacture and marketing of a new product) by describing the tasks involved, any precedent requirements (i.e., what must be done before a particular task can begin or end), task durations and costs, and events which could impact the process. The output of such a simulation might be the probability of successfully completing the undertaking (in a certain timeframe, or at a certain level of profitability). You could use the results to identify potential problems that might arise and design contingency plans. On a larger scale, such a tool could be then used to evaluate and manage portfolios of projects and investments.

Ecology: The growth of a group of animals could be simulated by describing in mathematical terms the initial number of animals, the birth

rate, the death rate, the rate at which animals migrate to or away from the group, possible catastrophic events, etc. The output of this simulation would then be the number of animals in the group as a function of time (e.g., one year from now, ten years from now, etc.). You could use the results to better manage the system in order to stabilize or increase the population (e.g., by limiting hunting, or introducing predators).

Environment: You could simulate the performance of a hazardous waste site by describing the initial conditions (e.g., the geometry of the system, the amount of contaminants in the system) and the processes acting on the system (e.g., degradation of the drums containing the waste, migration of contaminants through the environment). The output of this kind of simulation would be contaminant concentrations around the site as a function of time. You could use the results to design remediation measures which would minimize the environmental impacts at the site.

Reliability Engineering: The reliability of a proposed satellite system could be simulated by describing the components of the system and the processes and events which could compromise the system's integrity and lead to failure or downtime. The outputs of this kind of simulation would include the predicted reliability of the system and the probability and consequences of different types of failures. You could use the results to modify the design so as to maximize the reliability and minimize the probability and/or consequences of a failure.

Manufacturing: You could simulate the coupled dynamics of a manufacturing supply chain by defining the "links" in the chain (Retailer, Distributor, Manufacturer, Tier 1 supplier(s), Tier 2 suppliers, etc.) and how these organizations interact with each other. The model would simulate the movement of materials (parts to finished product) through the supply chain, and could be used to identify ways in which the system could be modified (e.g., via technology or improved decision rules) to operate more efficiently.

What Makes GoldSim Unique?

GoldSim is user-friendly and highly graphical, such that you can literally draw and subsequently present a picture (or *influence diagram*) of the system you wish to model in an intuitive way without having to learn a great deal of symbols, notation and functions.

Because simulation can be such a powerful tool for understanding and managing complex systems, a variety of graphical simulation tools currently exist. The following combination of features, however, makes the GoldSim approach unique:

GoldSim was specifically designed to quantitatively address the inherent uncertainty which is present in real-world systems. GoldSim provides powerful tools for representing uncertainty in processes, parameters and future events, and for evaluating such systems in a computationally efficient manner.

GoldSim provides powerful capabilities for superimposing the occurrence and consequences of discrete events onto continuously varying systems. This allows for the realistic simulation of discrete events such as financial transactions, accidents, system failures, storms, labor strikes, and lawsuits.

GoldSim was designed to facilitate the construction of large, complex models. You can build a model of your system in a hierarchical, modular manner, such that the model can readily evolve and add detail as more knowledge regarding the system is obtained. Other powerful features, such

as the ability to manipulate arrays, the ability to "localize" parts of your model, and the ability to assign version numbers to a model which is constantly being modified and improved, further facilitate the construction and management of large models.

GoldSim is dimensionally-aware. GoldSim has an extensive internal database of units and conversion factors. You can enter data and display results in any units. You can even define your own customized units. GoldSim ensures dimensional consistency in your models and carries out all of the unit conversions internally. As a result, when you use GoldSim, it is never necessary for you to carry out (error-prone) unit conversions.

GoldSim is highly extensible. You can dynamically link external programs or spreadsheets directly into your GoldSim model. In addition, GoldSim was specifically designed to support the addition of customized modules (program extensions) to address specialized applications.

GoldSim allows you to create compelling presentations of your model. A model that cannot be easily explained is a model that will not be used or believed. GoldSim was specifically designed to allow you to effectively document, explain and present your model. You can add graphics, explanatory text, notes and hyperlinks to your model, and organize it in a hierarchical manner such that it can be presented at an appropriate level of detail to multiple target audiences.

What Do I Need to Use GoldSim?

The program runs on personal computers using Microsoft Windows® 10 (Version 1903 or higher) . If you are linking GoldSim to Microsoft Excel, you must Excel 2010 or later (2016 or later recommended). You must have Administrative Privileges on the system during the installation and and a minimum of 500 MB disk space.

Because GoldSim is very powerful and flexible, it is relatively complex. Nevertheless, the software can be readily mastered by anyone familiar with the basic functions of a personal computer and the Windows operating system. Since a GoldSim model is built by describing functional relationships (equations) between the components of your system, however, you must be comfortable with the basics of quantitative analysis. This does not mean you must be a mathematician or a numerical modeler. As a rule of thumb, if you are comfortable using a spreadsheet you can learn to build a model in GoldSim.

Finally, although GoldSim can be run in a deterministic manner (i.e., with no uncertainty specified in the input parameters), one of the key features of the program is its ability to explicitly represent such uncertainty through the use of probability distributions. In order to do so, you must have at least a basic understanding of the representation and propagation of uncertainty. Appendix A provides a brief primer on this topic, along with suggestions for further reading.

How to Use this Manual

One way to learn a new program is to read the user's guide (if it exists and is well-written) from front to back, while simultaneously experimenting with the program. Although a few people may prefer this method, we realize that most software users (including ourselves!) rarely have the time or patience to do this. Instead, most of us prefer to read some introductory material (or take a training course), and then "dive in", referring to the documentation when we are stuck or need to learn a new feature. Therefore, this document is designed primarily to be used in this way, as a reference document.

Note: As will be discussed at the end of this chapter, because it can be time-consuming and inefficient to learn how to use a new software tool by only referring to detailed reference documentation, a number of other resources are available that complement this document and are specifically intended to help beginners learn to use GoldSim.

Read more: Learning to Use GoldSim (page 19)*.*

The document is heavily cross-referenced, such that each chapter and each major section can stand alone. To facilitate the use of these cross-references, whenever they appear in the manual, they are set off from the text and always proceeded by "Read More:"), as shown above.

This allows the document to be readily used as a reference guide, with the user accessing topics and features via the cross-references, the table of contents and/or the index on an as-needed basis. Furthermore, as will be discussed later in this introduction, nearly all of the information available in the printed documentation can also be accessed via an extensive help system.

Note: Although this manual is written primarily so that it can be used as a reference document, it is highly recommended that all users read Chapters 2 and 3 before starting to use GoldSim.

Example Models

Starting with Chapter 3, the manual references a number of examples that are relevant to features being discussed. When you install GoldSim, a number of examples are installed with the program. These example model files are mentioned in the text, and provide an excellent way to begin to experiment with GoldSim. Each example is internally documented with comments regarding the way the model was implemented.

Note: You can quickly access these files by selecting **File|Open Example…** from the main GoldSim menu.

Note: These examples are read-only files. If you wish to modify them, you will need to Save As.

Note: Additional (and generally more detailed) example models are available in the Model Library on the GoldSim web site.

How this Manual is Organized

This document is organized into ten chapters:

Chapter 1: Welcome to GoldSim! The remainder of this chapter discusses the information required for you to get started using GoldSim, including conventions used in the manual, installing the program, using online help, and obtaining technical support.

All users should read Chapters 2 and 3! These two chapters will provide you with enough information to start using GoldSim.

Chapter 2: GoldSim in a Nutshell. This chapter provides a broad overview of the features and capabilities of GoldSim. It is strongly recommended that you read this chapter, as it will tell you what the program is capable of doing, and direct you to those portions of the manual where you can obtain further information.

Chapter 3: Building a Model in GoldSim. This chapter describes the GoldSim user interface, and presents all of the techniques required for creating, editing, and navigating a GoldSim model. Before trying to experiment with GoldSim, it is highly recommended that you read this chapter in order to familiarize yourself with these basic techniques.

Chapter 4: Using the GoldSim Elements. GoldSim models are built using a wide variety of model objects (referred to as *elements*). This chapter describes the details of using the basic elements in GoldSim.

Chapter 5: Simulating Discrete Events. In many systems, processes occur that are discrete as opposed to continuous. These discrete occurrences are referred to within GoldSim as *events*. This chapter describes the GoldSim elements that you can use to simulate the occurrence and consequences of discrete events.

Chapter 6: Customizing the Interface. This chapter provides instructions for customizing the appearance of the user interface to meet your specific needs.

Chapter 7: Running a Model. After you have created a model, you need to run the model in order to produce results. This chapter describes the details of how to control your simulation (e.g., specify its duration), specify the types of results you wish to save, and run the model.

Chapter 8: Displaying Results in GoldSim. This chapter describes how you can view (via charts and tables), analyze, and present model results.

Chapter 9: Documenting and Presenting Your Model. GoldSim was specifically designed to allow you to effectively document, explain and present your model. This chapter describes how you can add graphics, explanatory text, notes and hyperlinks to your model, and organize it in a hierarchical manner such that it can be presented at an appropriate level of detail to multiple target audiences.

Chapter 10: Advanced Modeling Concepts. This chapter describes advanced and powerful capabilities of GoldSim that you will want to take advantage of once you become comfortable with the program, including using and manipulating arrays (vectors and matrices) in your models, simulating discrete events, and linking GoldSim to a database.

This manual also includes six appendices.

Appendix A: Introduction to Probabilistic Simulation. This appendix provides an introduction to basic concepts of probabilistic simulation, and provides suggestions for further reading.

Appendix B: Probabilistic Simulation Details. This appendix describes the mathematical details of the manner in which uncertainty is represented, propagated, and displayed in GoldSim.

Appendix C: Implementing External (DLL) Elements. This appendix provides instructions for users who wish to directly link external programs into a GoldSim model.

Appendix D: GoldSim Units Database. As mentioned above, GoldSim is dimensionally aware and carries out all unit conversions internally. This appendix lists all of the internal units and conversion factors provided by GoldSim.

Appendix E: Database Input File Formats. GoldSim allows data to be imported from an ODBC-compliant database directly into GoldSim. This appendix describes the required database structures and formats to facilitate such a data transfer.

Appendix F: Integration Methods and Timestepping Algorithm. This appendix describes the methods used by GoldSim to numerically integrate differential equations. It also discusses the unique timestepping algorithm GoldSim uses to accurately represent discrete events.

The manual also includes a Glossary of Terms and an Index.

Conventions Used in this Manual

The following conventions are used in this manual:

Convention	Description
Important Terms	New and important terms are presented in *bold italics*. These terms all appear in the Glossary of Terms at the end of the document.
File | Open…	Menus and menu selections are separated by a vertical bar. File | Open… means "Access the File menu and choose Open"
CTRL+C	Key combinations are shown using a "+" sign.. CTRL+C means press the Control and C keys simultaneously.
	**Warning**: This means watch out! Warnings typically alert you to potential pitfalls and problems that may occur if you perform (or fail to perform) a certain action.
	**Note**: Notes highlight important information about a particular concept, topic or procedure, such as limitations on how a particular feature can be used, or alternative ways of carrying out an action.

In describing various mouse actions, the following conventions are used:

Mouse Action	Definition
Click	Press and release the left mouse button once.
Double-click	Press and release the left mouse button twice in rapid succession.
Right-click	Press and release the right mouse button once.
Drag	Press the left mouse button, and while keeping it depressed, move the cursor to another location, then release the button.

Installing and Activating GoldSim

To install GoldSim, double-click the GoldSim installation file and follow the directions on the screen. The installation file for the latest version of GoldSim (as well as previous versions) is available on the GoldSim web site.

Note: In order to install GoldSim, you must have Administrator privileges on the computer.

During the installation process, the GoldSim License Agreement will be displayed in a dialog.

You can press the **Print…** button to print the document at this time to obtain a hardcopy version of the License Agreement. You must select "I accept the terms in the license agreement" to continue with the installation.

Note: After completing the installation of GoldSim, you can access the License Agreement at any time by selecting **Help|About GoldSim** from the main menu and pressing the **User License Agreement** link on that dialog.

Once the program is installed, GoldSim can be used by either activating a ***Standalone license*** on your computer, or by accessing a ***Network license*** that has been activated on a License Server.

Standalone licenses are activated on a single computer and, once they are activated, do not require connection to the internet (the license resides on the computer). Network licenses reside on a License Server, and in order to use the license, your computer must be persistently connected to the License Server (although as will be discussed below, licenses can be "borrowed" from the License Server so that they temporarily reside on your computer and a connection to the License Server is no longer necessary).

If you are unsure of what type of license you have, refer to the email you received from the GoldSim Technology Group when the license was provided (this may have been sent to a License Administrator).

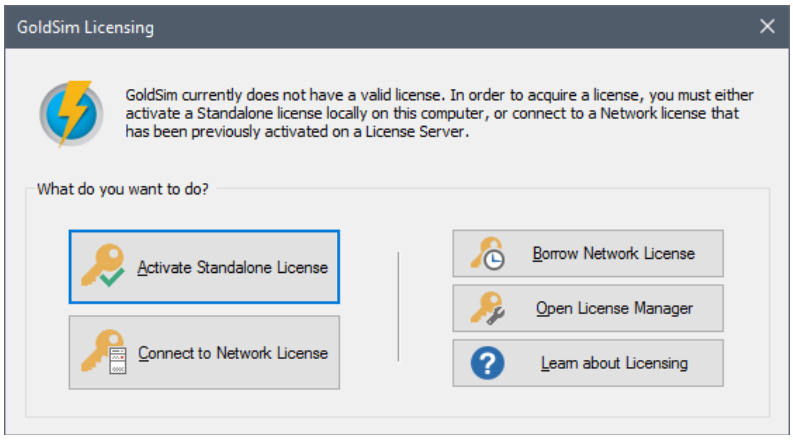
Using a Standalone License

There are two types of ***Standalone licenses***: Desktop Standalone licenses, and Enterprise Standalone licenses. The licenses are identical in all respects with one exception: Desktop Standalone licenses limit the number of license transfers (to 6 per year). Enterprise Standalone licenses allow an unlimited number of transfers.

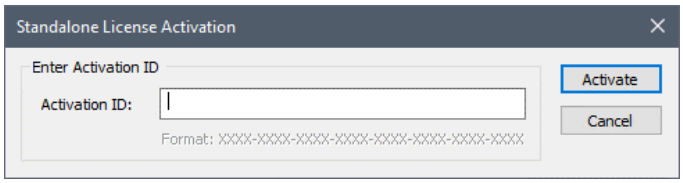
Activating a Standalone License

This section describes how to activate a GoldSim ***Standalone License*** (Desktop or Enterprise). The instructions below assume that you have an internet connection on the computer where you have installed GoldSim. If you do not have an internet connection, contact your License Administrator or GoldSim Technology Group for instructions on how to activate the license manually.

When you open an unlicensed copy of GoldSim, you will see the following dialog:

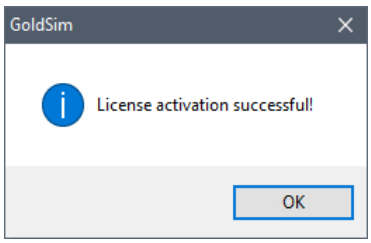


To activate a Standalone license, press the **Activate Standalone License** button. The following dialog will then be displayed:



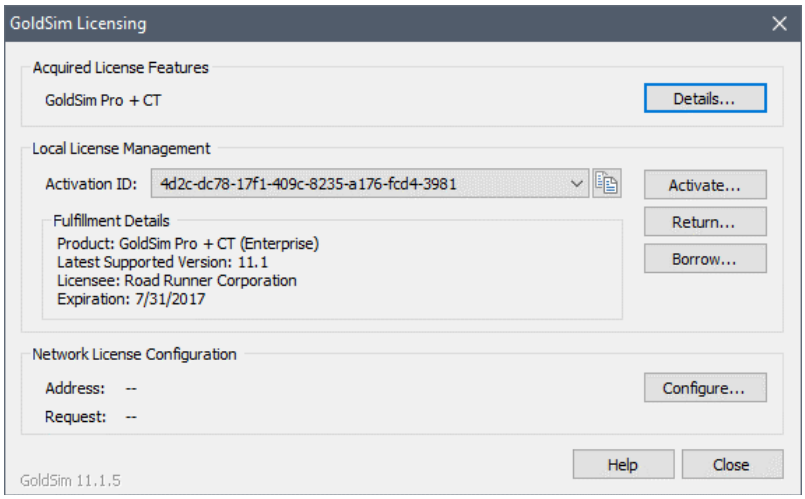
An ***Activation ID*** should have been provided to you (or your License Administrator) via email. The Activation ID is a 32-digit code (8 groups of 4 digits each, separated by hyphens) that is used to activate your license. To avoid errors, rather than typing the Activation ID in by hand, it is suggested that you copy your Activation ID (highlight it and press **Ctrl+C**) from the email that you received and paste it (**Ctrl+V**) into the **Activation ID** field.

After doing so, click the **Activate** button. You will momentarily see a progress dialog while GoldSim carries out the activation. If your license activation was successful, you will see the following message dialog:



When you click **OK**, GoldSim should open.

After successful activation, you can view your license details by selecting **Help|Licensing…** from the main GoldSim menu. This will open the GoldSim License Manager:

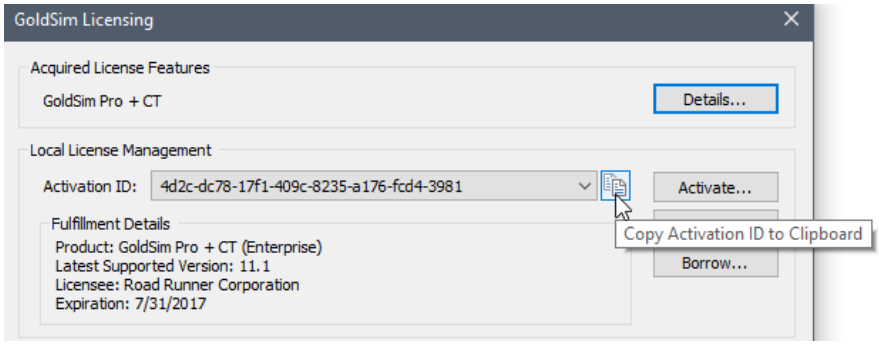


In this dialog, you can see details about your license. The middle section, *Local License Management*, displays your **Activation ID**, the **Product** name, the **Latest Supported Version**, the **Licensee** organization and the **Expiration** date of the license.

You can use any version of GoldSim including and prior to the **Latest Supported Version** with your GoldSim license. Note, however, that the current licensing system only supports GoldSim 10.5 (released in 2010) and later. If you need to use a very old version of GoldSim (previous to 10.5), contact the GoldSim Technology Group.

Although GoldSim licenses are perpetual, they still expire (typically after one year) and must be re-activated annually (at no charge). GoldSim will send reminders to your License Administrator several months prior to the **Expiration** date listed in the dialog.

If you ever need to provide your Activation ID to GoldSim Technology Group or to someone within your organization, you can copy the Activation ID to the clipboard using the copy button in the GoldSim License Manager dialog located to the immediate right of the Activation ID:



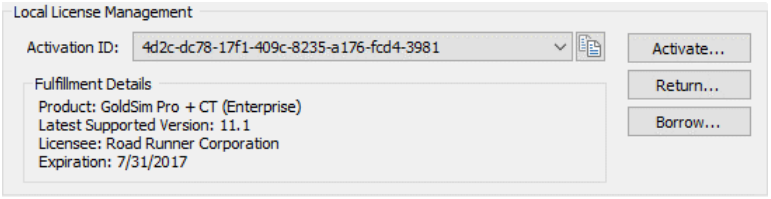
Returning (Deactivating) and Transferring a Standalone License

If you have already activated GoldSim on a computer and you wish to transfer the license to another computer, you can return (i.e. deactivate) the license and then activate it on another computer. This can be done very quickly without having to contact GoldSim Technology Group. This allows you to easily share your license with others.

Be aware, however, that if you are using a Desktop Standalone license, you are limited in the number of times you can transfer your license (6 times per year). If you plan to frequently move a Standalone license between computers and you

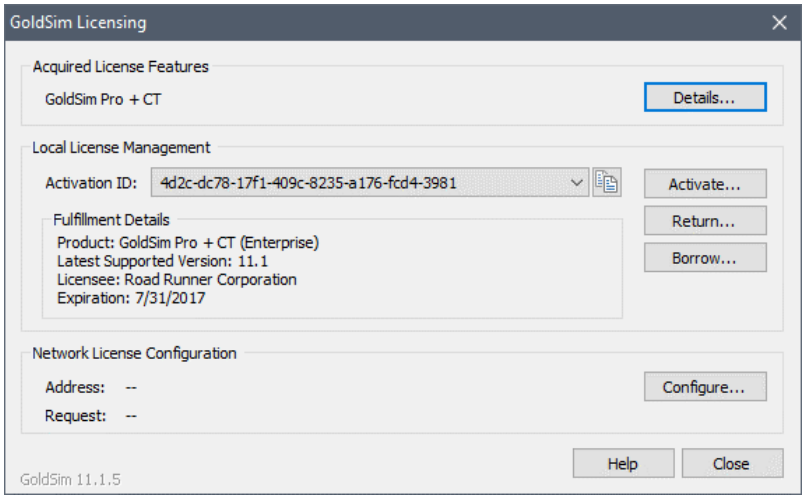
have a Desktop Standalone license, you can upgrade to an Enterprise Standalone license, which allows an unlimited number of transfers. This is useful in the case where you are frequently sharing the license with other users.

If you are unsure what type of license you have (Desktop or Enterprise), open GoldSim and from the main menu select **Help|Licensing…** to open the License Manager. In *the Local License Management* section, you can see information about your license. The license type is shown in parentheses in the **Product** line:



The instructions below for returning a license assume that you have an internet connection on the computer where you have installed GoldSim. If you do not have an internet connection, contact your License Administrator or GoldSim Technology Group for instructions on how to deactivate the license manually.

To return (deactivate) a Standalone license, open GoldSim and from the main menu select **Help|Licensing…** to open the License Manager:

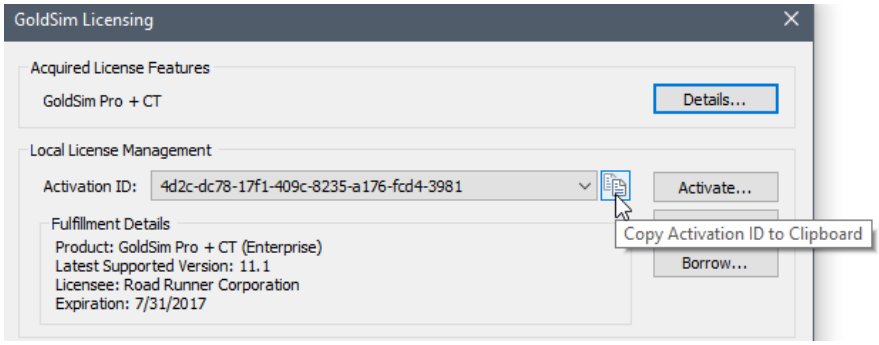


From the drop-list in the *Local License Management* section, select the **Activation ID** for the license that you want to return (in most cases, there will only be one in the list).

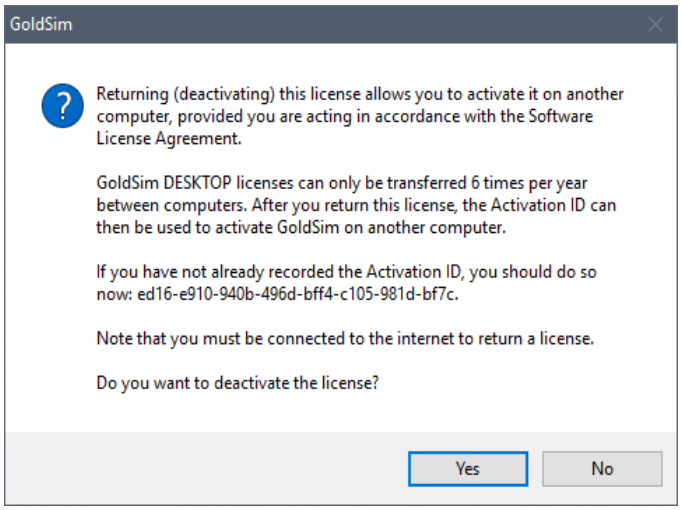
Note: The **Activation ID** is a drop-list, since under some license use scenarios, you could have multiple activations on your computer (e.g., if you temporarily needed to borrow a license with additional modules that was available on a Network license server, but not on your Standalone license). In most situations, however, there will only be a single Activation ID in the list. The *Fulfillment Details* refer to the selected Activation ID, so you can easily understand what each ID represents.

After you return a license, in most cases, you will want to communicate to others in your organization (e.g., your License Administrator, a colleague who wants to use the license) which Activation ID you have returned. Therefore,

before you return the license, you should copy the **Activation ID** to the clipboard so you can easily paste it into an email. You can do so by pressing the copy button to the right of the Activation ID:



Once the the Activation ID has been selected (and copied), click the **Return…** button. You will see a dialog asking you to confirm whether or not you want to proceed with the return. Note that his message indicates what type of Standalone license you have (Desktop or Enterprise):



It also prompts you to record the Activation ID (if you have not already done so). You cannot highlight and copy text in this dialog. Hence, if you have not already copied the Activation ID (as described above), the easiest thing to do is press **No** in this dialog, which will return you to the License Manager dialog. You can then copy the Activation ID using the copy button to the right of the Activation ID, and proceed again with the return.

If the return was successful, you will be notified. Once a license has been returned, it will no longer be used on the computer from which you returned the license. This means that you can activate that license on a different computer using the same Activation ID.

Reactivating or Upgrading a Standalone License

In addition to initially activating your Standalone license, there are three instances in which you will need to reactivate the license (provide a new Activation ID):

- Although GoldSim licenses are perpetual, they still expire (typically after one year) and must be re-activated annually (at no charge). GoldSim will send reminders to your License Administrator several months prior to the **Expiration** date (listed in the GoldSim License Manager dialog).

- When a new version of GoldSim is released that you are eligible to use (i.e., your license is under active maintenance).
- In some cases, you may decide to upgrade your license (e.g., add a specialized extension module, or convert from a Desktop to an Enterprise Standalone).

  Read more: Specialized GoldSim Modules (page 52).

In all of these instances, you will be provided with a new Activation ID by the GoldSim Technology Group. You will then need to reactivate your license with the new Activation ID by following these simple steps:

1. Select **Help|Licensing…** from the main GoldSim menu to open the GoldSim License Manager dialog.
2. Press the **Activate…** button in the GoldSim License Manager dialog to display this dialog:

3. Enter the new Activation ID and press **Activate**.

Using a Network License

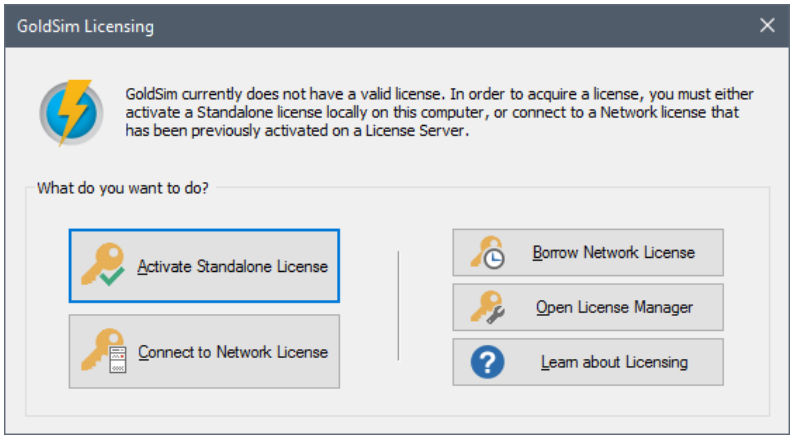
Network licenses allow you to easily share licenses across an organization. To use a Network license, you still must have GoldSim installed locally on your computer, but the license itself resides on a License Server.

In order to use the license, your computer must be persistently connected to the License Server (although as will be discussed below, licenses can be "borrowed" from the License Server so that they temporarily reside on your computer and a connection to the License Server is no longer necessary).

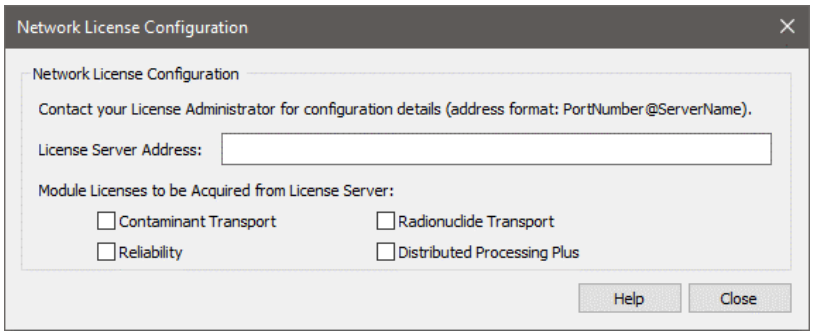
Connecting to a Network License

To use GoldSim by connecting to a Network license, your License Administrator must have already set up and activated the Network license and provided you with an address to the License Server.

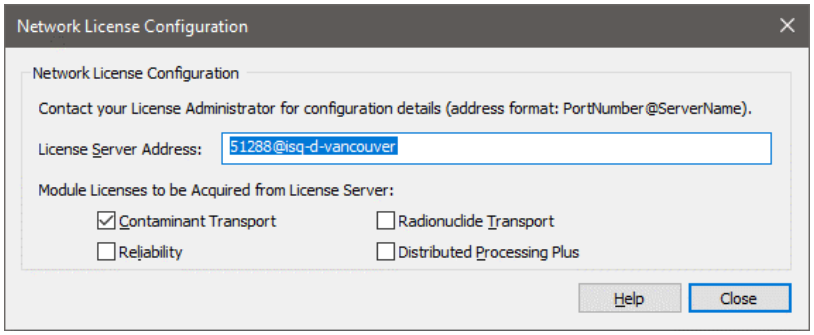
When you open an unlicensed copy of GoldSim, you will see the following dialog:



To use a Network license, press the **Connect to Network License** button. You will see the Network License Configuration dialog:



Enter the **License Server Address** provided to you by your License Administrator. This will take the form of a port number and a server name, such as 51288@isq-d-vancouver, where in this example 51288 is the port number and isq-d-vancouver is the server name). If there are modules available on the License Server that you would like to use, you can request a module by checking the box next to the module you would like to use:

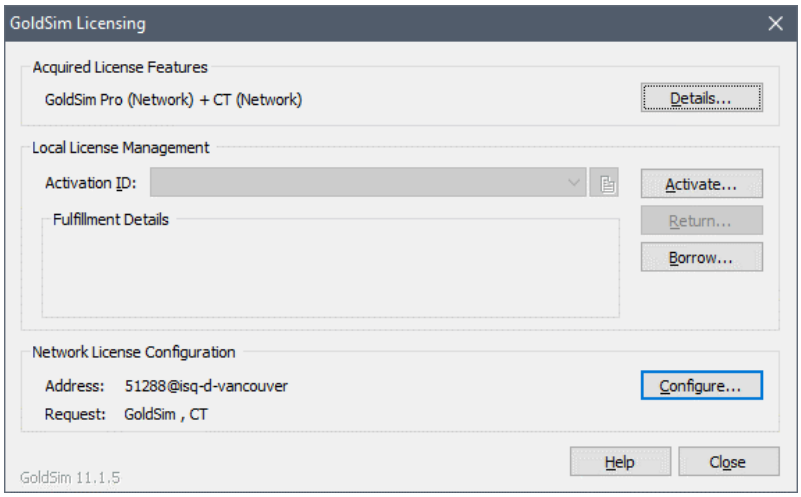


Note: When connecting to a Network license, you will only acquire those modules that you specifically request here. If you do not request a module, you will not acquire it (even if it is available on the License Server).

If there is an available license on the License Server, GoldSim will open after you press **Close**.

Note: If a GoldSim license was available, but a requested module was not, GoldSim will still open but a warning message will inform you that the requested module(s) were not acquired.

If you subsequently open the License Manager dialog (by selecting **Help|Licensing…** from the main GoldSim menu), the dialog will look something like this:



The top section, *Acquired License Features*, will indicate that your license is a Network license. If you were successful in acquiring any modules you requested from the License Server, this will also be indicated in this section.

The bottom section (*Network License Configuration*) shows the Network License Address and also the features you have requested from the License Server. Note that this section indicates what you have requested from the License Server. This does not indicate what you have actually acquired from the License Server. If all licenses are in use or the License Server does not have a module you are requesting, you will get one or more error messages indicating you were not able to acquire the requested feature(s). You can always see what features you have successfully acquired by looking at the *Acquired License Features* section.

Note that you only need to enter the Network License Address (and requested features) once. After you do so, the next time you open GoldSim, it will use that same information to attempt to acquire a license from the License Server.

Note: Once you have acquired a license, you can change the License Server and the modules you wish to request by pressing the **Configure…** button, which reopens the Network License Configuration dialog.

Borrowing a Network License for Offline Use

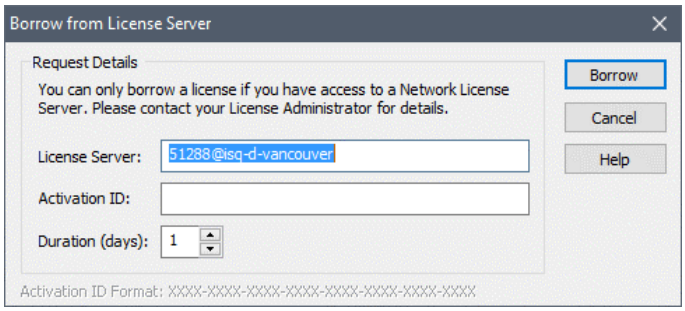
When using a Network license, you may occassionally need to use GoldSim while disconnected from the License Server (for example, when traveling). To facilitate this, GoldSim provides the option to ***borrow*** a license from a License Server for disconnected use. To initially borrow the license, you need to be connected to the License Server. But once the license is borrowed, you can disconnect from the License Server and use the license as though it were a local (i.e., Standalone) license.

At the time you borrow a license, you must specify a duration (in days) for the borrowing period. At the end of this period, the local license (on your computer) automatically expires and the license becomes available again on the License Server.

If you wish to borrow a license and are currently using a Network license, open the License Manager (by selecting **Help|Licensing…** from the main GoldSim menu). Within the License Manager dialog, press the **Borrow…** button.

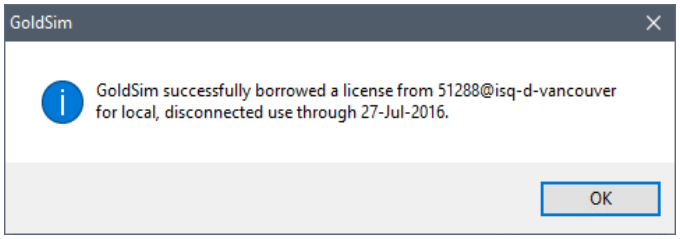
If your copy of GoldSim is currently unlicensed (but you do have access to the License server) and you wish to directly borrow a license, press the **Borrow Network License** button on the dialog that is displayed when you try to run GoldSim.

In both cases, the following dialog will appear:

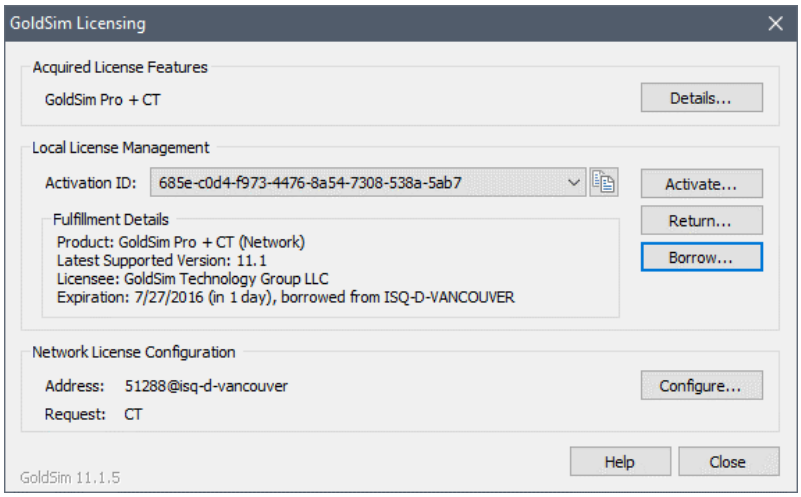


To borrow a license, you will need to enter a **License Server** address and the **Activation ID** for the license that you wish to borrow. You will need to get these from your License Administrator. You must also specify a **Duration** (in days) for which you wish to borrow the license. This can be no longer than 30 days (and may be further limited by your License Administrator).

After entering this information and pressing the **Borrow** button, you will see a progress dialog while GoldSim attempts to borrow the license from the License Server. This should typically only take a few seconds. If the borrow attempt is successful, you will see a message dialog that shows the License Server address and the date on which the borrowed license will expire:

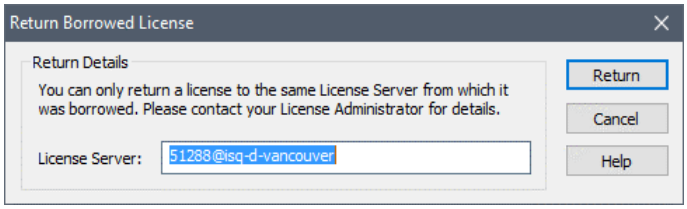


Once you have borrowed a license, in the *Local License Management* section of the License Manager, you can see details for the borrowed license. The details are similar to what would be shown for a local (Standalone) license, with the following exceptions: (1) the **Product** line indicates that the license is a Network license and (2) the **Expiration** line indicates that the license is borrowed (and displays the expiration date):



If you wish to return the license before the expiration date, you can return (deactivate) the license by pressing the **Return…** button. When you do this, you will see a message dialog asking you to confirm the return action. (Note that to return the borrowed license early, you must have access to the License Server.)

After you confirm that you want to return the borrowed license, you will be prompted for the License Server address:

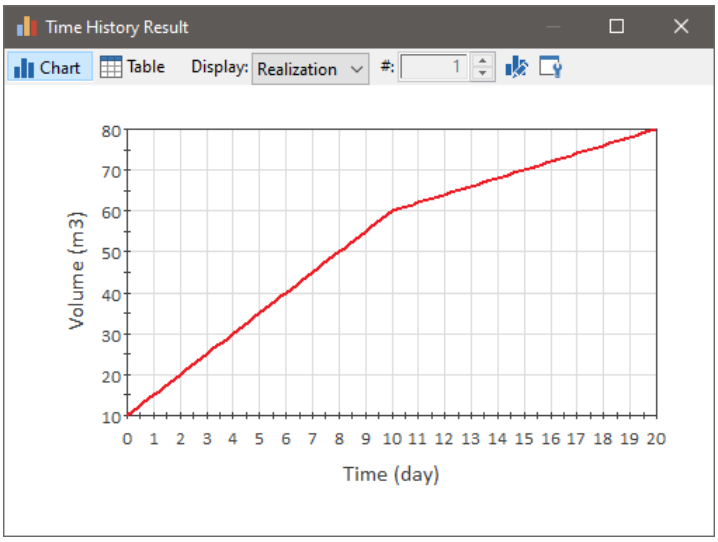


Once you have entered the License Server address, press Return. A progress dialog should appear while the return is carried out. If the return is successful, you will see a confirmation message.

Testing the GoldSim Installation

Once GoldSim is activated, you should ensure that the program was properly installed. To test the GoldSim installation, do the following:

1. Double-click on the GoldSim program icon (on the desktop or, using Windows Explorer, in the folder into which you installed GoldSim) to start the program.
2. Press **Esc** to close the Start dialog that is presented.
3. From the main menu, select **File | Open Example...**
4. Enter the folder named "General Examples".
5. Select a file named "FirstModel.gsm" and press **Open**.
6. Press **F5**.
7. A dialog stating that the simulation has completed will be displayed. Press **OK** to close the dialog.
8. You will see an object labeled "Volume" on the screen.
9. Right-click the object. A menu will be displayed. At the top of the menu, you will see a **Time History Result…** option.
10. Click on this option. The following chart will be displayed:



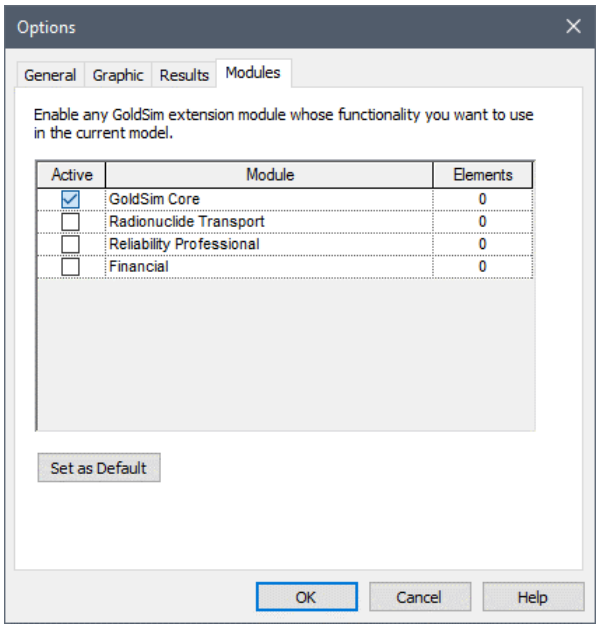
11. If you are able to complete these steps and you chart looks like this, GoldSim has been properly installed. (Close the chart, and you can close GoldSim.)

Activating and Deactivating Extension Modules

GoldSim was designed to facilitate the incorporation of add-on modules (program extensions) to enable the program to address specialized systems. These modules add additional features and capabilities to GoldSim. Your license determines which of these program extensions are available to you.

Read more: Specialized GoldSim Modules (page 52).

You can view which modules are available by selecting **Model| Options…** from the main menu, and selecting the **Modules** tab:



All extension modules that you are licensed to use appear in the dialog. If your license does not allow you to use a particular module, it will not be listed. You can activate and deactivate modules that you are licensed to use by clicking the **Active** checkbox. By default, whenever you activate GoldSim, none of the

available extension modules allowed by your license will be activated. To use them, you must activate them using this dialog.

If you deactivate a module, the specialized elements associated with that module will be deleted from your model (if any are present) and any menu options will be removed in the current file. If you make a module active, the various options associated with that module are made available again. If you press the **Set as Default** button, the selected modules will be activated for all new models that are created.

Note: If you try to open a file that contains elements associated with an extension module, and you are licensed to use that module but it is not currently active, GoldSim will automatically activate the module and open the file. If, however, you are not licensed to use the module, GoldSim will not open the file (and will display an error message).

Sharing a License Between GoldSim Versions on a Computer

GoldSim allows you to automatically share a single license between different GoldSim versions on a single computer. This is particularly useful when converting files from an old version of GoldSim to a new one. In such a case, you may want to have two versions of GoldSim on a single machine (e.g., Version 10.5 and Version 12), and be able to switch back and forth between versions or run both versions simultaneously.

GoldSim allows you to easily share a license in this way. After installing a second version on your machine and trying to run it, GoldSim will automatically detect and use your previously existing license (even if you are running the two versions simultaneously).

Learning to Use GoldSim

Although GoldSim's intuitive interface will tempt you to simply dive in and start playing with the software, you are strongly discouraged from doing so, even if you are an experienced modeler. Spending time up front (by following the steps outlined below) is the most efficient way to understand the software's features and capabilities and start building models in GoldSim.

1. **Take the GoldSim Tutorial**. The GoldSim Tutorial is by selecting **Help | Tutorial…** from the main GoldSim menu. The GoldSim Tutorial presents the basic concepts on which GoldSim is based and provides an overview of GoldSim's key features and capabilities. After taking the Tutorial (which takes perhaps one or two hours), you will have sufficient understanding to start using the software, and will get more out of the information presented in the Help topics. This is the minimum that you must do before using GoldSim.

2. **Take the Online "Introduction to GoldSim" Training Course**. Although the Tutorial is of value to quickly get an overview of GoldSim, it provides a very simple overview of only the most basic GoldSim concepts. The best and most effective way to learn GoldSim is to take a full training course. A free "hands-on" online Training Course is available that will provide you with a thorough understanding of the key concepts on which GoldSim is based and all of the fundamentals required to build complex models of nearly any kind of system. That is, it does not simply focus on the mechanics of using the GoldSim software; just as importantly, it explains the fundamental concepts underlying dynamic, probabilistic simulation in general.

Because the Course is quite thorough, it will likely take as long as 40 hours to complete. Of course, if you are already somewhat familiar with simulation (and/or have a strong quantitative background), you may in fact be able to cover the material in considerably less than 40 hours.

You can take the Course at your own pace (and the site will remember where you last left off). If you are new to simulation, the ideal pace is probably to spend perhaps just a couple hours per day with the Course. This then provides you with an opportunity to give some considered thought to the information that was presented, and prevent "information overload".

Although taking the Course is time-consuming, over the long-term it is by far the most efficient way to learn to use the software. Trying to learn a complex and powerful software tool such as GoldSim on your own by simply experimenting and consulting the reference material is likely to take far in excess of 40 hours, and by doing so, you will likely not discover many of GoldSim's most powerful features.

You can find the Course here:
https://www.goldsim.com/Courses/BasicGoldSim/.

3. **Request your free one hour web-based training session.** When you purchase GoldSim, you are entitled to a free one hour, live web-based training session in which one of our analysts provides an interactive training session via the Internet and telephone. You are strongly encouraged to take advantage of this free training.

4. **Open and explore the Example Files**. When you install GoldSim, a folder labeled "General Examples" is installed with the program. (You can quickly access these files by selecting **File|Open Example…** from the main GoldSim menu). The example model files show how to use each of the elements (the examples are referenced in the Help system and User's Guide where the element is introduced). These example model files are an excellent way to begin to experiment with GoldSim. While exploring the files, use GoldSim's context-sensitive Help (i.e., the **Help** button in each dialog) to access a detailed discussion of the element. (Note that these example files are installed in such a way that to edit and save them, you must "Save As", which prevents the original files from being overwritten).

5. **Download Example Files from the Model Libaray**. The GoldSim Help Center (https://goldsim.zendesk.com) contains a Model Library with a number of models illustrating how GoldSim can be used for particular applications. These models tend to be more complex than the simple example files found in the General Examples folder, but still relatively simple. Again, while exploring the files, use GoldSim's context-sensitive Help (i.e., the **Help** button in each dialog) to learn more about particular elements or features utilized in the model.

6. **Browse the User's Guide or Help System**. GoldSim has a large number of features, and you will not discover all of them by experimenting with simple example models. To fully utilize GoldSim's powerful features, browse through the User's Guide, using the index and table of contents as your guide. Each section of the User's Guide is heavily cross-referenced, so it is easy to just jump around. Note that the Help system contains all of the contents of the User's Guide, with the exception of the technical appendices.

7. **Contact us with questions**. When you purchase GoldSim, you are entitled to one year of free support. This does not include assistance in building and debugging your models, but it does include answering questions on how to use GoldSim's features, so feel free to contact us!

Using GoldSim's Help System

GoldSim has an extensive in-product help facility, which can be used to supplement this manual. The Help system can be accessed by selecting **Help | Help Topics** from the main GoldSim menu, pressing the **F1** key, or clicking on the Help button (the question mark) on the standard toolbar. Pressing the **Help** button (or **F1**) within any of the dialogs also provides access to Help (in a context-sensitive manner). All of the information in this document (with the exception of the appendices) is accessible via GoldSim Help.

Technical Support, User Resources and Software Upgrades

The GoldSim Technology Group is dedicated to providing complete solutions for our customers. We pride ourselves in providing prompt and extensive support and resources to our users, and are committed to ensuring that each installation of our software is successful and adds value to the customer.

GoldSim Maintenance Program

When you purchase GoldSim software, you receive one year of Software Maintenance, entitling you to the following:

- Free software upgrades so that you always have the latest version of the GoldSim software.
- Basic Technical Support via email and phone. Basic support covers installation and licensing questions, as well as questions about GoldSim's features and capabilities.

After the first year, if you wish to continue to have access to new versions and technical support, Software Maintenance can be extended each year with payment of an annual fee.

Details regarding the GoldSim Maintenance Program can be found at www.goldsim.com/Web/Products/BuyGoldSim/Pricing/MaintenanceProgram/.

Getting Technical Support

Users with active Software Maintenance can submit questions directly to the GoldSim support team. Evaluation users are also welcome to contact us with questions on GoldSim functionality. The **GoldSim Help Center** (https://goldsim.zendesk.com) is the primary portal for technical support. You can submit your questions directly from the Help Center. If your register and log in through the Help Center, you will be able check the status and view a history of all of your support requests.

The Help Center also includes:

- The **GoldSim Forum**, where you can you can post questions to the GoldSim community, or just browse existing messages;
- Articles on licensing questions and modeling tips; and
- An archive of past webinars (which demonstrate GoldSim features and capabilities).

Free Basic Technical Support does not include consulting, model trouble-shooting or detailed assistance with applying GoldSim to a particular problem.

Assistance of this nature is defined as Advanced Technical Support. Users may purchase Advanced Technical Support in pre-paid 10 hour blocks.

Details regarding Advanced Technical Support can be found at www.goldsim.com/Web/Resources/TechnicalSupport/.

Other GoldSim Resources

In addition to the GoldSim Help Center, additional resources are also available. These three resources can be accessed directly from the GoldSim website (www.goldsim.com):

- A free **Online Training Course** that will provide you with a thorough understanding of the key concepts on which GoldSim is based and all of the fundamentals required to build complex models of nearly any kind of system.
- The **GoldSim Model Library**, which contains a collection of example models to allow you to see how specific features of GoldSim can be used and/or how GoldSim can be used for specific applications.
- The **GoldSim Blog**, which provides an informal mechanism for GoldSim staff to share their knowledge, point out some of the more advanced (and perhaps overlooked) GoldSim features, share and discuss common mistakes we see in GoldSim applications, discuss interesting applications, and keep you abreast of our plans for further GoldSim developments.

You can stay up to date on the latest GoldSim news through these resources:

- The GoldSim LinkedIn Group, which is primarily used for announcements (e.g., new versions, interesting applications). You can join the Group here: www.linkedin.com/groups/1798413)
- Periodic email newsletters are sent two to three times per year. To be added to the newsletter list, contact us via the GoldSim Help Center (https://goldsim.zendesk.com).

Note: When you purchase GoldSim, you are entitled to a free one hour, live web-based training session in which one of our analysts provides an interactive training session via the Internet and telephone. You are strongly encouraged to take advantage of this free training.

Chapter 2: GoldSim in a Nutshell

> The purpose of computing is insight, not numbers.
>
> R.W. Hamming, *Numerical Methods for Scientists and Engineers*

Chapter Overview

This chapter provides an introduction to and "quick tour" of GoldSim. It presents the basic concepts of how simulation techniques can be applied to solve problems, and how a simulation model is created in GoldSim. It also provides an overview of the features and capabilities of the program.

If you read nothing else before starting to use the program, it is strongly recommended that you read this chapter, as it will tell you what the program is capable of doing, provide an overview of how to build a model, and direct you to those portions of the manual where you can obtain further information.

In this Chapter

This chapter discusses the following:

- Understanding Simulation
- What is GoldSim?
- Basic GoldSim Concepts
- Advanced Computational Features
- Documenting and Presenting Your Model
- Specialized GoldSim Modules
- The GoldSim Player

Understanding Simulation

Before describing what the GoldSim simulation framework is, and what it can be used to do, it is important to first discuss in general terms what we mean when we use the term ***simulation***.

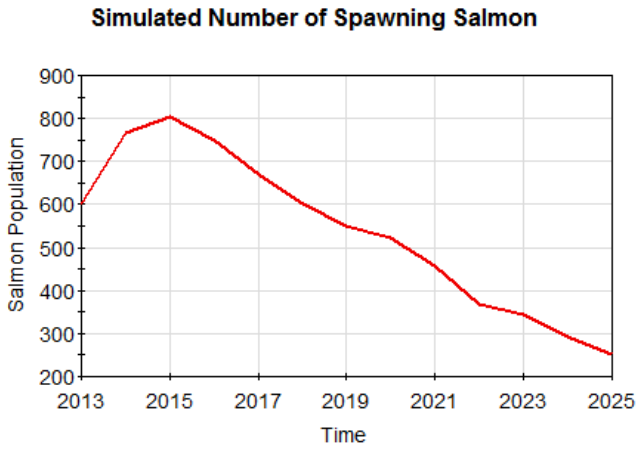
The term *simulation* is used in different ways by different people. As used here, simulation is defined as the process of creating a model (i.e., an abstract representation or facsimile) of an existing or proposed system (e.g., a business, a mine, a watershed, a forest, the organs in your body, the atmosphere) in order to identify and understand those factors which control the system and/or to predict (forecast) the future behavior of the system. Almost any system which can be quantitatively described using equations and/or rules can be simulated.

Dynamic Simulation

Simulations can be static or dynamic. In a static simulation, the system does not change with time. Static simulations can be useful for carrying out simple risk calculations and decision trees, in which there is no dynamic component to the model.

In a dynamic simulation, the system changes and evolves with time (in response to both external and internal influences), and your objective in modeling such a system is to understand the way in which it is likely to evolve, predict (forecast) the future behavior of the system, and determine what you can do to influence that future behavior.

In effect, a dynamic simulation is used to predict the way in which the system will evolve and respond to its surroundings, so that you can identify any necessary changes that will help make the system perform the way that you want it to. For example, a fisheries biologist could dynamically simulate the salmon population in a river in order to predict changes to the population, and quantitatively understand the impacts on the salmon of possible actions (e.g., fishing, loss of habitat) to ensure that they do not go extinct at some point in the future:



Probabilistic Simulation

In many systems, the controlling parameters, processes and events may be uncertain and/or poorly understood. In a ***deterministic simulation***, these parameters are represented using single values (which typically are described either as "the best guess" or "worst case" values). ***Probabilistic simulation*** is the process of explicitly representing this uncertainty by specifying inputs as ***probability distributions*** and specifying any random events that could affect the system.

If the inputs describing a system are uncertain, the prediction of future performance is necessarily uncertain. That is, the result of any analysis based on inputs represented by probability distributions is itself a probability distribution.

Hence, whereas the result of a deterministic simulation of an uncertain system is a *qualified statement* ("if we build the dam, the salmon population could go extinct"), the result of a probabilistic simulation of such a system is a *quantified probability* ("if we build the dam, there is a 20% chance that the salmon population will go extinct"). Such a result is typically much more useful to decision-makers who might utilize the simulation results.

A more detailed description of probabilistic simulation concepts, including a discussion of the advantages and disadvantages of probabilistic simulation, is provided in Appendix A, "Introduction to Probabilistic Simulation".

Steps in Carrying Out a Simulation

In order to illustrate what is involved in simulating a system, the steps necessary to carry out any kind of simulation are briefly summarized below:

1. **Define your objectives and measures of performance.** Before attempting to simulate a system, it is important to clearly identify what types of questions you are trying to answer with the model. The objectives of the model define the ***performance measures*** for the system. A performance measure is a model output by which you can judge the performance of the system (e.g., the salmon population in a river, or the net present value of a project).
2. **Develop the conceptual model**. The most important step in simulating any system is developing a ***conceptual model*** of the system. A conceptual model is a representation of the significant features, events and processes controlling the behavior of the system. It is essentially a body of ideas, based on available information, that summarizes the current understanding of the system.
3. **Create the mathematical model.** Once a conceptual model of the system is developed, it is necessary to represent it quantitatively within a ***mathematical model***. A mathematical model consists of a set of input assumptions, equations and algorithms describing the system.
4. **Quantify the input parameters.** The mathematical model identifies specific inputs (e.g., the flow rate for a river, the financial discount rate) which are required in order to simulate the system. These must be quantified by specifying their values or probability distributions.
5. **Implement and solve the mathematical model using a computational tool.** After developing the mathematical model and quantifying all of the input parameters, the model must be implemented within a computational tool capable of solving the equations representing the system. This implementation of the mathematical model within a computational tool is referred to as the ***simulation model.*** For simple systems, the computational tool might be your brain (if you can solve the equations in your head), a calculator, or perhaps a spreadsheet program. For more complex systems, a specialized computer program (such as GoldSim) is required.
6. **Evaluate, explain and present the results.** The final step in the simulation process is to produce results, evaluate and draw conclusions from these results, and present them to interested parties.

For very simple simulations, the steps described above could be carried out in order, proceeding from step 1 to step 6. For most real-world simulations, however, these steps should be carried out in an iterative manner. That is, as

new data and/or new insights into the behavior of the system are obtained, the model is refined and reanalyzed.

Models which are constructed and continuously updated in such a manner can provide a systematic framework for organizing and evaluating the available information related to a complex system, and can act as management tools to aid in ongoing decision-making.

As will be discussed below, GoldSim was specifically designed to make the construction of such models as easy and intuitive as possible.

The Power of Simulation

Simulation is a powerful and important tool because it provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment on a real system, which may be prohibitively costly, time-consuming, or simply impractical to do. That is, it allows you to ask “What if?” questions about a system without having to experiment on the actual system itself (and hence incur the costs of field tests, prototypes, etc.).

A few wide-ranging examples of how simulation can be used to ask such "What if?" questions in order to solve real-world problems in science, engineering and business are listed below:

Wildlife management: By simulating an animal population (such as salmon or elk), you can determine which combination of management practices is most likely to be successful at maintaining a stable population.

Strategic planning: By simulating the development, regulatory approval, and marketing of a new drug, you can determine a strategy that will maximize profits.

Reliability and Systems Engineering: By simulating the components, processes, failure modes and events controlling a complex engineering system (such as a space system, a machine, or a large industrial facility), you can predict the reliability of the system, and modify the design so as to increase reliability and decrease the probability and/or consequences of failures.

Water resources: By simulating the inflows and future demands on a water supply reservoir, you can optimize management practices to minimize the probability of needing to seek other sources and/or impose water use restrictions at some future date.

Environment: By simulating the performance of a proposed landfill, you can modify the design to minimize environmental impacts.

Manufacturing: By simulating the supply chain for a product, you can experiment with technological changes (e.g., improved communication) and changes in decision rules (e.g., ordering practices) to stabilize inventory levels throughout the chain.

Resource Planning and Management: By simulating a natural resource (such as a forest), you can determine which combination of management practices (e.g., selective harvesting, development of recreational facilities) maximizes the use of the resource and best satisfies the various stakeholders.

As will be shown in the following sections, GoldSim is flexible and powerful enough to be readily applied to any of these problems.

What is GoldSim?

GoldSim is a highly-graphical simulation program that runs on personal computers using the Windows operating system. Although it was specifically designed for carrying out dynamic, probabilistic simulations of complex systems, it can also be readily applied to simpler static and/or deterministic simulations.

Because simulation can be such a powerful tool for understanding and managing complex systems, a variety of graphical simulation tools currently exist. The following combination of features, however, makes the GoldSim approach unique:

GoldSim is user friendly, highly graphical, and very flexible. It can be applied to nearly any kind of system. You start to build a model in an intuitive manner by literally drawing a picture (an influence diagram) of your system.

GoldSim was specifically designed to quantitatively address the inherent uncertainty which is present in real-world systems. GoldSim provides powerful tools for representing uncertainty in processes, parameters and future events, and for evaluating such systems in a computationally efficient manner.

GoldSim provides powerful capabilities for superimposing the occurrence and consequences of discrete events onto continuously varying systems. This allows for the realistic simulation of discrete events such as financial transactions, accidents, system failures, storms, labor strikes, and lawsuits.

GoldSim was designed to facilitate the construction of large, complex models. You can build a model of your system in a hierarchical, modular manner, such that the model can readily evolve and add detail as more knowledge regarding the system is obtained. Other powerful features, such as the ability to manipulate arrays, the ability to "localize" parts of your model, and the ability to assign versions to a model which is constantly being modified and improved, further facilitate the construction and management of large models.

GoldSim is dimensionally-aware. GoldSim has an extensive internal database of units and conversion factors. You can enter data and display results in any units. You can even define your own customized units. GoldSim ensures dimensional consistency in your models and carries out all of the unit conversions internally. As a result, when you use GoldSim, it is never necessary for you to carry out (error-prone) unit conversions.

GoldSim is highly extensible. You can dynamically link external programs or spreadsheets directly into your GoldSim model. In addition, GoldSim was specifically designed to support the addition of customized modules (program extensions) to address specialized applications.

GoldSim allows you to create compelling presentations of your model. A model that cannot be easily explained is a model that will not be used or believed. GoldSim was specifically designed to allow you to effectively document, explain and present your model. You can add graphics, explanatory text, notes and hyperlinks to your model, and organize it in a hierarchical manner such that it can be presented at an appropriate level of detail to multiple target audiences.

These features allow GoldSim to be applied at multiple levels, depending on the nature of the application:

- as a powerful, flexible simulator;
- as a system integrator; and
- as a visual information management system.

A Powerful, Flexible Simulator

At the most fundamental level, GoldSim can be used as a powerful, flexible simulator. That is, you may only wish to apply it to a very specific problem in a technical discipline such as finance, industrial engineering, environmental science, or chemistry.

GoldSim's graphical interface and powerful computational features facilitate a wide range of simulations, ranging from a simple homework assignment put together in less than an hour, to a complex professional application built over a period of several months.

A System Integration Tool

Most real-world problems are multi-disciplinary in nature. That is, the system being simulated actually consists of many subsystems, and the sub-models for each subsystem must typically be built by people from a wide variety of disciplines. For example, a model intended to help manage an ecological system (e.g., a river) in order to support management decisions to protect an endangered species (e.g., salmon) likely would include sub-models that are developed by biologists, urban planners, hydrologists, civil engineers, economists, forestry professionals, and social and political scientists (among others).

Unfortunately, in many such cases, the model builders get caught up in the details of their sub-models, and lose sight of the "big picture". The end result is typically separate sub-models which are unnecessarily complex. More importantly, the complex interactions and interdependencies between subsystems are often ignored or poorly represented. Such an approach not only wastes resources, but is often too complex to be explained (and hence used) effectively, and too poorly integrated to represent the entire system in a cohesive and realistic way.

What is needed for such complex, multi-disciplinary systems is a tool that can be used to integrate all of the various sub-models into a single ***total system model***. A total system model focuses on creating a consistent framework in which all aspects of the system, as well as the complex interactions and interdependencies between subsystems, can be represented.

Because GoldSim is flexible and powerful enough to represent practically any aspect of your system, and because GoldSim provides unique capabilities for building your model in a hierarchical, modular manner, it is ideally suited to act as a system integrator. *In fact, this was the original and primary objective around which GoldSim was designed*.

A Visual Information Management System

Complex models often require a great detail of input data. These inputs may reside in databases, spreadsheets, or in written documentation. The user of a model (e.g., the author of the model, a reviewer of the model, or a decision-maker evaluating the results) can be most effective if this input information can be visually integrated with (and readily accessed and viewed alongside) the simulation model. In addition, for a complex model which requires a great deal of input, it may be desirable (or even mandated) that the simulation model can directly access various data sources (e.g., databases or spreadsheets) to ensure the quality of the data transfer. GoldSim was designed to facilitate both of these tasks.

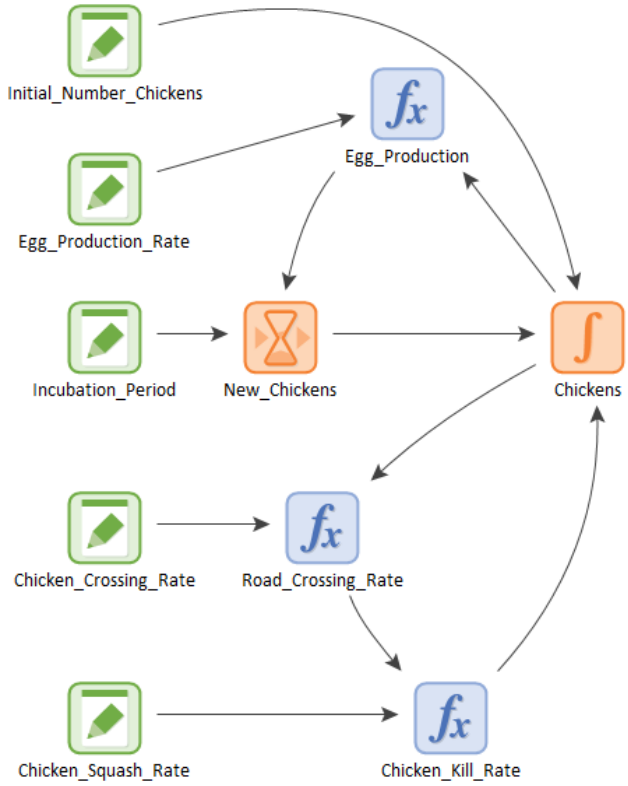
Even if you can directly and visually access the input data for your model, in order for your simulation model to be useful, you must also be able to explain its assumptions (and the implications of the simulation results) in a compelling and effective manner. GoldSim provides the tools to enable you to do so.

Hence, at the highest and most powerful level, GoldSim can used as a *visual information management system*, providing you with the ability to directly link to data sources, as well as describe, document and explain your model in a compelling and effective manner to any audience.

Basic GoldSim Concepts

The GoldSim Simulation Environment

The GoldSim simulation environment is highly-graphical and completely object-oriented. That is, you create, document, and present models by creating and manipulating graphical objects representing the components of your system, data and relationships between the data:



In a sense, GoldSim is like a "visual spreadsheet" allowing you to visually create and manipulate data and equations. As can be seen in the simple example shown above, based on how the various objects in your model are related, GoldSim automatically indicates their influences and interdependencies by visually connecting them in an appropriate manner. GoldSim also sets up and solves the equations represented by the objects and their interdependencies.

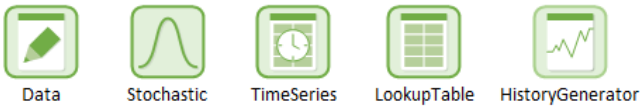
Elements: The Basic Building Blocks in GoldSim

The various objects with which a GoldSim model is constructed are referred to as ***elements***. Each element represents a building block of the model, and has a particular symbol or graphical image (which you can subsequently customize) by which it is represented on the screen. Typically, you give each element a unique name by which it is referenced (e.g., X, Revenue, Rainfall, Discount_Rate). Most elements accepts inputs, and in turn produce outputs.

GoldSim provides a wide variety of elements. Some of these elements provide a mechanism for the user to *enter input data* into the model. Other elements represent *functions* which operate on one or more inputs and produce one or more outputs. A special class of elements (stocks and delays) is critical for generating the dynamics in your models.

Input Elements

Input elements define the inputs to your model. There are five types of input elements: Data, Time Series, Stochastics, Lookup Tables and History Generators:



The most basic of the input elements are Data, Stochastics and Time Series. Data elements allow you to specify a single scalar value (e.g., the discount rate) or an array of related values (e.g., the salaries of each individual in a group). Time Series elements allow you to specify a time series of a value (e.g., monthly rainfall rates, quarterly cashflows). Stochastic elements allow you to specify that a particular value is uncertain by defining it as a probability distribution.

Lookup Tables and History Generators are somewhat more complex input elements. Lookup Tables can be used to define a response surface specifying how an output varies as a function of up to three inputs. History Generator elements generate random (stochastic) time series based on specified statistics (e.g., to represent the price of a security such as a stock or bond).

Function Elements

Function elements instantaneously compute outputs based on defined inputs. That is, they require one or more inputs, carry out a specified calculation on those inputs, and produce one or more outputs. GoldSim provides fifteen function elements.

The simplest and most general function element is an ***Expression element***. Expressions produce a single output by calculating user-specified formulas, such as 2 + 3, A*B, or sqrt(55). Similar to a cell in a spreadsheet, when defining an expression, you can use a wide variety of mathematical operators and functions. You can even use conditional operators (e.g., >,<, =) and *if, then* logic to define Expressions.

Other function elements have predefined functionality. For example, a Selector element provides an easy and transparent way to specify if..then logic in a model.

Stock and Delay Elements

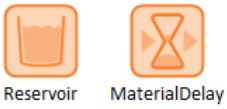
Stock and Delay Elements are specialized function elements with the unique property that their outputs are influenced by what has happened in the past. That is, unlike standard function elements, whose outputs at any given time are computed based solely on the current (instantaneous) values of their inputs, the outputs of these elements are determined by the *previous* values of their inputs. Such elements accumulate past events and provide systems with inertia and memory, and hence are responsible for internally generating the dynamic behavior of a system.

An example of a Stock element is the ***Reservoir***. A Reservoir accumulates materials, and is useful for representing things like bank accounts and quantities of materials or items (e.g., water, soil, salmon). In its simplest form, a Reservoir

requires as inputs an Initial Value, a Rate of Addition and a Rate of Withdrawal, and outputs a Current Value using the following equation:

$$\text{Current Value} = \text{Initial Value} + \int (\text{Rate of Addition} - \text{Rate of Withdrawal})dt$$

An example of a Delay element is the ***Material Delay***. Delays allow you to represent processes in which the output lags the input. The Material Delay accepts as input a flow of material (e.g., gal/day, $/yr, widgets/hr), moves it through a "conveyor" or "pipeline" (while optionally dispersing it), and then outputs the flow. Such an element can be used to represent such processes as the movement of water through soils or the movement of parts in a conveyor.



Linking Elements

GoldSim models are built by connecting the outputs of one (or more) elements to the inputs of other elements. These connections are referred to as links:

A complex GoldSim model can have hundreds (or thousands) of elements and links.

A Simple Example

The easiest way to understand GoldSim is to walk through a very simple example. In what follows, we illustrate how GoldSim could be used to carry out a simple dynamic simulation which computes the volume of water in a pond as a function of time.

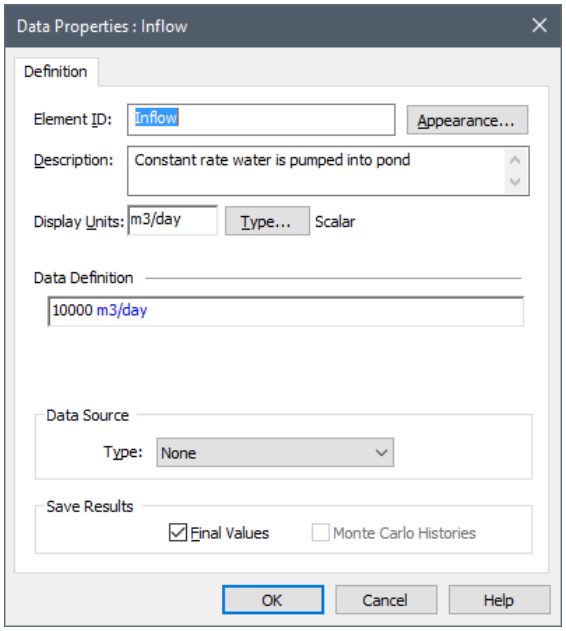
Note: The objective here is not for you to follow along and try to build this model (as you have not yet learned the basics of how to do so). Rather, the objective is simply to provide a very general indication of how GoldSim models are constructed and the kinds of results they produce.

Assume that the pond that we wish to simulate is initially empty. We continuously pump water out of a nearby river and into the pond at a rate of 10,000 m3/day. The pond leaks right back into the river, however, at a rate that is proportional to the current volume of water in the pond (i.e., the more water in the pond, the faster it leaks). In particular, 15% of the pond volume is assumed to leak out every day. We wish to predict the water level in the pond as a function of time.

We will build this model using three elements: a Data element, a Reservoir and an Expression. The Data element represents the rate of inflow to the pond, the Expression calculates the leakage from the pond, and the Reservoir represents the volume of water in the pond.

Therefore, we begin by inserting a Data element named "Inflow", an Expression named "Leakage" and a Reservoir named "Volume_in_Pond":

Next, we define the properties of the Data element "Inflow" by double-clicking on the element, which causes its editing dialog to be displayed:



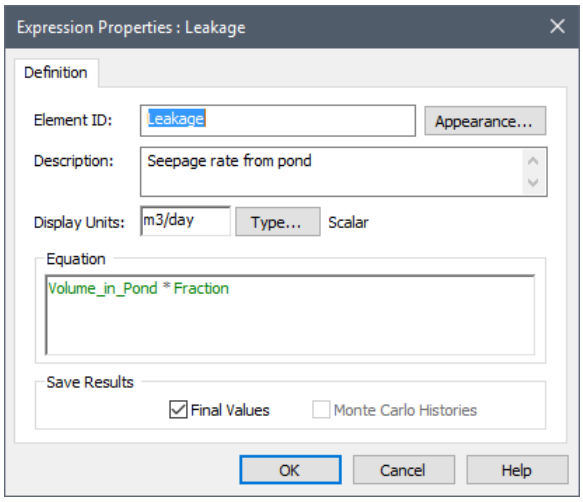
*The name of the element is specified in the **Element ID** field. You add a brief description to the element in the **Description** field. The data defining the element is specified in **Data Definition** field. When writing the Data Definition, the units of the input are specified following the value.*

To define the element, we enter the inflow rate of 10,000 m3/day. Note that we specifically define not only the value, but also the dimensions (the units) of the input. Note also that we do not add punctuation (the comma).

Next, we define the Expression element representing the leakage (outflow) from the pond. The leakage is equal to 15% of the pond volume per day. Mathematically, this can be written as:

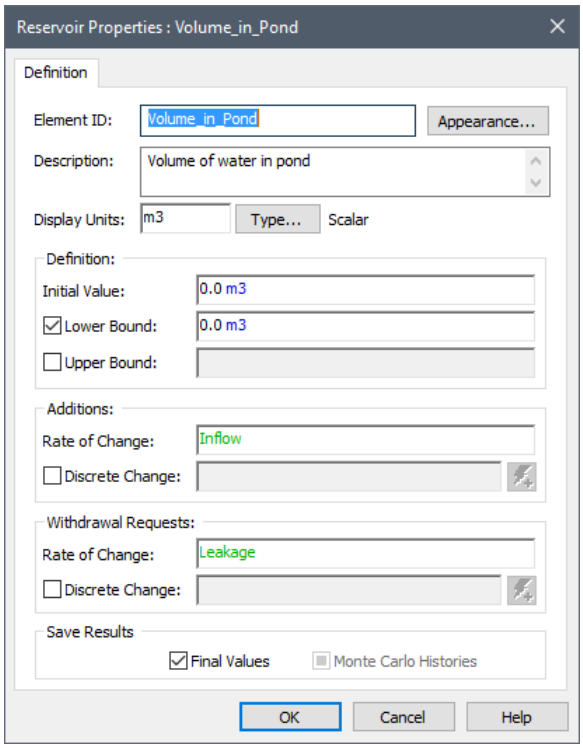
$$\text{Leakage} = \text{Volume\_in\_Pond} * 15\,\%/\text{day}$$

We type the right-hand side of this equation into the input field for the Expression representing the leakage:



*The expression representing the leakage is entered in the **Equation** field.*

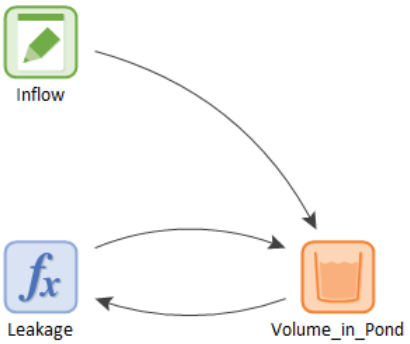
Finally, we must link the Inflow and Leakage to the Reservoir element. The properties dialog for a Reservoir (which is somewhat complex) is shown below.



*It is assumed that the pond is initially empty. The Inflow and Leakage are specified as **Additions** and **Withdrawa Requests** from the Reservoir. The remaining input fields for the Reservoir are not utilized in this simple example.*

For this example, the only required inputs for the Reservoir are the **Initial Value** (in this case, zero), the **Rate of Change *Addition*** (set equal to the Inflow), and the **Rate of Change *Withdrawal Request*** (set equal to the Leakage).

After defining the elements in this way, the screen looks like this:



The lines (referred to as an "influence") between the elements will initially be drawn as straight lines (rather than as curve lines). GoldSim allows you to subsequently change the appearance of these influences (e.g., make them curved).

The arrows indicate how the three elements are related. In this case, the system has a ***feedback loop***: Volume_in_Pond is a function of Leakage and Inflow, and the Leakage is a function of Volume_in_Pond. In fact, this is a classc example of a negative feedback loop: as Volume_in_Pond increases, the Leakage increases; as the Leakage increases, the Volume_in_Pond decreases. Negative feedback loops are self-correcting: rather than the pond volume continuing to increase, the feedback loop will eventually force it toward a steady state value.

Understanding Dynamic Simulation

GoldSim is a dynamic simulator, which means that your model can evolve and change with time. In this example, we are interested in predicting how the volume of water in the pond changes with time.

In order to do so, GoldSim must solve the equations represented by the elements and their linkages. In this particular example, the system can be represented by the following differential equation:

$$\frac{\delta V}{\delta t} = \text{Inflow} - \text{Leakage} = \text{Inflow} - 0.15 * V$$

where V is the volume in the pond, and $\delta V/\delta t$ is the time derivative of the volume (the rate of change of volume with respect to time).

This particular equation can actually be solved analytically:

$$V = V(0)\ e^{-0.15t} + \frac{\text{Inflow}}{0.15}\left[1 - e^{-0.15t}\right]$$

In general, however, a particular system will not have an analytical solution (i.e., it cannot be solved exactly), and must be solved *numerically* (i.e., using an algorithm that provides a numerical approximation to the actual solution).

GoldSim solves differential equations such as this through ***numerical integration***. That is, GoldSim solves for V as a function of time by integrating the right-hand side of the equation:

$$V(\tau) = V(0) + \int_0^{\tau} (\text{Inflow} - 0.15\ V)\ dt$$

To solve this (or any) integral numerically, it is necessary to discretize time into discrete intervals referred to as ***timesteps***. GoldSim then "steps through time" by carrying out calculations every timestep, with the values at the current timestep

computed as a function of the values at the previous timestep. In the case of the integral represented above, after discretizing time, GoldSim solves the equation by numerically approximating it as a sum:

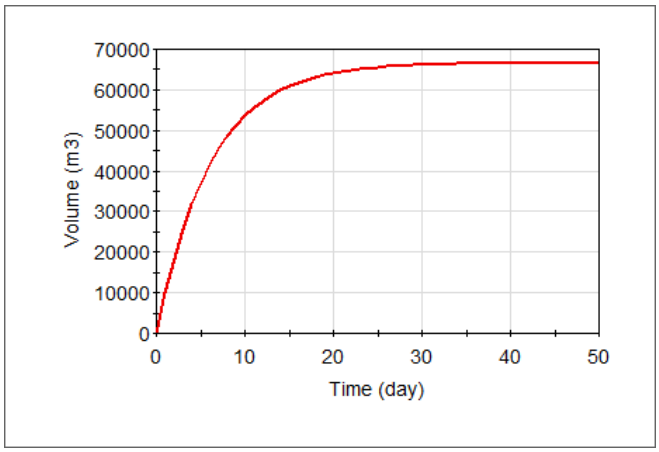
$$V(\tau) = V(0) + \sum_{0}^{\tau} [\text{Inflow} - 0.15 * V(\tau - \Delta t)] \Delta t$$

where Δt is the length of the timestep.

Hence, the value of V at time τ is computed based on the value of the Leakage (which is in turn a function of V) at the previous timestep. This particular numerical integration method (referred to as ***Euler integration***) is discussed further in Appendix G.

In order to dynamically simulate a system in GoldSim, you must specify the duration of the simulation (e.g., 365 days) and the length of the timestep (e.g., 1 day). The appropriate timestep length is a function of how rapidly the system represented by your model is changing: the more rapidly it is changing, the shorter the timestep required to accurately model the system.

For this simple example, we choose to run the model for a duration of 50 days with a timestep length of 1 day. The result, in the form of the volume of water in the pond as a function of time, is shown below:



As can be seen, the pond reaches a constant (steady-state) value after about 40 days. At this point, the flow rate into the pond matches the leakage rate out of the pond.

GoldSim is Dimensionally-Aware

As you no doubt noticed in the example, when data were entered, the dimensions were specified. One of the more unique and powerful computational features of GoldSim is that the program is *dimensionally aware*.

GoldSim has an extensive internal database of units and conversion factors. You can enter data and display results in any units. You can even define your own customized units.

When elements are created, you must specify their output dimensions. For example, when the Inflow element was created in the previous example, it was defined to have dimensions of volume per time (m^3/day). When elements are linked, GoldSim ensures dimensional consistency and carries out all of the unit conversions internally. For example, you could add meters and feet in an equation, and GoldSim would internally carry out the conversion. Note, however, that if you tried to add meters and hours, GoldSim would issue a warning message and prevent you from doing so.

As a result, when you use GoldSim, it is never necessary for you to carry out (error-prone) unit conversions.

Read more: Using Dimensions and Units (page 89).

Representing Uncertainty

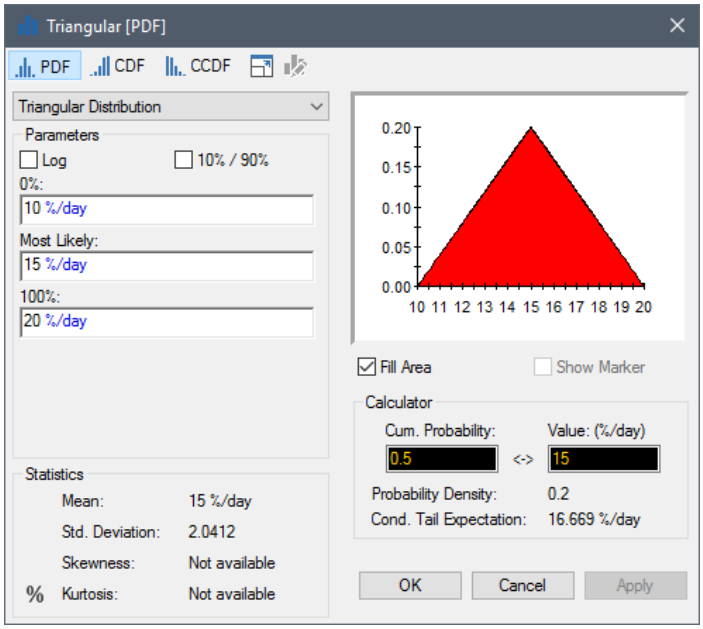
In many systems, you may be uncertain about some of the input parameters. In such a case, GoldSim allows you to define these parameters as probability distributions.

In the example presented above, suppose that we were uncertain of the leakage fraction. In particular, we will assume that rather than being 15%, the leakage fraction could be anywhere between 10% and 20% of the pond volume per day.

To represent this, we create a new ***Stochastic*** element (named Fraction), and modify the equation for Leakage as follows:

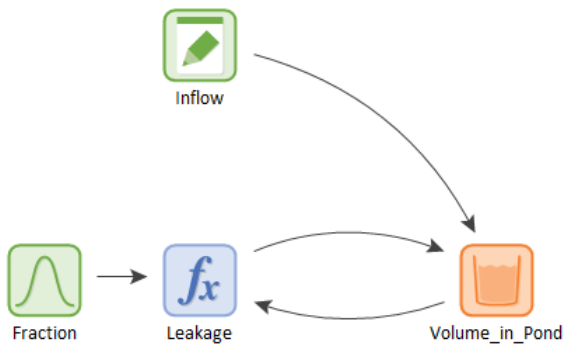
Leakage = Volume_in_Pond * Fraction

A Stochastic element is used to define a probability distribution. In this example, we will define Fraction (the leakage fraction) as a triangular distribution, with a minimum value of 10%/day, a most likely value of 15%/day, and a maximum value of 20%/day:



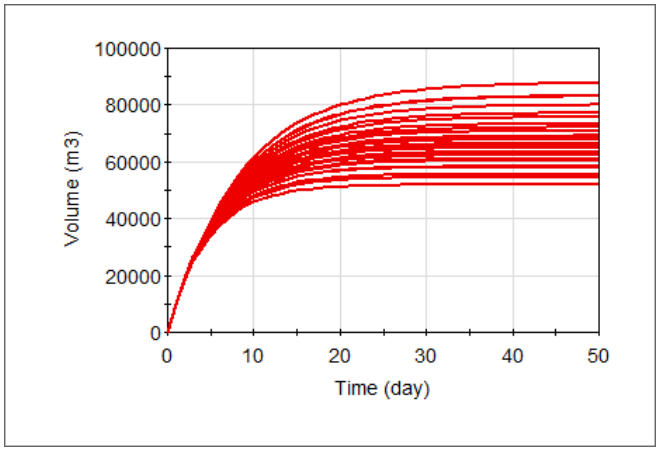
The type of probability distribution is selected from the list at the top of the dialog box. The parameters describing the shape of the distribution are defined under "Parameters".

The model would then look like this:

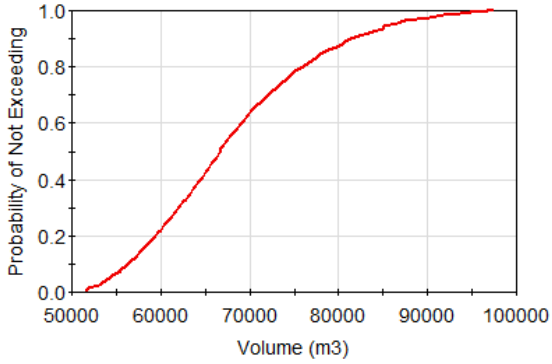


If the inputs to a model are uncertain, the outputs are necessarily uncertain. GoldSim *propagates* (translates) the input uncertainties into uncertainties in the results using ***Monte Carlo simulation***. In Monte Carlo simulation, the entire system is simulated a large number (e.g., 1000) of times. Each simulation is assumed to be equally likely, and is referred to as a ***realization*** of the system. For each realization, all of the uncertain parameters are sampled (i.e., a single random value is selected from the specified distribution describing each parameter). The system is then simulated through time (given the particular set of input parameters) such that the performance of the system can be computed.

This results in a large number of separate and independent results, each representing a possible "future" for the system (i.e., one possible path the system may follow through time). For example, 25 realizations of the pond example using an uncertain Leakage fraction produces 25 separate time history results:



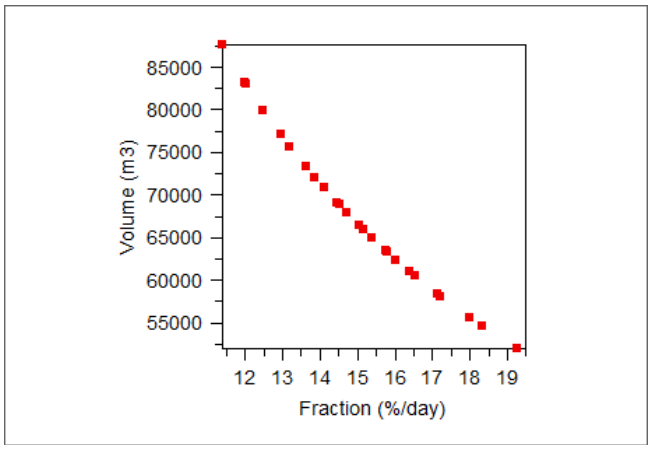
Another way to view these results is by plotting a probability of the final volume of water in the pond (after 50 days):



This plot (presented as a cumulative distribution function) indicates that the median final volume is about 65,000 m^3, and there is a probability that the final volume could be as high as about 95,000 m^3.

Probabilistic simulations are particularly useful because you can often use them to obtain a better understanding of the factors controlling the system.

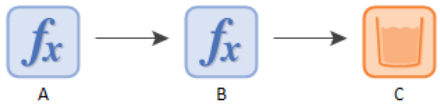
For example, by plotting the final volume in the pond as a function of the leakage fraction, we can better understand and quantify the sensitivity of the system to this key factor:



A primer on probabilistic simulation is presented in Appendix A.

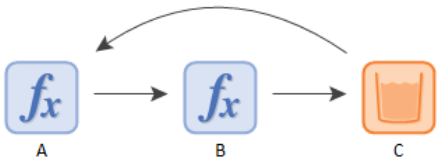
Representing Feedback Loops

Simple models have a direct chain of causality: input data affect some elements, which affect other elements, and so on, until eventually the elements which calculate the desired results of the model are reached:



GoldSim automatically analyzes your entire model to identify "who affects who", and ensures that the "upstream" elements are calculated prior to the "downstream" elements. At each time-step the elements are updated in this causality-based sequence.

Many systems, however, contain elements whose output can, directly or indirectly, affect one of their own inputs. This creates a looping or circular system (i.e., a "***feedback loop***").



Feedback loops are present in one form or another in most real-world systems, and can be readily modeled in GoldSim. The simple pond model presented previously is a good example of a system with a feedback loop. In the example above, A affects B which affects C, and then C “feeds back” to affect A and so on. That is, feedback loops represent a closed chain of cause and effect. Note that the terms “feedback” and “cause and effect” intentionally imply that the relationship between the variables is dynamic and the system changes over time (although systems with feedback loops can also reach a dynamic equilibrium).

In some cases, however, you may need to define circular logic in your model that is not dynamic at all. A simple simultaneous system of equations is an example of such a system. Such logic does not represent a feedback loop, in that there is no chain of “cause and effect” and no dynamics – in fact, the variables may not change with time at all. In GoldSim, these are referred to as ***recursive loops***, and they are treated differently from feedback loops. GoldSim can still solve such systems, but in order to do so, it is necessary for you to take some additional steps to define the sequence in which the calculations are carried out.

Read more: Evaluating Feedback Loops (page 361); Creating Recursive Loops Using Previous Value Elements (page 1033).

Simulating Delays

In many systems, a signal (e.g., a flow of material, a piece of information) is not transmitted instantaneously within a system or process, but instead is delayed. Examples include the movement of water though soils, the movement of material along a conveyor, and the transfer of information from one person to another.

Material or information can be conceptualized as moving through (transiting) a delay process. In some cases, the material or signal may be dispersed while in transit. For example, if you post 100 letters all at once, they will not be delivered all at once. Rather, there will be some variability in the time at which they are delivered (i.e., the delay time). In other cases, the material or signal is not dispersed. If a conveyor belt moves at a fixed speed, there will be no variability in the transit times for items that are placed on the conveyor.

Delays can have a major impact on the dynamics of a system, and it is therefore important to be able to represent them in a straightforward and realistic manner. GoldSim provides several types of powerful ***Delay elements*** to represent these delays.

Read more: Using Delay Elements (page 334).

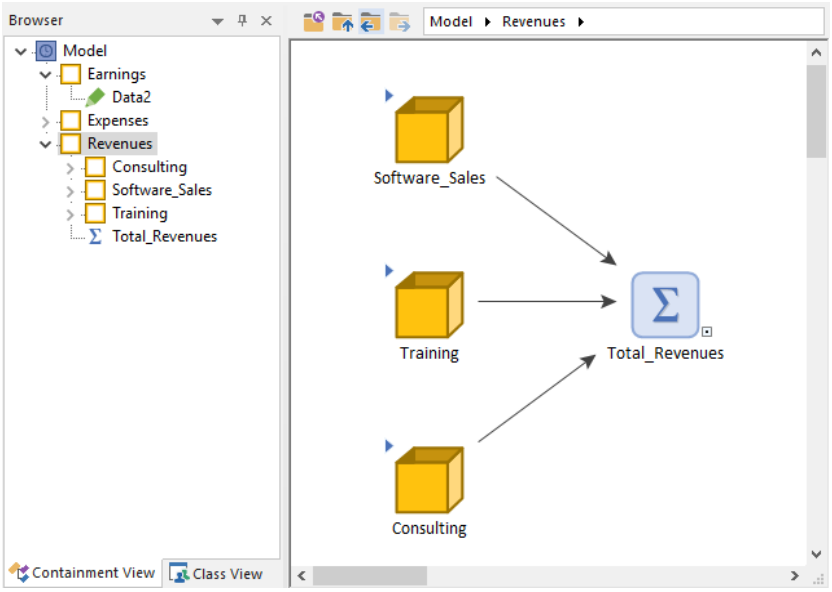
Building Hierarchical Top-Down Models

Complex models can have hundreds (or thousands) of elements. In order to manage, organize and view such a model it is useful (in fact, essential) to group the elements into ***subsystems***. A subsystem is simply a collection of elements.

Subsystems are created in GoldSim by placing elements into ***Containers***. A Container is simply a "box" into which other elements have been placed. In a sense, it is like a directory folder on your computer.

Containers can be placed inside other Containers, and any number of levels of containment can be created. This ability to organize model elements into a hierarchy provides a powerful tool for creating "top-down" models, in which the level of detail increases as you "push down" into the containment hierarchy.

The example below shows a system that has been divided into a number of distinct subsystems:



GoldSim provides an optional browser view of the system in a pane on the left of the window. The tree in the browser shows the containment hierarchy in a manner similar to how a computer's directory hierarchy is shown.

You can "drill down" into the next level of detail in the model by "opening" the Container. (One way to do this is by clicking on small triangle in the upper left-hand side of the Container.)

The ability to create hierarchical, top-down models, coupled with GoldSim's powerful documentation and presentation abilities, allows you to effectively describe and explain your model at different (and appropriate) levels of detail to different audiences.

Read more: Understanding Containers (page 96).

Additional Function Elements

Although you can create complex models using only the elements introduced in the previous sections, GoldSim provides a variety of additional elements that provide further modeling capabilities, including:

- **Logical elements**, which allow you to add easy-to-read logic diagrams to your models;
- A **Selector**, which provides a powerful and user-friendly way to create complex equations involving nested if…then logic; and
- An **Extrema**, which dynamically computes the highest or lowest values achieved by a specified parameter throughout a simulation (e.g., peak concentration in a river, minimum water level in a reservoir, minimum balance in a checking account).

Read more: Chapter 4: Using the GoldSim Elements (page 125).

Advanced Features

In addition to the basic features and capabilities discussed above, GoldSim provides a large number of advanced computational features which increase the power, flexibility and ease-of-use of the software. Several of these features are discussed below.

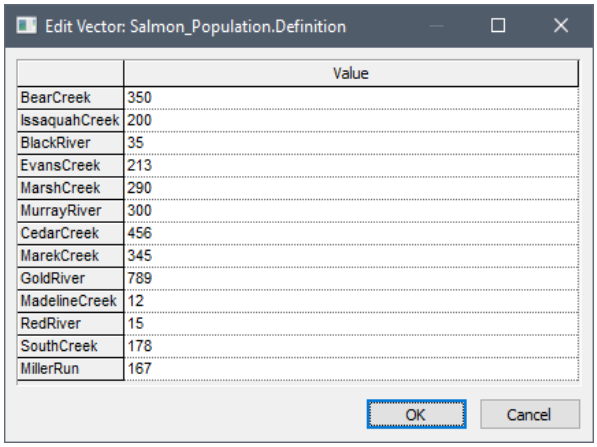
Manipulating Arrays (Vectors and Matrices)

In many systems, you will want to create and manipulate elements that represent collections of data, rather than individual items. For example, you may want to create an element that represents your company's revenue for each of five separate divisions, or an element that represents the salmon population in each of a number streams.

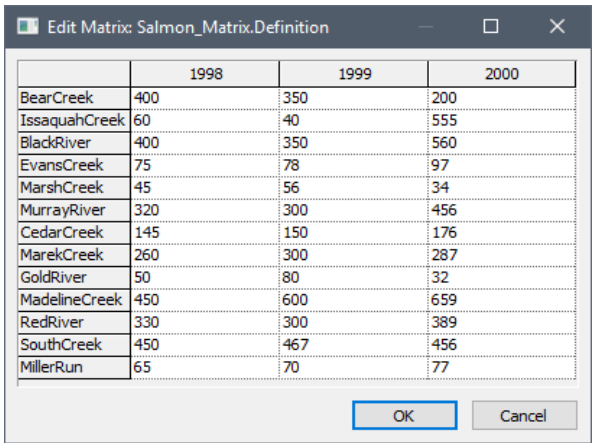
One way to do this, of course, would be to create separate elements for each object you wanted to model (e.g., five elements representing revenue, 13 elements representing salmon populations in different streams). Such an approach, however, is not desirable for two reasons:

- It could require you to create a very large number of elements (e.g., if you wanted revenues for 100 subgroups or wanted to evaluate salmon populations in 200 streams). This could result in very large, cluttered models.
- Usually, you will want to carry out the same types of calculations and operations on all related objects in such a collection (e.g., multiply all revenues by 2, compute the number of salmon eggs this year for all the streams based on the current salmon population). Having to do this individually for every object in a large collection would be very cumbersome and time-consuming.

To address these kinds of problems, GoldSim allows you to create and manipulate ***vectors*** and ***matrices*** (collectively referred to as ***arrays***). For example, you could create a vector Data element that represented the salmon populations in each of the streams, as shown below:



You could also create a matrix Data element that represented the salmon population in each of a number of streams for a period of 3 years, as shown below:



	1998	1999	2000
BearCreek	400	350	200
IssaquahCreek	60	40	555
BlackRiver	400	350	560
EvansCreek	75	78	97
MarshCreek	45	56	34
MurrayRiver	320	300	456
CedarCreek	145	150	176
MarekCreek	260	300	287
GoldRiver	50	80	32
MadelineCreek	450	600	659
RedRiver	330	300	389
SouthCreek	450	467	456
MillerRun	65	70	77

In addition to adding data in the form of vectors and matrices, you can manipulate these arrays in equations. For example, you could create an Expression element, and define it as:

2 * Salmon_Population

The output of the Expression would be an array, identical to the Salmon_Population array, except each item of the array would be two times greater. Note that if you did not use arrays to carry out this calculation, rather than creating 2 elements, you would need to create 26 elements (2 for each stream: 13 Data elements and 13 Expression elements) to accomplish the same thing!

If required, you can access a particular item of the array in an equation. For example,

Salmon_Matrix[BearCreek, 1999]

references a single (scalar) value representing the salmon population in Bear Creek in 1999.

GoldSim provides a wide variety of special operators which allow you to manipulate arrays. For example, if the name of the vector was Salmon_Population, the expression

Sumv(Salmon_Population)

would result in a single (scalar) value representing the sum of all items in the vector.

Read more: Using Vectors and Matrices (page 848).

Modeling Discrete Events

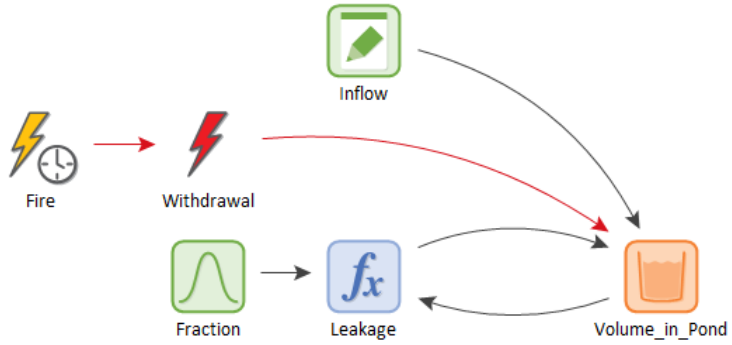
GoldSim provides powerful capabilities for superimposing the occurrence and effects of discrete events onto continuously varying systems. This allows for the realistic simulation of discrete events such as financial transactions, accidents, system failures, storms, labor strikes, and lawsuits. Events such as these can have important effects on the performance of many systems, and it is therefore important to represent them in a realistic manner.

GoldSim provides a variety of specialized elements for simulating the occurrence and consequences of discrete events. Events can be generated regularly ("occur exactly once a year on January 1"), randomly ("occur, on average, once a year"), or based on certain set of conditions (“when A is greater than B and the value of C has changed”). An event can trigger one or more consequences, such as changing the status of something in the model (“this task

is now complete"), achieving a specified milestone, or making a discrete change to some quantity in your model ("add $1000 to the account").

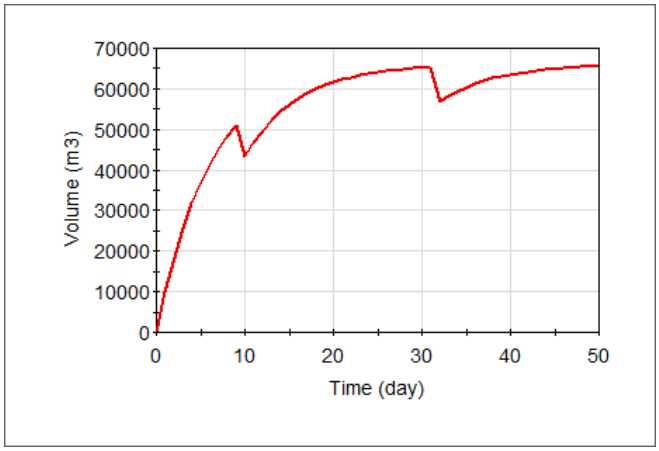
To provide an indication of how you can use this feature, let's add a simple event to the example involving the pond presented above in "A Simple Example". Suppose that water in the pond is used for fire suppression, and if a brush fire occurs nearby, firefighters withdraw 10,000 m^3 from the pond. Let's assume that it is summer, and there is a small fire nearby about once every 25 days.

We could simulate this using GoldSim's ***Timed Event*** and ***Discrete Change*** elements:



The Event "Fire" triggers the Discrete Change "Withdrawal" which modifies the Reservoir element representing the volume in the pond.

The result of such a simulation would look like this:



In this particular realization of the system, fires occurred around the 10th and 32nd days of the simulation. Because the event was specified as being random, it did not occur exactly every 25 days.

Read more: Chapter 5: Simulating Discrete Events (page 365).

Activating and Deactivating Portions of a Model

GoldSim provides the ability to make subsystems of your model (i.e., Containers) conditional. Conditionality allows you to make a Container and all of its contents inactive unless specific events occur and/or conditions are met. Elements in an inactive container are "dormant". That is, they are not updated or recalculated each timestep, and while they are inactive their output values never change. When other specific events occur and/or conditions are met, the Container (and its contents) can become active (and hence carry out their normal calculations). A conditional Container can activate and deactivate multiple times during a simulation.

Conditionality is a very powerful feature, and can be used to 1) temporarily "turn off" certain parts of your model (e.g., during a testing phase); or 2) simulate processes or features which themselves only exist or are active during certain parts of your simulation. This feature is particularly useful when using GoldSim to simulate projects.

Read more: Using Conditional Containers (page 968).

Controlling the Timestep in a Model

GoldSim provides a powerful timestepping algorithm that allows you represent the dynamics of your system very accurately. This includes the following:

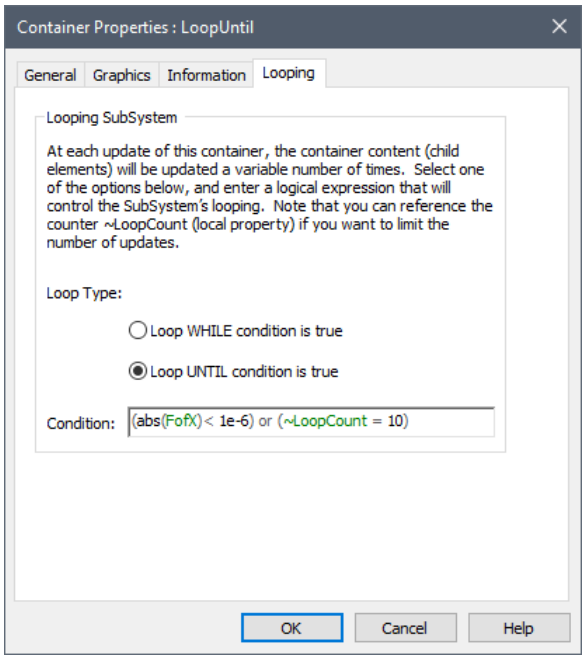
- You can define *Reporting Periods*, which compute and report *accumulated*, *average*, the *change* or the *rate of change* of values over specified periods (e.g., monthly, annually). Reporting Periods can be used in conjunction with a shorter "Basic Step" (e.g., you may model the movement of water or money through a system using a daily timestep, but need to report the cumulative amount of money or water that moved from one point to another each month)..
- You can increase or decrease the timestep length according to a specified schedule during a simulation (e.g., start with a small timestep, and then telescope out to a larger timestep). This can be useful, for example, if you know that early in a simulation, parameters are changing rapidly, and hence you need a smaller timestep.
- You can dynamically adjust (adapt) the timestep during a simulation based on the values of specified parameters in your model. For example, you could instruct GoldSim to use a timestep of 1 day if X was greater than Y, and 10 days if X was less than or equal to Y. Similarly, you could instruct GoldSim to use a short timestep for a period of 10 days after a particular event occurs, and then return to the default timestep.
- You can apply dynamic adaptive timestepping to specific Containers. This allows you, for example, to specify different timesteps for different parts (i.e., Containers) in your model. For example, if one part of your model represented dynamics that changed very rapidly (requiring a 1 day timestep), while the rest of the model represented dynamics that changed much more slowly (requiring a 10 day timestep), you could assign a 10 day timestep to the model globally, and a 1 day timestep to the Container representing the subsystem that changed rapidly.
- For some special types of systems, GoldSim provides additional dynamic timestepping algorithms (different from the timestep algorithms described above) to more accurately solve these equations. In particular, the Contaminant Transport Module utilizes dynamic timestep adjustment to accurately solve the coupled differential equations associated with mass transport.

Read more: Defining Reporting Periods (page 479); Advanced Timestep Options (page 484).

Carrying Out Iterative (Looping) Calculations

In some models, you may want to carry out an iterative calculation at each timestep. This might be useful, for example, if you have a coupled system of nonlinear equations that must be solved every timestep by iterating.

GoldSim allows you to create a Looping Container in which the elements inside are iteratively updated every timestep until a specified condition is met:



Such a looping calculation is facilitated by the fact that GoldSim also provides a specialized element that allows you to reference the previous value (of any variable in your model).

Read more: Using Looping Containers (page 1036); Referencing an Output's Previous Value (page 1030).

Dynamically Linking to Spreadsheets

GoldSim allows you to dynamically link a spreadsheet directly into your model.

In the simplest use of such a spreadsheet link, you can use the spreadsheet as a data source. In particular, a ***Spreadsheet element*** can import data from specified cells in a spreadsheet, assign specified units to these data, and make them available in your GoldSim model (as outputs of the element).

Note: When you import a row or column of spreadsheet cells into GoldSim (e.g., A1:A10), the data become items in a vector within GoldSim. When you import a range of cells involving multiple columns and rows (e.g., A1:E10), the data become items in a matrix within GoldSim.

In addition to importing data from a spreadsheet, you can use a spreadsheet as a custom element (with specific functionality). That is, you can dynamically send data from GoldSim to a spreadsheet, force the spreadsheet to recalculate, and then retrieve (updated) data from the spreadsheet back into GoldSim during a simulation (e.g., every timestep).

GoldSim also provides powerful capabilities to easily import lookup tables and time series data from spreadsheets to GoldSim. You can also readily export GoldSim results to a spreadsheet.

Read more: Spreadsheet Elements (page 982); Linking a Lookup Table to a Spreadsheet (page 319); Importing Data into a Time Series from a Spreadsheet (page 199); Exporting from a Time History Result Element to a Spreadsheet (page 786).

Importing Inputs from a Database

In simulations which require a great deal of input, it may be desirable (or even mandated) that the simulation model can access the various data sources directly to facilitate and ensure the quality of the data transfer.

As discussed above, one way to accomplish this in GoldSim is to import data from spreadsheets. GoldSim also provides a more powerful method. In particular, GoldSim input elements can be linked directly to an ODBC-compliant database. After defining the linkage, you can then instruct GoldSim to download the data at any time. When it does this, *GoldSim internally records the time and date at which the download occurred*, and this information is stored with the model results. This mechanism provides very strong and defensible quality control over your model input data.

Read more: Linking Elements to a Database (page 1107).

Building Custom Elements Using Scripts

In some situations, you may wish to define a complex function which cannot be readily implemented using the expression editing features supplied by GoldSim. For example, calculation of an output may require very complex logic which would be cumbersome to represent using a Selector element, or it may require a numerical solution technique (e.g., iteration); or perhaps you need to construct an array using complex logic.

To deal with such situations, you can specify a sequence of statements directly within the GoldSim interface using a Script element; in effect, building a custom element.

Scripts are created by inserting and editing statements or statement blocks, which may be variable definition statements, variable assignment statements, statements controlling the sequence of execution in the script (e.g., loops and if statements), or statements used for writing messages to the Run Log. The Script element sequentially evaluates the specified sequence of locally defined statements to determine its output(s).

Note: The Script element does not expect the user to learn or be familiar with a particular language. As a result, scripts are *not* created using a text editor. Rather, statements are inserted and edited within a "controlled environment" within the element's property dialog in which the user selects from a number of available statement types. The syntax is already defined for each type of statement – the user simply specifies the attributes and properties for each statement via a dialog box when the statement is inserted. Statements can subsequently be moved, deleted, and edited.

Read more: Script Elements (page 929).

Dynamically Linking to External Models

If GoldSim's built-in elements, the Script element or a dynamically-linked spreadsheet are not sufficient for representing a particular aspect of your model, you can dynamically link an external computer program directly to GoldSim. You must specify the parameters (outputs of existing GoldSim elements) which you wish to send to the external program, and the parameters that the external program will return to, and make available within, GoldSim.

In most cases, you need to only make minor modifications to the external program code to which you want to link in order for it to communicate with (i.e., be dynamically called by) GoldSim.

Note that this ability greatly increases the power and flexibility of GoldSim, allowing nearly any program to be dynamically linked into the dynamic, probabilistic and highly graphical GoldSim framework.

Read more: External (DLL) Elements (page 1004).

Building Large, Complex Models

In addition to the ability to build hierarchical models using Containers, GoldSim also provides a number of other features that were specifically designed to facilitate the construction, maintenance, and presentation of very large, realistic (and hence, often complex) models.

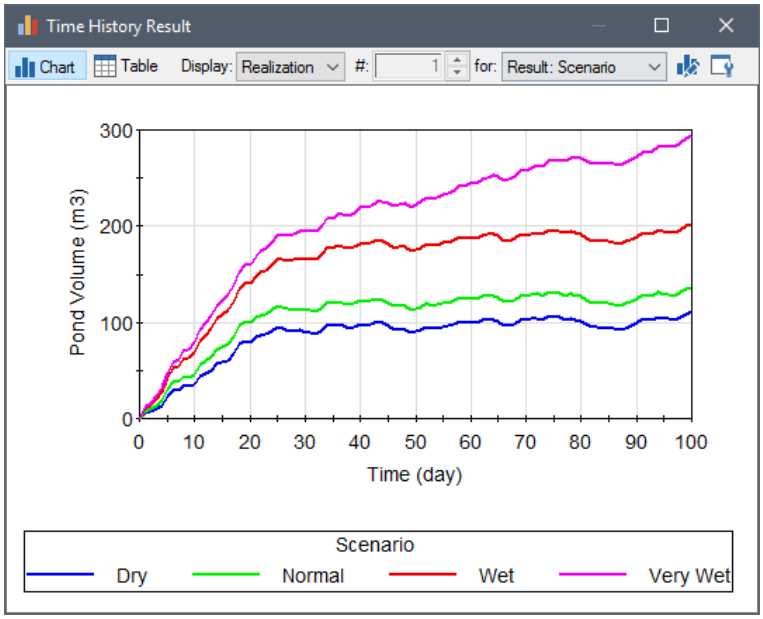
This includes:

- The ability to "localize" subsystems in your model so that variable names can be repeated without causing conflicts. This is particularly useful when your model contains numerous parallel systems (e.g., different divisions of a company), in which many of the equations and variable names would be identical. It also allows multiple people to work on different subsystems in a model without worrying about conflicting variable names.
- The ability to record versions (revisions) of a particular model file, so that you can identify the differences between the various versions of the file as the model is iteratively modified. (Which elements have changed? Which elements were deleted? Which elements have been added?)

Read more: Localizing Containers (page 1018); Tracking Model Changes (page 1099).

Modeling Scenarios

GoldSim provides a powerful capability that allows you to create, run and compare different scenarios for your model. Scenarios are differentiated by having different sets of input data. GoldSim's scenario modeling capability allows you to directly compare results generated by different sets of input parameters. In effect, when you use this capability, your model can store (and subsequently compare) multiple sets of outputs:



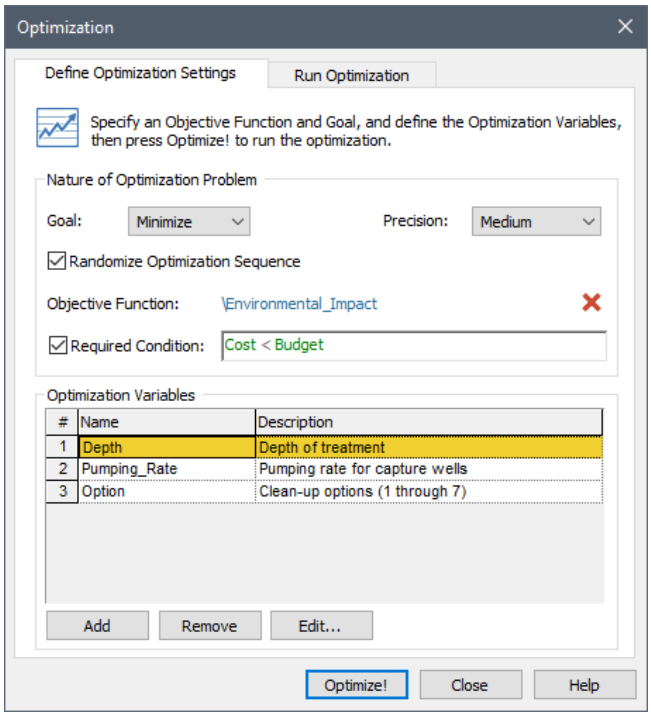
This can be very useful for carrying out sensitivity analyses, testing and comparing alternative designs, and asking "what if" questions.

Read more: Creating, Running and Comparing Scenarios (page 525).

Optimizing a Model

GoldSim provides the ability to carry out a special type of run to facilitate optimization of your model. For this type of run, you specify an objective function (a specific result that you would like to minimize or maximize), an optional constraint (a condition that must be met), and one or more optimization variables (variables in your model that you have control over).

GoldSim then runs the model multiple times, systematically selecting combinations of values for each of the optimization variables. By doing so, GoldSim can determine the values of the optimization variables that optimize (minimize or maximize) the objective function while meeting the specified constraint.



Typical uses of optimization include:

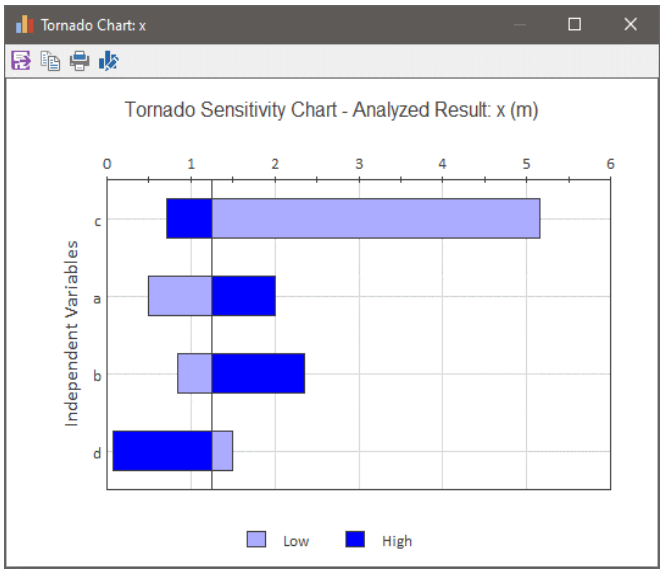
- Finding the best input data values for a model, in order to match observed historical data (i.e., calibration).
- Selecting the "best" option from among alternatives. "Best" could mean safest, cheapest, most reliable, or another appropriate measure.
- Optimizing the timing of actions or policy changes during the course of a simulation.

Read more: Running an Optimization (page 548).

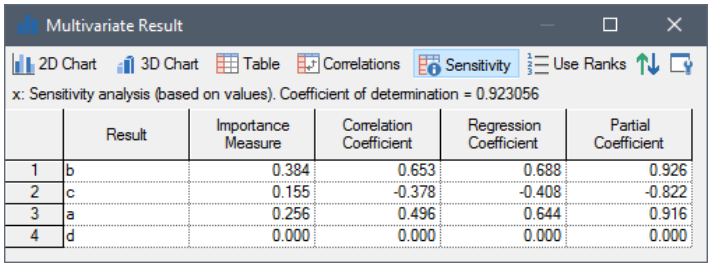
Carrying Out Sensitivity Analyses on a Model

GoldSim provides the ability to carry out a special type of run to facilitate sensitivity analyses. For this type of run, you specify the result you are interested in, and one or more variables that you want to analyze (which must be Stochastics or Data elements).

GoldSim then runs the model multiple times, systematically sampling each variable over a specified range, while holding all of the other variables constant. This then allows GoldSim to produce sensitivity plots (i.e., a tornado chart and X-Y function charts) to assist you in graphically identifying the variables in your model to which the result is most sensitive.



GoldSim also provides a second type of sensitivity analysis in which statistical sensitivity measures are computed by analyzing the results of multiple realizations of the model where all of the Stochastic variables are simultaneously sampled each realization:



	Result	Importance Measure	Correlation Coefficient	Regression Coefficient	Partial Coefficient
1	b	0.384	0.653	0.688	0.926
2	c	0.155	-0.378	-0.408	-0.822
3	a	0.256	0.496	0.644	0.916
4	d	0.000	0.000	0.000	0.000

Read more: Running Sensitivity Analyses (page 560); Viewing a Sensitivity Analysis Table (page 746).

Features for Documenting and Presenting Your Model

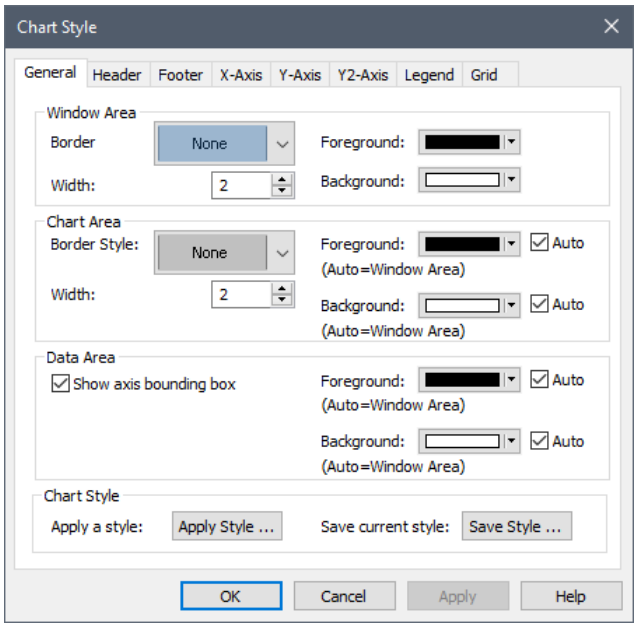
A model which cannot be easily explained is a model that will not be used or believed. As a result, GoldSim was specifically designed to allow you to effectively document, explain and present your model.

You can add graphics, explanatory text, notes and hyperlinks to your model, and organize it in a hierarchical manner such that it can be presented at an appropriate level of detail to multiple target audiences.

Creating Report Quality Result Graphics

GoldSim has powerful charting and display functions that allow you to plot and view your data in a variety of ways. You can plot time histories of your data, view probability distributions, create scatter plots and bar charts, and view tables of results. You can also combine multiple results on a single plot, and view multiple plots simultaneously. Using ***Result elements***, result charts and tables can be easily collected into one place for easy access within a model.

In addition, you can modify and save ***chart styles***, which allow you to customize (and reuse) the style (i.e., appearance) for each type of chart you may wish to produce:



Using these tabs, you have complete control over the appearance of your chart. You can customize the header, footer and legend, modify the chart axes, and change the data style (e.g., color, size and type of line). You can create also ***chart styles*****,** *which can subsequently be applied to similar charts.*

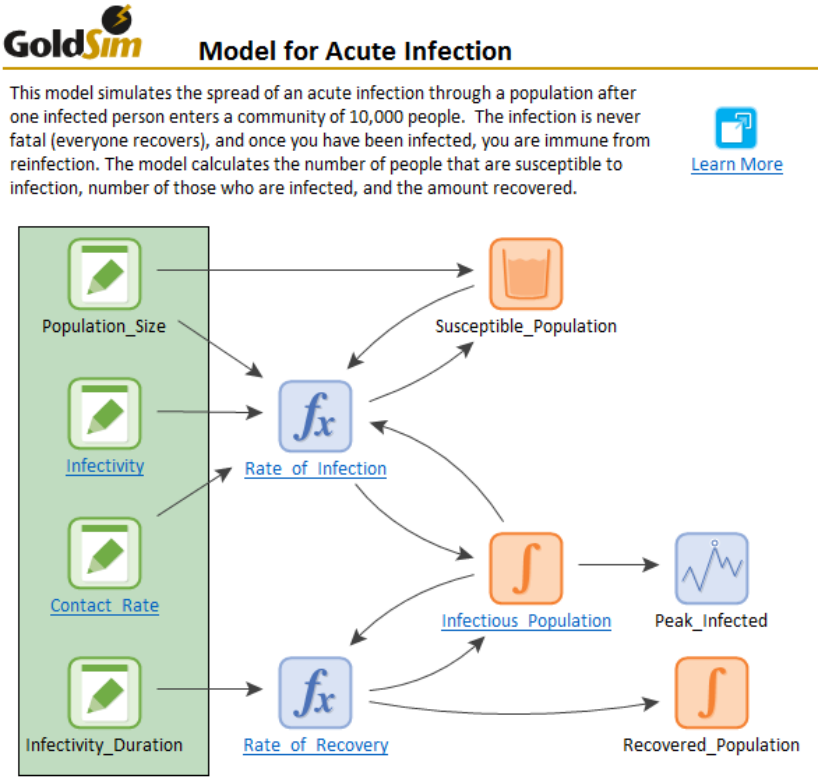
The charts and tables produced by GoldSim can be pasted into other applications (e.g., a word processor or a spreadsheet), or saved as separate graphics files.

Read more: Chapter 8: Displaying Results in GoldSim (page 577).

Internally Documenting Your Model

In order for a complex model to be understood and easily explained to others, it is critical that it be properly documented. GoldSim provides tools that allow you to internally document your model such that the documentation becomes part of the model itself, and hence is immediately available to anyone viewing the model.

GoldSim allows you to add text, images and other graphic objects directly to your model. In addition, you can add hyperlinks to other documents (e.g., a web site or a report). Clicking on the hyperlink then opens that document.



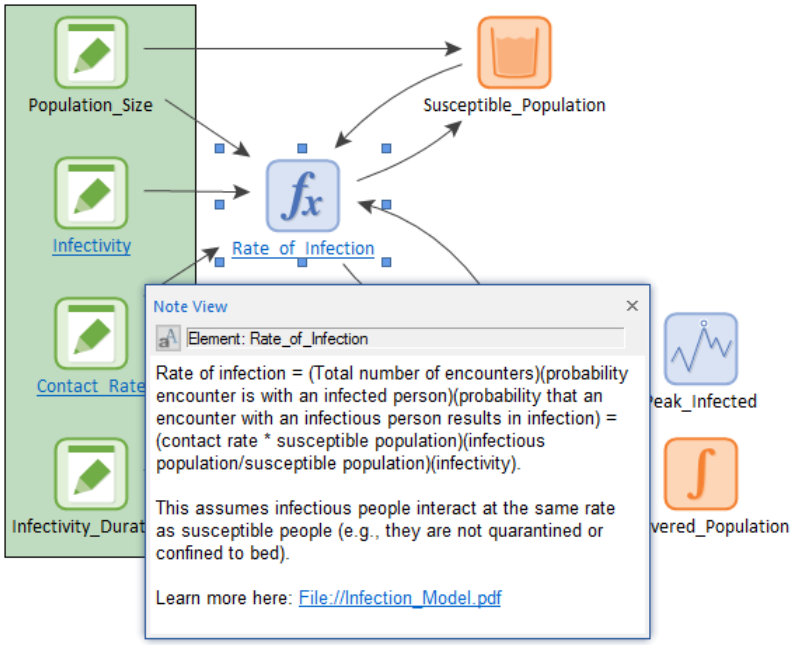
You can add text in any font or color, such as the title and description shown here. GoldSim provides drawing tools you can use to add text, lines, boxes (such as the one surrounding the four elements on the left) and other graphical objects. Hyperlink objects, such as the one labled "Learn More", can link directly to a separate document or a web site. You can also import graphics, such as logos (as seen here) or maps.

Note: To further facilitate documentation and presentation of your model, the default graphic images for a GoldSim element can be replaced by a custom image of your choice. For example, if a Reservoir element was being used to represent the population of a city, you could replace the default Reservoir image with an image of people or buildings.

Adding Descriptions and Notes

In addition to adding graphics, text and hyperlinks, you can provide a Description for each element. The Description is displayed in a tool-tip whenever you place your cursor over the element in GoldSim.

To provide more information, you can also attach a Note to any element in your model. Notes are text files of arbitrary length that are stored with the model:



Notes can include hyperlinks to documents or websites. In this example, the Notes links to a document stored in the same directory as the model file.

Using GoldSim as a Presentation Tool

As discussed previously, GoldSim was specifically designed to allow you to organize model elements into a hierarchy (using *containers*). This facilitates the creation of "top-down" models, in which the level of detail increases as you "push down" into the containment hierarchy.

Such a capability is essential if you wish to effectively describe and explain your model at different levels of detail to different audiences. For example, your manager may only want to see the "big picture", while a technical colleague may want to see the low-level details of a particular model.

The ability to create hierarchical, top-down models, in which at any level, details can be "hidden" (inside containers), coupled with GoldSim's powerful documentation features, allows you to design models which can be effectively explained to any audience at the appropriate level of detail.

Read more: Chapter 9: Documenting and Presenting Your Model (page 803).

Specialized GoldSim Modules

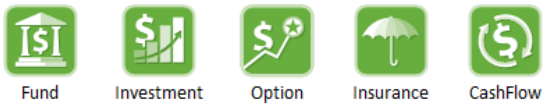
Although the standard elements incorporated within GoldSim can be used to build powerful and complex models, it was realized from the outset of the development of GoldSim that in some situations specialized elements and features may be required in order to efficiently model some kinds of systems. As a result, GoldSim was designed to readily facilitate the incorporation of additional modules (program extensions) to enable the program to address specialized problems.

Because extension modules can be highly specialized, they are described in separate documents.

The existing GoldSim extensions are briefly described below.

Financial Module

The Financial Module allows you to probabilistically simulate financial systems that include components such as accounts and funds, investments, options, projects or undertakings with specified cash flows, and insurance policies:



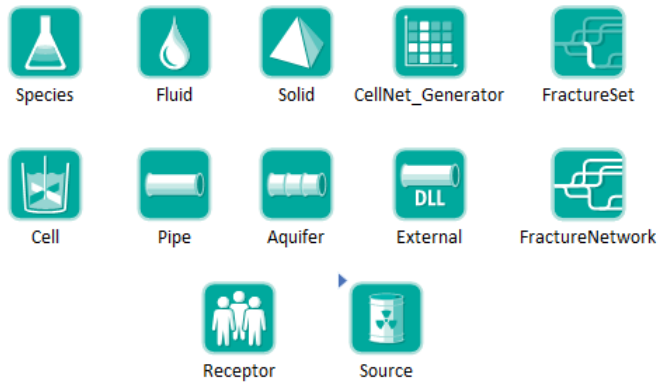
The Financial Module adds these five specialized elements to GoldSim.

By combining the specialized financial elements in the Financial Module with GoldSim's underlying probabilistic, dynamic simulation framework, you can quickly simulate and analyze complex financial systems, as well as complex engineering and business systems that have a financial component.

The Financial Module is described in detail in the **GoldSim Financial Module User's Guide**.

Contaminant Transport Module

The Contaminant Transport Module consists of specialized elements for representing contaminant species, transport media, transport pathways, contaminant sources, and receptors, and the coupled sets of differential equations underlying these systems:



The Contaminant Transport Module (RT version) adds these twelve specialized elements to GoldSim.

Note: Two versions of the Contaminant Transport Module are available (called CT and RT). RT is a premium version of the Contaminant Transport Module, and contains some specialized features and elements not included in the CT version.

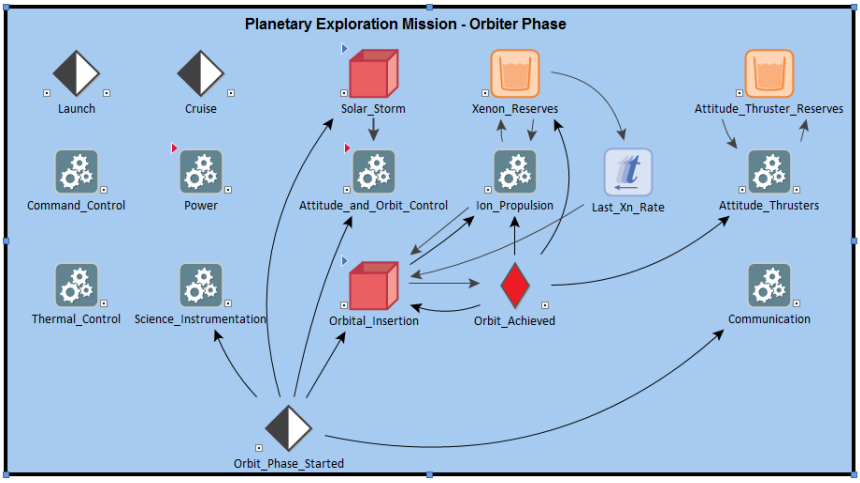
By linking these environmental elements together (and integrating them with GoldSim's basic elements), you can build complex contaminant transport simulations.

The Contaminant Transport Module is described in detail in the **GoldSim Contaminant Transport Module User's Guide**.

Reliability Module

The GoldSim Reliability Module allows you to probabilistically simulate the reliability of complex engineered systems over time. GoldSim provides the ability to model the interdependence of components through requirements and fault trees, as well as the capability to define multiple independent failure modes for each component.

The fundamental outputs produced by the Reliability Module consist of predicted reliability metrics (e.g., reliability, maintainability and availability) for the overall system, and for individual components within that system. In addition, GoldSim catalogs failure scenarios, which allows for key sources of unreliability to be identified.



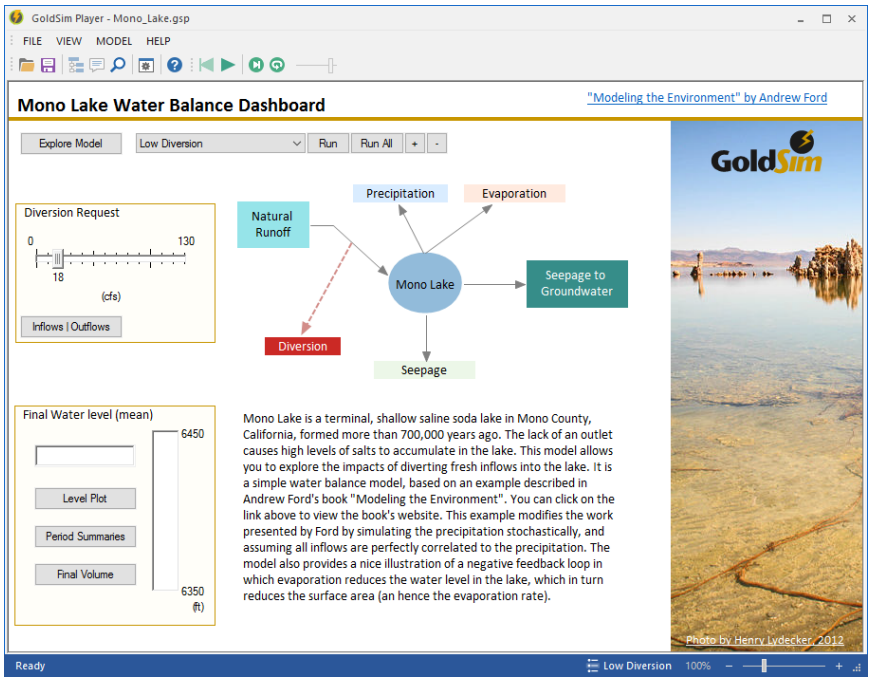
The Reliability Module can be used to:

- evaluate the reliability performance of systems and ascertain their compliance with customer or regulatory requirements;
- investigate the impact of the operational environment on system reliability; and
- simulate the effects of reliability on system throughput, or on other user-defined metrics.

The Reliability Module is described in detail in the **GoldSim Reliability Module User's Guide**.

Dashboard Authoring Module

GoldSim provides a set of tools that allow a GoldSim modeler to design and construct "dashboard" interfaces for models. The interfaces can be designed to look like "dashboards" or "control panels", with buttons, gauges, sliders and display panels, and the author can imbed instructions, tool-tips and graphics to provide instructions on the use of the model. Such an interface allows a model to be easily used by someone without requiring them to be familiar with either the GoldSim modeling environment or the details of the specific model:



In effect, the Dashboard Authoring tools enable you to use GoldSim as a high-level programming language to create custom simulation applications for distribution to end users who may not necessarily be modelers. Users do not need to have a licensed version of GoldSim to view and run a "dashboarded" model. They simply need to download the free GoldSim Player.

Read more: The GoldSim Player (page 55).

The Dashboard Authoring tools are incorporated into all versions of GoldSim. They are described in detail in a separate document, the **GoldSim Dashboard Authoring Module Users Guide**.

Distributed Processing Module

Monte Carlo simulation, in which multiple realizations of a system are simulated, naturally lends itself to distributed processing, since each realization is totally independent of the others. GoldSim has the capability to utilize multiple computers (linked over a network such as a LAN or even the Internet) to carry out probabilistic simulations of a system. Such a feature greatly facilitates probabilistic simulation of highly complex systems (in which a single realization may take many minutes or even hours).

The Distributed Processing Module is described in detail in the **GoldSim Distributed Processing Module Users Guide**.

The GoldSim Player

The GoldSim Player is a special version of GoldSim that allows you to "play" or “read” an existing GoldSim model without having to license the GoldSim software.

In general, the user interface for the GoldSim Player is identical to that of the full GoldSim version, with menu options and controls for editing the model removed or disabled. You can view and navigate any GoldSim model using the GoldSim Player. This allows a modeler to distribute a model to others without requiring them to license GoldSim.

If a Dashboard was created for the model using the Dashboard Authoring Module, you can even modify selected inputs and run the model using the GoldSim Player.

The GoldSim Player can be downloaded (for free) from the GoldSim Web site (www.goldsim.com/player).

Read more: Dashboard Authoring Module (page 54); Creating a GoldSim Player File (page 844).