User Manual

Software Version: 2017-06
June 21, 2017

Table of Contents

1 Introduction

JaamSim (Java Animation Modelling and Simulation) is a discrete-event simulation software package first developed in 2002 as the foundation for simulation applications. JaamSim includes a drag-and-drop graphical user interface, 3D animation, and a full set of built-in objects for model building. It is object oriented, extremely fast, and scalable to the largest of applications. Windows, Linux, and OSX are all supported.

JaamSim is free open-source software, licensed under Apache 2.0. The latest version of the software and manuals can be downloaded from the JaamSim website: www.jaamsim.com. The source code is published on GitHub: www.github.com/jaamsim/jaamsim. Presentations and tutorials for JaamSim can be found by following the Videos link on the JaamSim website.

JaamSim provides all the key functions needed for any simulation model:

- Controls for launching and manipulating simulation runs;
- Drag-and-drop user interface;
- Interactive 3D graphics;
- Input and output processing; and
- Model development tools and editors.

JaamSim also provides a full suite of built-in objects for model building, including:

- Objects for process flow type models (servers, queues, etc.);
- Objects for modelling continuous processes (integrator, PID controller, etc.
- Text objects for labelling and documentation;
- Graphs for visualizing simulation outputs;
- Probability distributions for random sampling; and
- Graphical objects for background maps and logos.

Advanced users can create additional palettes of application-specific objects. A separate Programming Manual can be downloaded from the JaamSim website.

2 Installing and Running JaamSim

2.1 System Requirements

JaamSim runs under Windows, Linux, and OSX on most modern computers. Any computer with an Intel Core i3, i5, and i7 series processor is sufficient for JaamSim (second generation "Sandy Bridge" processor and later).

For models with complex 3D graphics, a NVIDIA GeForce graphics card is recommended. Workstation-type graphics cards such as NVIDIA Quadro series also work well, but do not provide improved performance over less expensive GeForce cards. Although it is possible to use a computer with an AMD graphics card, NVIDIA cards generally provide better support for OpenGL graphics and are preferred for JaamSim.

2.2 Installing Java

JaamSim requires a recent (Version 7 or later) installation of the Java Runtime Environment (JRE), available for download free-of-charge from www.java.com.

The default JRE for Windows computers is the 32-bit version, in which case the 32-bit version of JaamSim must be used.

For computers running 64-bit Windows, the 64-bit version of JaamSim offers improved performance. To obtain the 64-bit version of the JRE, follow the link "See all Java downloads" and select "Windows Offline (64-bit)".

It is acceptable to install both the 32-bit and 64-bit JREs on the same computer.

2.3 Installing JaamSim

JaamSim consists of a single executable that can be copied directly to the user's computer. No special installation program is required. Copy the JaamSim executable file to a working directory, such as the directory that will contain the model input files.

Three versions of the JaamSim executable are available for each release:

- JaamSimYYYY-NN.exe (the 64-bit executable for Windows)
- JaamSimYYYY-NN_x86.exe (the 32-bit executable for Windows)
- JaamSimYYYY-NN.jar (the executable jar file for Windows, Mac OSX, and Linux)

JaamSim releases are denoted by the year of release (YYYY) and by release number (NN) within the year.

If JaamSim does not run correctly on your computer, the most likely cause is an older graphics driver. Updating the driver to the latest version will solve the problem.

2.3.1 Mac Computers with the Retina Monitor

Mac computers with the Retina monitor require the use of the "Display Menu" app that can be downloaded from the Apple App Store. This app compensates for the non-standard way in which

Apple uses the higher resolution of the Retina monitor. If JaamSim is launched without this app, it will not be possible to select objects using the mouse.

2.4 Running JaamSim from the GUI

JaamSim can be launched by double-clicking on the executable file.

2.5 Running JaamSim from the Command Line

JaamSim can also be launched, configured and started automatically from the command line or a batch file using the command:

```
JaamSim.exe config1.cfg -tags
```

or, when using the .jar file:

```
java -jar JaamSim.jar config1.cfg -tags
```

Here, config1.cfg is the name of the input file to be loaded and -tags are the optional tags for the run. Multiple tags must be separated by a space. The following tags are supported:

Table 2-1 Batch Mode Run Tags

Tag	Description
-b or -batch	Starts the simulation immediately after the input file has been read, and exits when the run has completed. This tag is useful for batch file execution.
-m or -minimize	Minimizes the graphical user interface, allowing the simulation to run slightly faster when visualizations are not required (for instance, in overnight simulation runs).
-s or -script	Directs JaamSim to accept configuration file inputs piped to JaamSim through standard-in and to direct its outputs specified by the RunOutputList keyword to standard-out. The .jar file (jaamsim.jar) must be used with this feature, not the executable (jaamsim.exe).
-h or -headless	Runs JaamSim without the graphical user interface so that it can be executed on a server that has no graphics capability. Batch mode (-b) is set automatically with this option.

It is also possible to load two or more configuration files into a single model using the following command:

```
JaamSim.exe config1.cfg config2.cfg -tags
```

or,

```
java -jar JaamSim.jar config1.cfg config2.cfg -tags
```

Multiple simulation runs can be executed one after the other by using a batch file that contains a series of these commands. For example, a batch file containing the following two lines would execute two runs: run1.cfg and run2.cfg:

```
JaamSim.exe run1.cfg -b
JaamSim.exe run2.cfg -b
```

Note that the batch file and input configuration files must be in the same directory for this example to work.

JaamSim can be interfaced with other software packages using the -s (script) tag. For example, the following command instructs JaamSim to load the configuration file config.cfg and then accept additional configuration file inputs from program1. The outputs specified by the RunOutputList keyword for Simulation are then directed as inputs to program2.

```
program1.exe | java -jar JaamSim.jar config.cfg -s -b | program2.exe
```

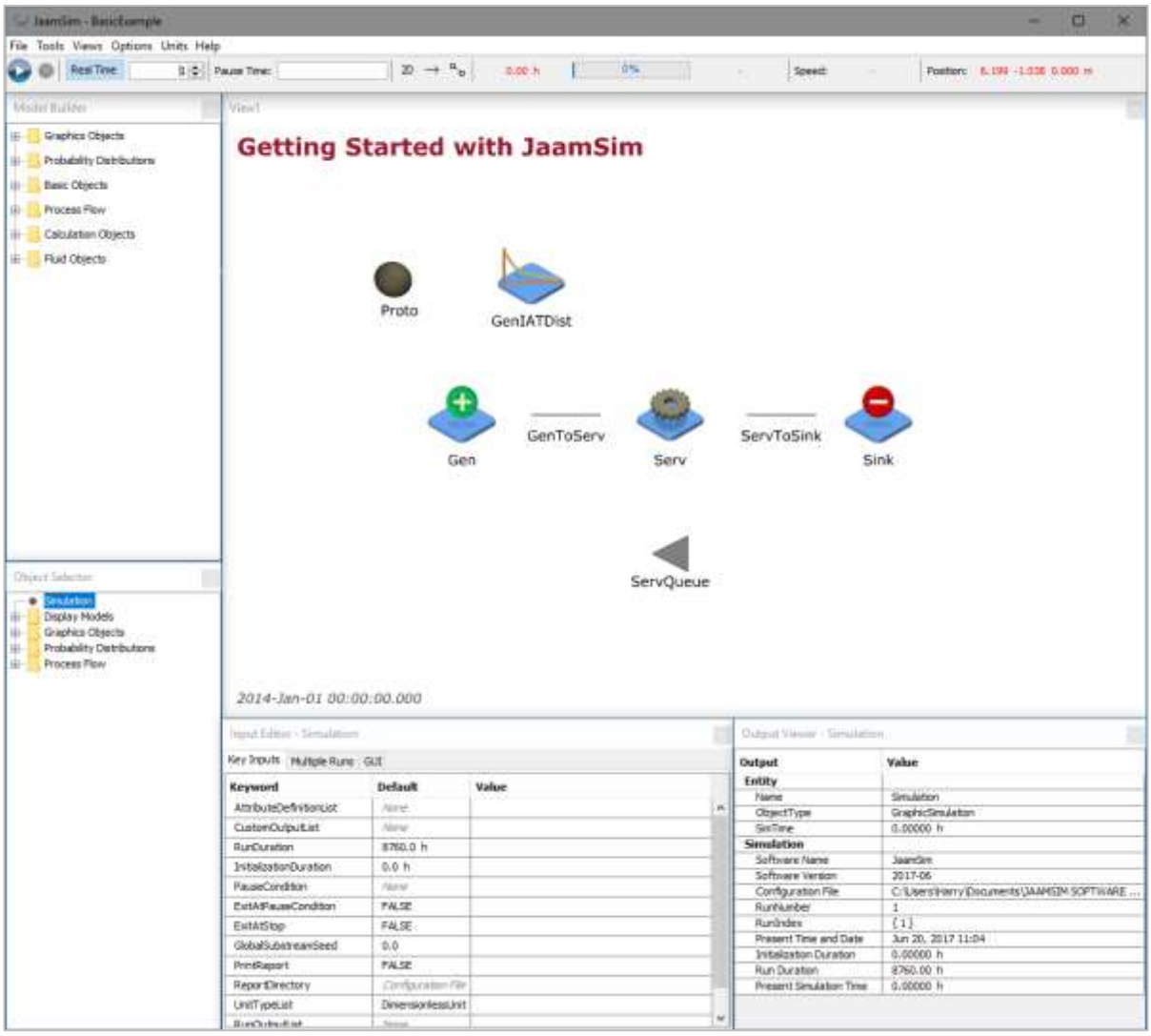
At present, the script tag is supported only for the .jar file version of JaamSim - it does not work with the .exe file version.

Note that “java -jar” must be used in this command for standard-in and standard-out to be connected correctly to JaamSim. Without the "java -jar" portion of the command, the java virtual machine sets both standard-in and standard-out to null.

3 JaamSim Basic Example

In this example, you will be guided through building a basic model using the graphical user interface (GUI). The example model simulates a typical single-server queuing system, with entities being generated, processed, and consumed. The finished model is shown below.

Figure 3-1 Screenshot of the JaamSim Basic Example



This example is divided into four steps:

- Step 1: Creating Model Objects
- Step 2: Putting the Object Together
- Step 3: Changing Model Graphics
- Step 4: Adding a Probability Distribution

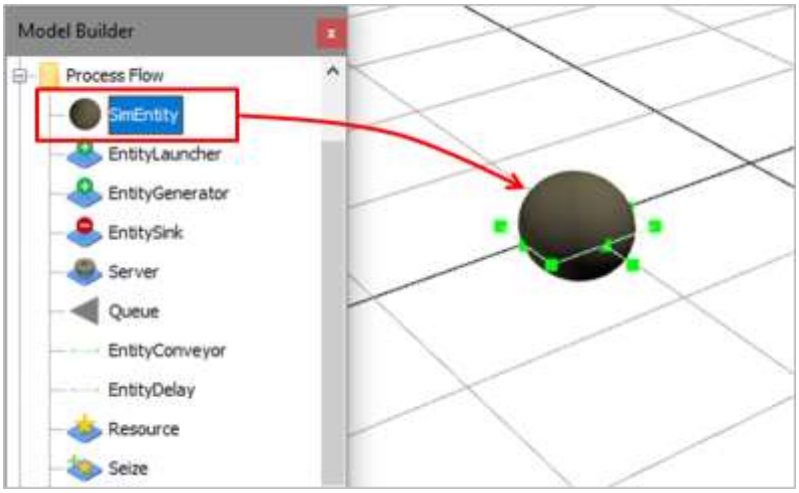
3.1 Step 1: Creating Model Objects

After launching JaamSim, the following windows will appear:

- Control Panel – provides a number of run control features;
- View Window – displays a graphical representation of the model;
- Model Builder – offers a selection of objects that can be added to the model;
- Object Selector – lists the objects present in the model;
- Input Editor – allows for editing of keywords for a selected object; and
- Output Viewer – displays outputs for a selected object.

In the Model Builder, expand the Process Flow palette and then drag-and-drop a SimEntity into the View Window (View1). This creates a SimEntity object with a default name (SimEntity1) and shape (Sphere) and automatically selects it, denoted by green highlighting as below.

Figure 3-2 SimEntity Dragged to the View Window



This object will serve as the prototype for entities that will be processed in the model. In the Object Selector, select SimEntity1 and press F2 to rename the object as 'Proto'.

Table 3-1 SimEntity Object to Create

Model Builder Palette	Object Type	Name
Process Flow	SimEntity	Proto

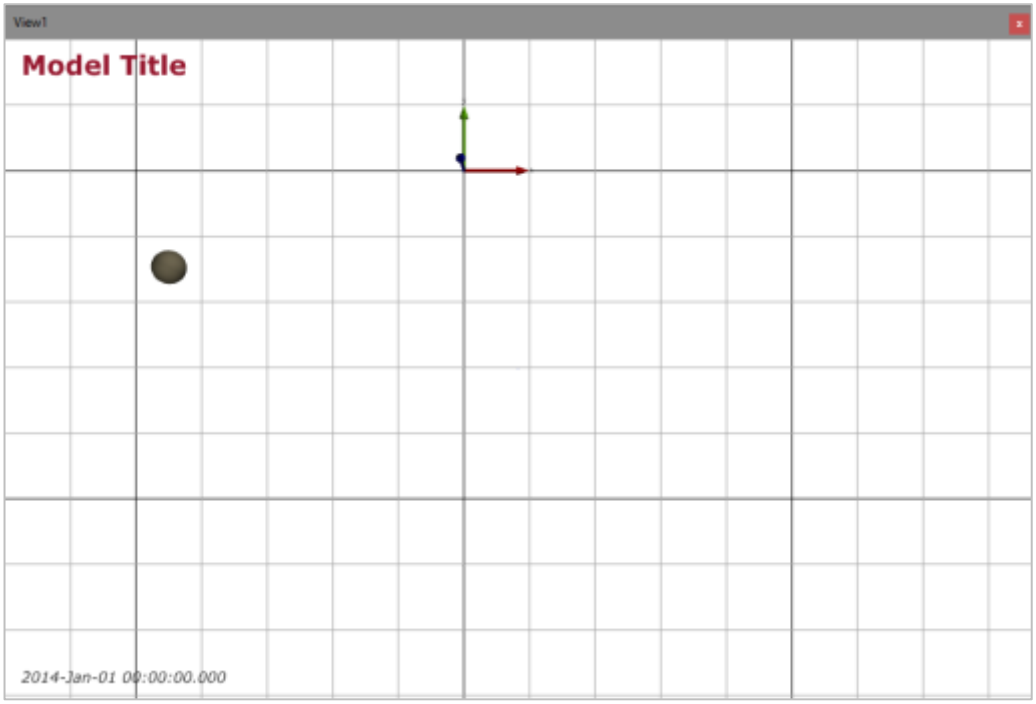
Since the model graphics will be 2D, aside from the Proto entity, click the '2D' button on the Control Panel, so that the view becomes bird's eye. Adjust the viewing position using the actions listed below.

Table 3-2 View Adjustments

Action	Description
Left Click + Drag	Pan in the XY-plane
Scroll Wheel	Zoom in or out

After adjusting the view position and zoom, the View window should appear similar the following figure.

Figure 3-3 Configured View Window



Now create and rename the objects listed below:

Table 3-3 Additional Objects to Create

Model Builder Palette	Object Type	Name
Process Flow	EntityGenerator	Gen
Process Flow	EntityConveyor	GenToServ
Process Flow	Server	Serv
Process Flow	EntityConveyor	ServToSink
Process Flow	EntitySink	Sink
Process Flow	Queue	ServQueue

It is often easier to rename an object by turning on its label, which can then be edited. Start by right-click on the object and selecting 'Show Label'. Then double-click on the label and enter the new name. Changing an object's label causes it to be renamed accordingly. Renaming is completed by pressing the Return button or by clicking elsewhere in the View window. The label can be left in place or it can be turned off by right-clicking on the object and de-selecting 'Show Label'.

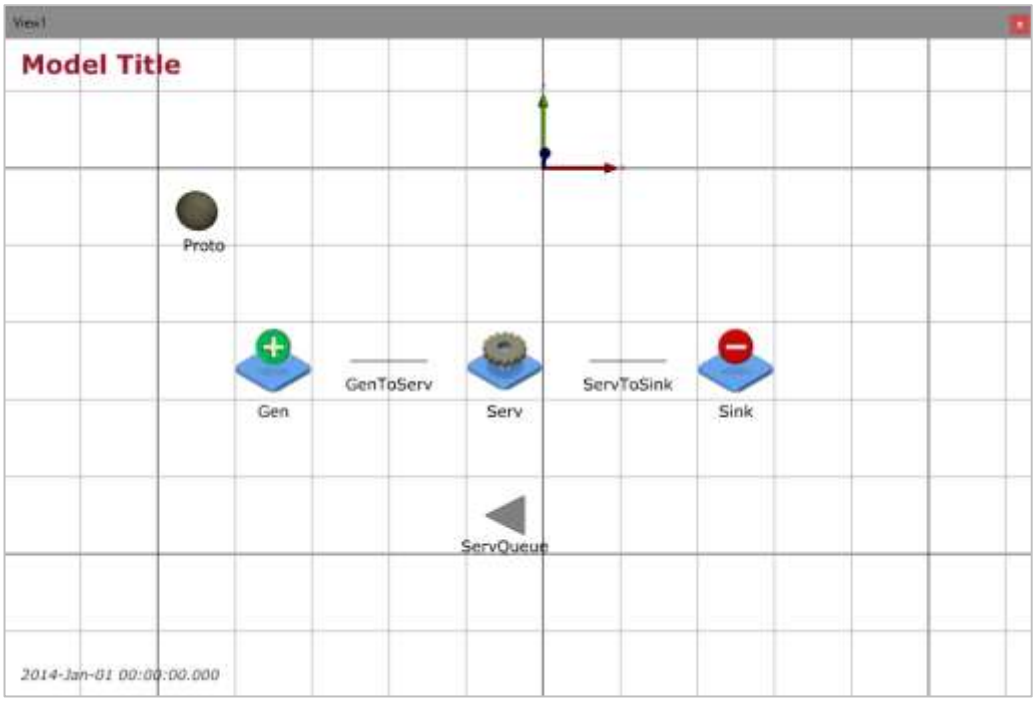
An object can be moved by selecting it and using CTRL + Left Click + Drag. The position of a label relative to its object can be changed using the same method. Position the first five objects from left to right in the following order:

Gen - GenToServ - Serv - ServToSink - Sink

Place the final object, ServQueue, below the Serv object.

After positioning the objects, the model should look similar to the following figure.

Figure 3-4 Screenshot of Step 1



3.2 Step 2: Putting the Objects Together

In this step, the objects placed in Step 1 must be set to interact with one another. Connect the objects together by setting the keyword values listed below.

Table 3-4 Object Connections

Object	Keyword	Value
Gen	PrototypeEntity	Proto
Gen	NextComponent	GenToServ
GenToServ	NextComponent	ServQueue
Serv	WaitQueue	ServQueue
Serv	NextComponent	ServToSink
ServToSink	NextComponent	Sink

The PrototypeEntity input tells the EntityGenerator to make copies of the SimEntity named Proto. The NextComponent input tells each object where to send the generated SimEntities after it has finished its processing. The WaitQueue input tells the Server to store its waiting SimEntities in the Queue named ServQueue.

Model inputs are normally set using the Input Editor. However, for the setting inputs that specify the flow of entities through a model, it is often more convenient to use the 'Create Entity Links' and 'Show Entity Flow' buttons on the Control Panel. Depressing the 'Show Entity Flow' button will display an

arrow between objects as the flow connections are made. Depressing the 'Create Entity Links' button allows the user to make the above connections by clicking on each object in the order in which the SimEntities flow through the model. In this case, click on the objects in the following sequence:

Proto – Gen – GenToServ – ServQueue – Serv – ServToSink - Sink

If you make a mistake, you can interrupt the connection process by clicking on the background, and start again with the next object to be connected. When finished, click on the 'Create Entity Links' button again to de-activate it. You can confirm the connections by checking the relevant inputs using Input Editor.

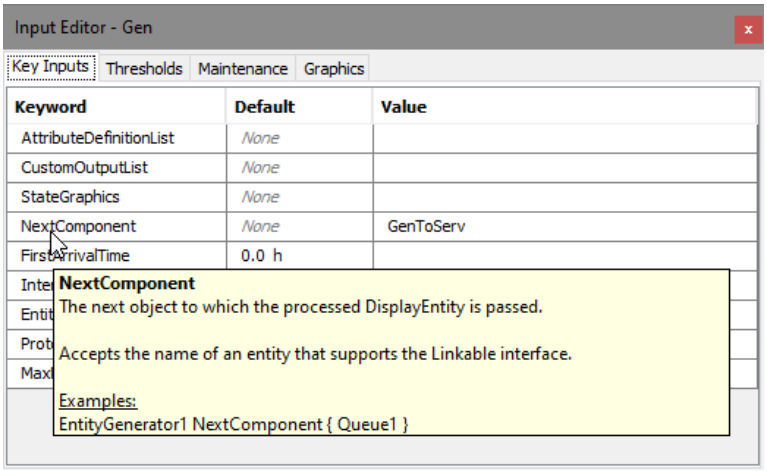
Now, use the Input Editor to set remaining inputs, i.e. the time at which Proto entities will be added to the model by Gen, and the time that entities will spent at each stage of the model.

Table 3-5 Transit and Handling Durations

Object	Keyword	Value
Gen	InterArrivalTime	2 s
GenToServ	TravelTime	1 s
Serv	ServiceTime	1 s
ServToSink	TravelTime	1.5 s

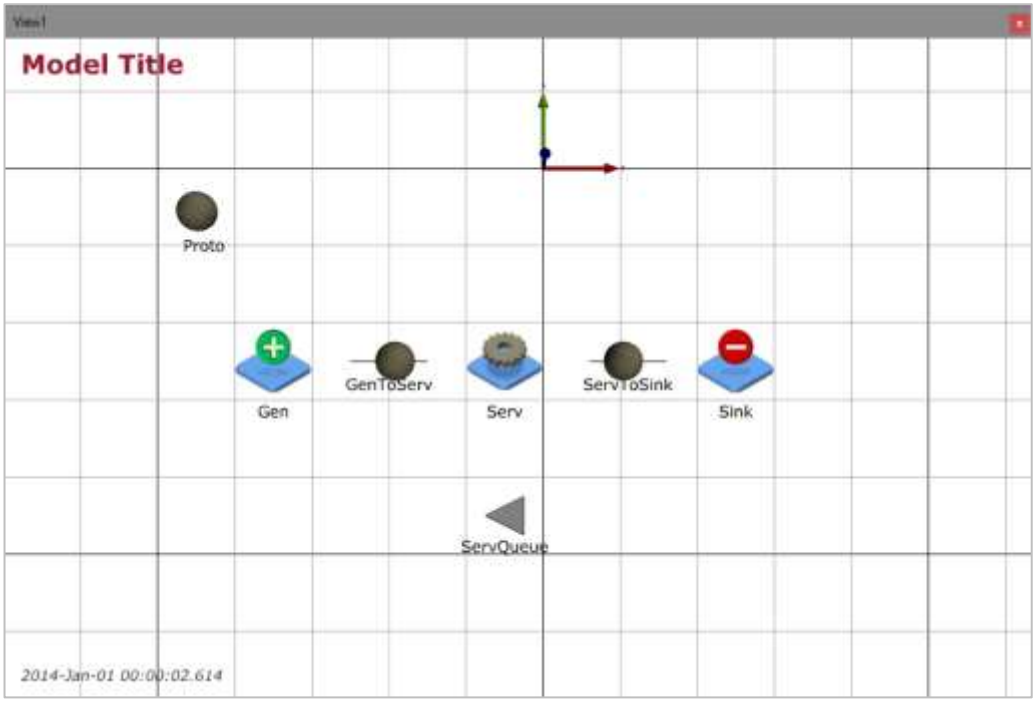
Hovering the cursor over keywords in the Input Editor will display a brief description of the keyword. For example, the mouse-over for the NextComponent keyword is shown in the following figure.

Figure 3-5 Mouse-Over Tooltips



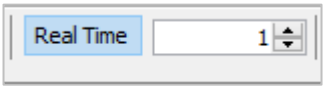
Save the model by selecting 'Save As…' from the File menu, and press the Play button to run the simulation. The model should appear similar to the following screenshot.

Figure 3-6 Screenshot of Step 2



Note that the Real Time button in the Control Panel is depressed, as shown below.

Figure 3-7 Real Time Controls



This indicates that the model speed is restricted to the Real Time speed multiplier shown in the text box to the right of the Real Time button. The Real Time speed multiplier controls how fast the simulated time elapses in the model. The default Real Time speed multiplier is 1, meaning that each real (wall-clock) second corresponds to one simulated second. It can be changed by entering the desired Real Time speed multiplier into the text box, or by pressing the up or down arrow buttons (which double or halve the Real Time speed multiplier factor respectively).

To continue, Pause or Reset the model by selecting the corresponding buttons on the Control Panel. Pausing the model allows the simulation to resume later starting from the paused time, while resetting the model forces the model to start from time zero.

3.3 Step 3: Adding a Probability Distribution

In this step, dynamic variability is added to the model by including a probability distribution to control the inter-arrival time of Proto entities.

Create an exponential distribution object as listed below.

Table 3-6 Object to Create for Step 3

Model Builder Palette	Object Type	Name
Probability Distributions	ExponentialDistribution	GenIATDist

Set the keyword values for GenIATDist as shown below.

Table 3-7 GenIATDist Inputs

Tab	Keyword	Value
Key Inputs	UnitType	TimeUnit
Key Inputs	MinValue	0 s
Key Inputs	MaxValue	10 s
Key Inputs	Mean	2 s

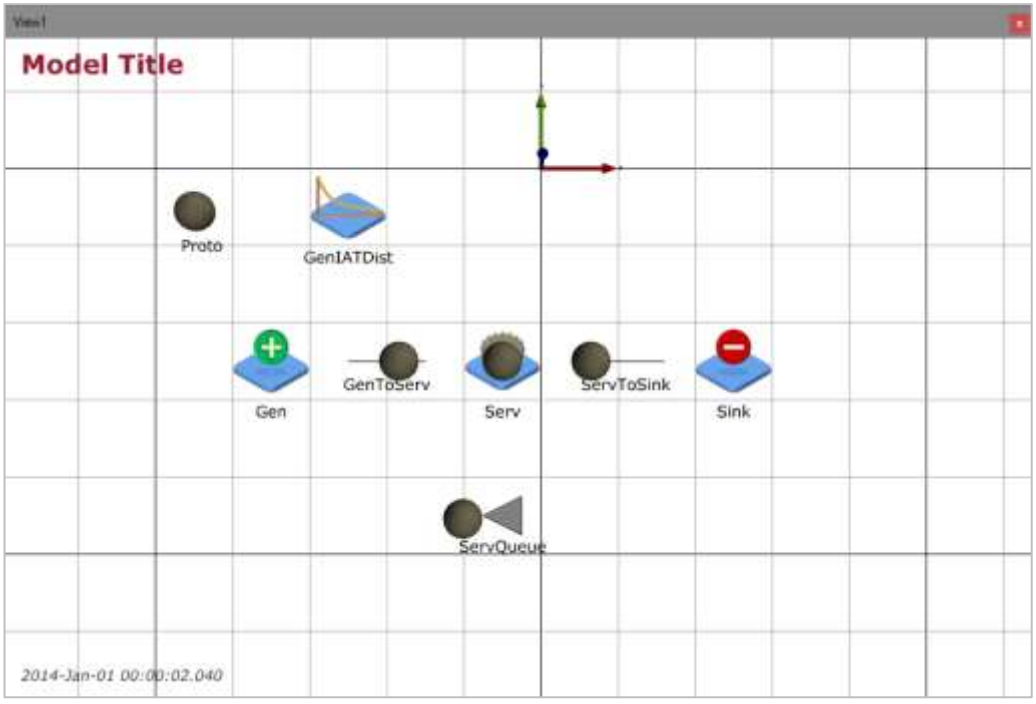
Update the Gen object to sample the GenIATDist distribution for its interarrival time:

Table 3-8 Gen Inputs

Tab	Keyword	Value
Key Inputs	InterArrivalTime	GenIATDist

Save the model again and press Play. Observe that the Proto entities are now generated randomly, and that there are now times when Proto entities are waiting in ServQueue to be processed, as seen in the following figure.

Figure 3-8 Screenshot of Step 3



3.4 Step 4: Changing Model Graphics

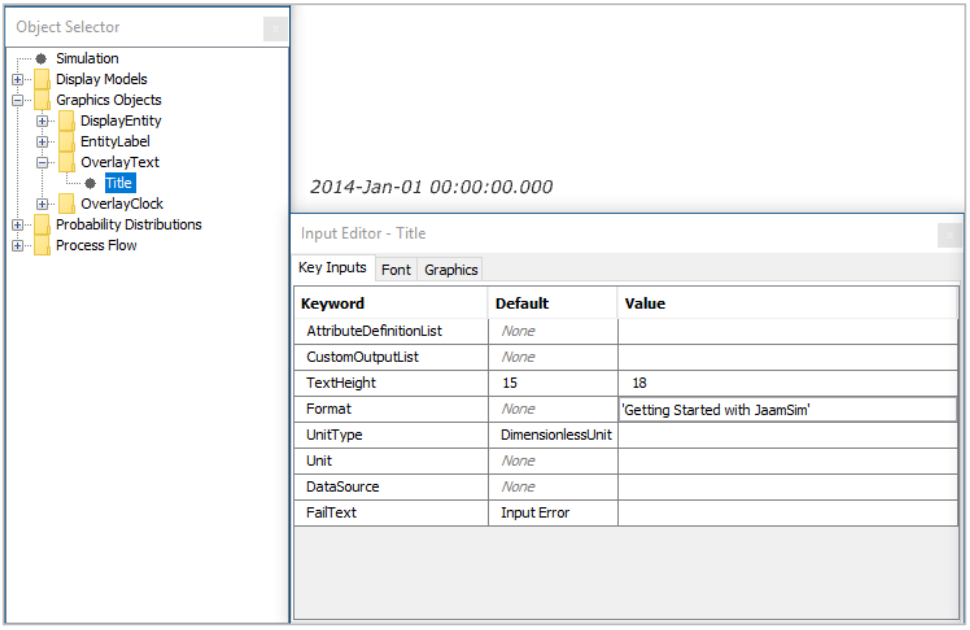
In this step, some graphical adjustments will be made to improve the appearance of the model. While the changes in this step will not impact the functionality of the model, graphics are invaluable when confirming proper operation in more complex models. For the basic example model, the changes are very simple:

- Turn off the XYZ-Axis display
- Turn off the background grid
- Add a title for the model

The first two tasks can be performed by clicking on the Options menu item on the Control Panel and de-selecting the entries 'Show Axes' and 'Show Grid'.

The model's title changed as follows. In the Object Selector, expand the OverlayText palette under Graphics Objects. Now, select the object named 'Title', and enter the new name in the Input Editor under the Format keyword, as shown in Figure 3-9.

Figure 3-9 Changing the Model Title



The model should now look the same as Figure 3-1, shown at the start of this section.

4 Graphical User Interface

The graphical user interface (GUI) consists of the Control Panel, one or more View windows, the Model Builder, the Object Selector, the Input Editor, and the Output Viewer.

4.1 Control Panel

The Control Panel provides a number of run controls and output displays to monitor and control the progress of a simulation run. The Control Panel for an example simulation run is shown in the figure below.

Figure 4-1 JaamSim Control Panel

The Control Panel is divided into two rows, consisting of the Menu Bar and the Tool Bar:

4.1.1 Menu Bar

File

The File entry displays a menu with actions related to saving and loading model input configuration files.

Table 4-1 File Menu

Menu Entry	Description
New	Launches a new-blank model with no objects defined
Open	Loads a saved input configuration file
Save	Saves the model under the present input configuration file name.
Save As…	Saves the current model as a new input configuration file.
Import…	Imports one or more 3D models or images. Creates both the ColladaModels/ImageModels containing the graphics and the corresponding DisplayEntities.
Print Input Report	Prints the present inputs in a standard file format (.inp).
Exit	Closes all windows and exits JaamSim.

Tools

The Tools entry displays a menu that provides options for showing the windows of the JaamSim graphical user interface:

Table 4-2 Tools Menu

Menu Entry	Description
Show Basic Tools	Shows the four main tools: Model Builder, Object Selector, Input Editor, and Output Viewer.
Close All Tools	Closes all of the tools that are open.
Model Builder	Drag and drop creation and placement of simulation objects.
Object Selector	Tree listing of all objects in the present simulation model.
Input Editor	View and edit keyword inputs for the selected simulation object.
Output Viewer	Key output values of the selected object.
Property Viewer	Detailed list of the internal properties of the selected object.
Log Viewer	Console for viewing input warnings and error messages.

The Property Viewer is typically used by programmers who are developing and debugging JaamSim applications, and so its usage is beyond the scope of this manual.

Views

The Views entry displays a menu containing a list of currently defined View windows and provides the ability to create new Views. A View window shows a graphical 3D representation of the model.

Table 4-3 Views Menu

Menu Entry	Description
View1	Opens the window for View1, the default View. Does nothing if the window has already been opened.
Define New View	Creates a new View object and displays its window.

Options

The Options entry in the menu bar contains the following entries:

Table 4-4 Options Menu

Menu Entry	Description
Snap to Grid	If checked, an object being dragged with the mouse will automatically position itself to the nearest grid point.
Show Axes	If checked, coordinate axes are displayed at the origin (0, 0, 0) of the coordinate grid.
Show Grid	If checked, the coordinate grid is displayed on the xy-plane.
Always On Top	If checked, the control panel will always remain on top of other windows.
Graphic Debug Info	If checked, information on video memory usage and rendering time will be shown as an overlay on the View windows.

Units

The Units entry in the menu bar is used to set the units in which to display model outputs in the Control Panel, Output Viewer, and output reports. The default values in the Input Editor will also be displayed in the selected unit.

For example, if you want simulation time to be displayed in seconds instead of hours, select TimeUnit from the submenu of unit types and click on the entry labelled 's'. With this change, the Control Panel will display simulation time in seconds and every output in the Output Viewer with units of time will be displayed in seconds.

Note that the choice of output unit has no effect on the internal calculations in a simulation model. Furthermore, model inputs can always be entered in any valid unit.

Help

The Help entry in the menu bar displays a single menu option that shows the software version number and copyright information.

4.1.2 Tool Bar

The left side of the Tool Bar contains controls for manipulating the simulation run and the 3D view for the active View window. The right side shows the status of the simulation run with parameters such as the elapsed simulation time.

Run Controls

The following controls are provided for starting, pausing, and resetting a simulation model and for controlling its execution speed.

Table 4-5 Run Controls

Tool Bar Item	Description
Run/Pause Simulation	Starts, pauses, and resumes the simulation run.
Reset Simulation	Stops the model, clears any generated entities, and sets the simulation time to zero.
Real Time Mode	If pressed, the simulation speed is held to a constant multiple of wall-clock time.
Speed Multiplier	The ratio of simulated time to wall-clock time that is used when the Real Time mode is set.
Pause Time:	The time at which the software automatically pauses the simulation. Accepts numbers with time units (e.g. 500 h, 1 y) or date/time format (`hh:mm:ss.s` or `'YYYY-MM-DD hh:mm:ss.s'`).

Misc. Buttons

A number of buttons are provided to change display features and to assist in model building.

Table 4-6 Misc. Buttons

Tool Bar Item	Description
2D	Moves the camera for the active View window to a bird's eye view directly above the xy-plane of the simulation and locks it in this position.
 Show Entity Flow	When selected, arrows are shown between objects to indicate the flow of entities.
 Create Entity Links	When selected, entities are linked when selection is changed. For example, left-clicking on a Server and then on an Assign object, will set the NextComponent input for the Server to the Assign object.

Run Status

The right side of the Tool Bar consists of indicators to illustrate the progress and status of the simulation run:

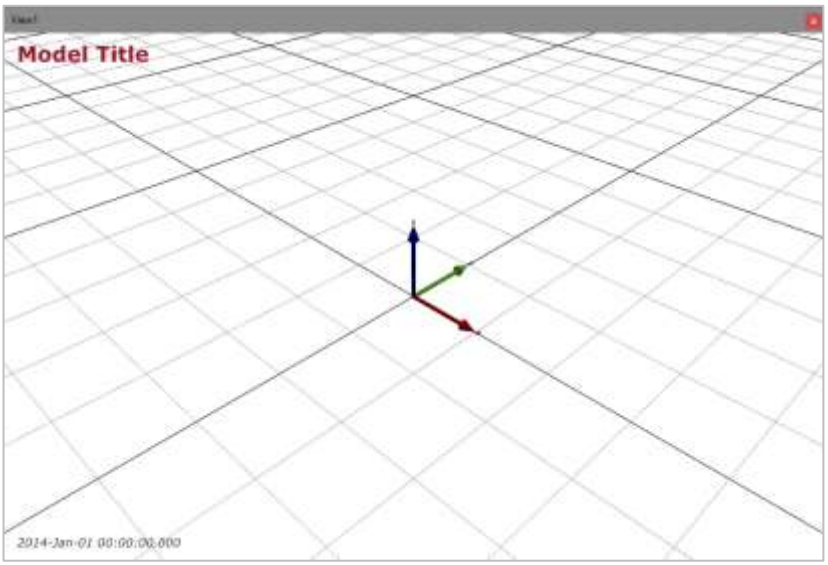
Table 4-7 Run Status

Tool Bar Item	Description
Simulation Time	The present simulation time, displayed in the Preferred Unit for time (see Section **Error! Reference source not found.**).
Run Progress	Percentage of the simulation run that has been completed.
Remaining Time	Wall-clock time remaining until the simulation run is completed.
Achieved Speed Multiplier	The ratio of elapsed simulated time to wall-clock time.
Position	Location of the mouse cursor in the active View window expressed in (x, y, z) coordinates.

4.2 View Windows

View windows display a graphical representation of a simulation. Multiple View windows can be defined depicting different parts of a model. Each View window is an instance of a View object and can be modified. The following screenshot shows the default View window.

Figure 4-2 Default View Window



4.2.1 Default Graphical Objects

When a new model is created, a default View window is created with some default graphical objects: XY-Grid, XYZ-Axis, Title, and Clock.

The XY-Grid and XYZ-Axis objects are intended as visual aids for placing new objects, and as such they are regular static graphics DisplayEntity objects. The Movable keyword is set to FALSE for both objects, so that they cannot be moved accidentally and do not respond to mouse clicks.

The other two objects are a placeholder for the model title and a clock to show simulation time. These objects are overlay objects (OverlayText and OverlayClock, respectively) that appear in a fixed position on the View window and are not part of the 3D scene.

The position and format of the default objects can be modified through the Input Editor. The Title and Clock objects can be deleted using the Object Selector. The XY-Grid and the XYZ-Axis objects can be turned on or off through Options items in the Menu Bar.

4.2.2 Camera Movement

The basic camera movements are zoom, pan, and orbit. Scrolling the mouse wheel zooms the camera in and out. Clicking and dragging the mouse cursor pans the camera around the View window. Dragging the mouse with the right-button depressed causes the camera to orbit around the current point of interest. These movements are described in more detail in the following table, along with various other useful camera manipulations.

Table 4-8 View Camera Controls

Mouse/Keyboard Action	Effect
Left Click	Selects the point of interest. The point on the surface of the object under the cursor becomes the point of interest. If no object is under the cursor, the point on the xy-plane is used.
Scroll Wheel	Zooms the camera in or out. The camera is moved towards or away from the point of interest. One click moves the camera 10% closer to or farther away from the point of interest.
Left Drag	Pans the xy-plane. The camera is moved in the xy-plane from its present position but the cursor stays fixed on the same point in the View. The point of interest is reset to the cursor position.
Shift + Left Drag	Pans the z-axis. The camera is moved along the z-axis from its present position so that the cursor stays fixed on the same point in the View. The point of interest is reset to the cursor position.
Right Drag	Orbits the camera. The camera orbits left/right and up/down around the point of interest, following the mouse movement.
Shift + Right Drag	Look around. The camera looks left/right and up/down, following the mouse movement. The point of interest is unchanged.

4.2.3 Moving and Resizing Objects

Individual objects can be moved around using mouse controls that are analogous to the camera controls. To avoid moving an object accidentally, it is necessary to hold the Control key during any movement. After selecting an object in the Object Selector or by clicking on it in a View window, its position, size, and orientation can be manipulated interactively by holding the Control key and dragging the entire object, a corner of the object, or its rotation handle using the mouse. By default, dragging an object moves it in the xy-plane. An object can be moved in the z-direction by holding down both the Control and Shift keys and dragging the object up and down.

These actions are described in more detail in the following table.

Table 4-9 Moving and Resizing Objects

Mouse/Keyboard Action	Effect
Left Click	Selects the object. The object under the cursor is selected for input/output viewing and for repositioning, resizing, or rotating. The selected object is indicated by a green rectangle bordering it. Green handles allow the object to be resized or rotated.
Control + Left Drag	Moves the object parallel to the xy-plane, while holding its z-coordinate constant, following the cursor.
Shift + Control + Left Drag	Moves the object parallel to the z-axis, while holding its x-coordinate and y-coordinate constant, following the cursor.
Control + Left Drag on a Handle	Resizes/rotates the object. The selected object is resized or rotated using the selected handle.

4.2.4 Moving and Reshaping Linear Objects

In addition to the standard controls described above, linear objects, such as Arrow objects, can be reshaped by adding, removing, and moving individual points.

The actions for linear objects are described in the following table:

Table 4-10 Moving and Reshaping Linear Objects

Mouse/Keyboard Action	Effect
Left Click on the Line	Selects the line. The line under the cursor is selected for input/output viewing and for repositioning, resizing, or rotating. The selected line turns green, and coloured handles appear at each point in the line. The start of the line is coloured blue, the end is coloured yellow, and intermediate points are coloured green.
Control + Left Drag on the Line	Moves the entire line in the xy-plane. The selected line is moved in a plane parallel to the xy-plane, following the cursor.
Shift + Control + Left Drag on the Line	Moves the entire line along the z-axis. The selected line is moved along the z-axis, following the cursor.
Control + Left Drag on a Handle	Moves location of the point in the xy-plane. The lines on either side of the point adjust to following the point.
Shift + Control + Left Drag on a Handle	Moves the location of the point along the z-axis.
Alt + Control + Left Click on the Line	Adds a new point and handle to the line.
Shift + Alt + Control + Left Click on an Intermediate Point	Deletes the point and reconnects the points on either side of the deleted point.

4.2.5 Context Menu

Right-clicking displays a list of all objects under the cursor. Selecting one of these objects displays the context menu for the selected object shown in the following table. If only one object is under the cursor, the context menu is displayed right away. A right click is ignored if no object is under the cursor.

Table 4-11 Context Menu Entries

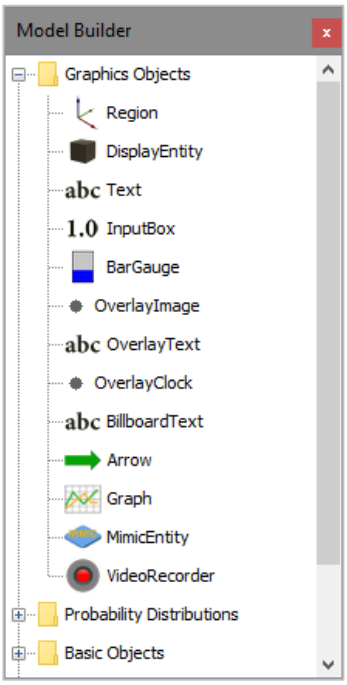
Menu Item	Description
Input Editor	Selects the object and opens its Input Editor window. Information for the selected object is shown in Input Editor, Output Viewer, and the Property Viewer.
Output Viewer	Selects the object and opens its Output Viewer window. Information for the selected object is shown in Input Editor, Output Viewer, and the Property Viewer.
Property Viewer	Selects the object and opens its Property Viewer window. Information for the selected object is shown in Input Editor, Output Viewer, and the Property Viewer.
Duplicate	Creates a copy of the selected object in the current View window.
Delete	Deletes the selected object.
Change Graphics	Opens a dialog box to select a new DisplayModel graphical representation for the selected object.
Show Label	Creates an EntityLabel object that displays the present name of the selected object. The object's name can be changed by double-clicking on the EntityLabel and editing the displayed name.
Set RelativeEntity	Allows the position of the object to be set relative to the position of a second object. If the second object is moved, the first object moves with it.
Set Region	Allows the position of the object to be set in a local coordinate system defined by the Region. If the region is moved or rotated, the objects in the Region move with it.
Center in View	Centers the current View on the object.

4.3 Model Builder

The Model Builder provides palettes of objects that can be dragged and dropped to construct a new model or to modify an existing one.

The following figure shows the Model Builder with the Graphics Objects palette expanded.

Figure 4-3 Model Builder



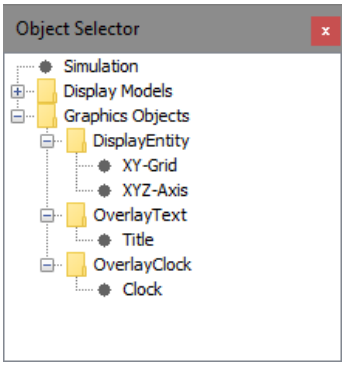
Some objects, such as DisplayModels and Units, do not have a graphical representation and cannot be dragged and dropped by the user. These objects appear in the Object Selector, but not in the Model Builder.

4.4 Object Selector

The Object Selector contains all objects that have been created for the present model, including ones that were created automatically by JaamSim. Objects are grouped according to their palette and type in a tree format that mirrors the structure of the Model Builder. A specific object can be selected either by clicking its node in the Object Selector or by clicking it in a View window.

The following figure shows the Object Selector with the Graphics Objects nodes expanded.

Figure 4-4 Object Selector



Objects that have been created using the Model Builder can be renamed or deleted using the Object Selector. Once an object has been selected, it can be renamed by pressing F2 or by left-clicking on its highlighted entry in the Object Selector, similar to the convention in Windows. A selected object can be deleted by pressing the Delete key, or by right-clicking in either a View window or the Object Selector and selecting Delete.

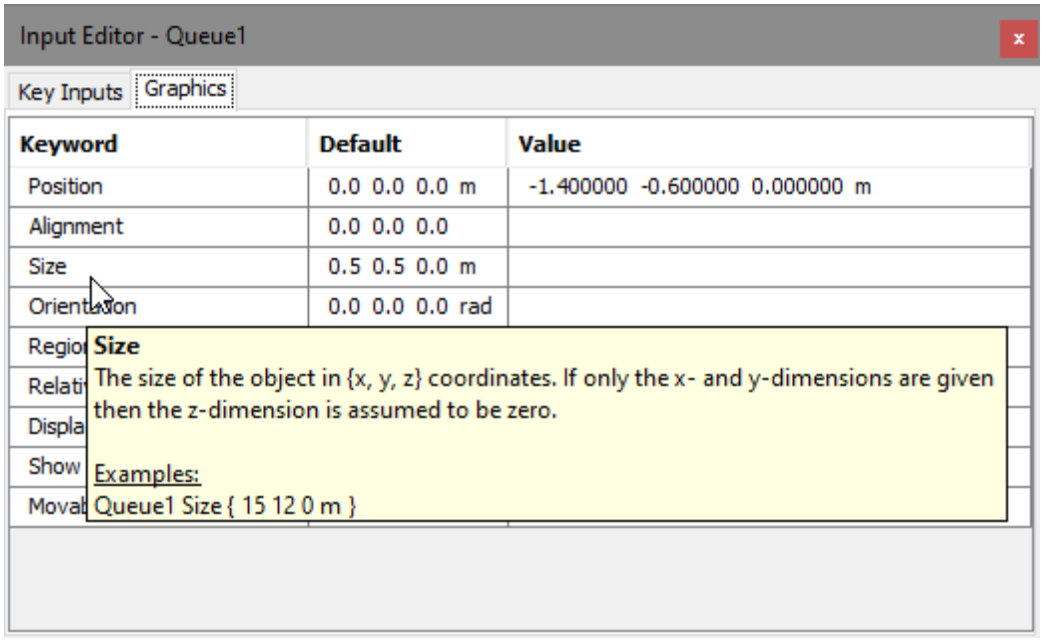
The default objects: XY-Grid, XYZ-Axis, Title, and Clock, can be deleted by the user. However, for the XY-Grid and XYX-Axis, it is better to hide them by de-selecting their entries in the Options menu, which allows them to be re-instated at a later time.

4.5 Input Editor

The Input Editor allows the user to modify inputs for existing objects or assign inputs to new objects. When an object is selected, its parameters appear in the Input Editor window, grouped under a number of tabs. If a keyword has a default value assigned, it is shown in the Default column.

Hovering the cursor over a keyword will display a tooltip containing a brief description of the keyword and an example input. The Input Editor with the tooltip for Size is shown below.

Figure 4-5 Input Editor



The example input in the tooltip is given in the format used when editing the configuration file. The entry to place in the Input Editor is the text appearing between the braces, which in this case would be: `15 12 0 m`. For examples with multiple pairs of braces, the entry to place in the Input Editor is the portion between the outer-most pair of braces.

The input for a keyword can be modified by clicking on the entry in the Value column and entering a new value with the appropriate units. Numbers must be entered without spaces or commas and Boolean keywords must take the value TRUE or FALSE (case sensitive). If an entry is made in the Value column, it will overwrite the default. If an input is not valid, an error message will be displayed showing the cause of the error.

Depending on the object, different keyword values will have different data types as shown in the following table.

Table 4-12 Input Data Types

Data Type	Description	Examples
Numbers without units	A number with or without a decimal point.	5 5.0
Numbers with units	A number followed by a unit separated by one or more spaces.	1000 mm 1.0 m 0.001 km

Times	Times can be entered normally as a number and time unit or it can be entered in date/time format. The following formats are supported:
	`hh:mm:ss.s,`
	`'YYYY-MM-DD hh:mm:ss.s'`
	`YYYY-MM-DDThh:mm:ss.s.`
	Midnight on January 1 of year 0 (0000-01-01) is taken to be zero simulation time regardless of the year displayed by the OverlayClock. If the date/time format includes a space, the entire text must be enclosed by a pair of single quotes.
		30.4 h
		30:24:00.0
		'0000-01-02 06:24:00.0'
		0000-01-02T06:24:00.0

Vectors and Points	Values for the three components followed by a unit. One or more spaces separate the values and unit. If only two values are entered, the z-component is assumed to be zero.	2.0 1.0 0.0 m 2.0 1.0 m
Expressions	A formula containing object outputs and/or mathematical functions. Expressions are described in detail in Section 6.1.	'1 + 2*[Queue1].QueueLength' '2[s] + [Queue1].QueueTimes(1)'
Booleans	A value of either TRUE or FALSE (case-sensitive).	TRUE FALSE
Colours	A colour can be specified by a colour keyword or by RGB values. A list of named colours and their RGB equivalents are given in Section 0. Transparency can be specified by adding a fourth number after the RGB values.	pink 255 192 203 255 192 203 125
Strings	Text enclosed by a pair of single quotes. The single quotes can be omitted if the text does not include any spaces.	'Quick red fox' Quick_red_fox
Objects	Specified by the object's name.	Server1 Queue1

Braces are used to delineate distinct entries in a list. For example, a list of two points would be entered as `{ 0.0 1.0 0.0 m } { 1.0 1.0 0.0 m }`. When an input has only one set of inner braces, it can be entered without the inner braces. For instance, `{ 1 2 3 }` can be entered as `1 2 3`.

A drop-down menu is available for many types of inputs. For Boolean inputs, the drop-down menu offers the choice of TRUE or FALSE. For an object input, the drop-down menu lists all the objects of the appropriate type. For a colour input, a suitable colour selector dialog box is provided.

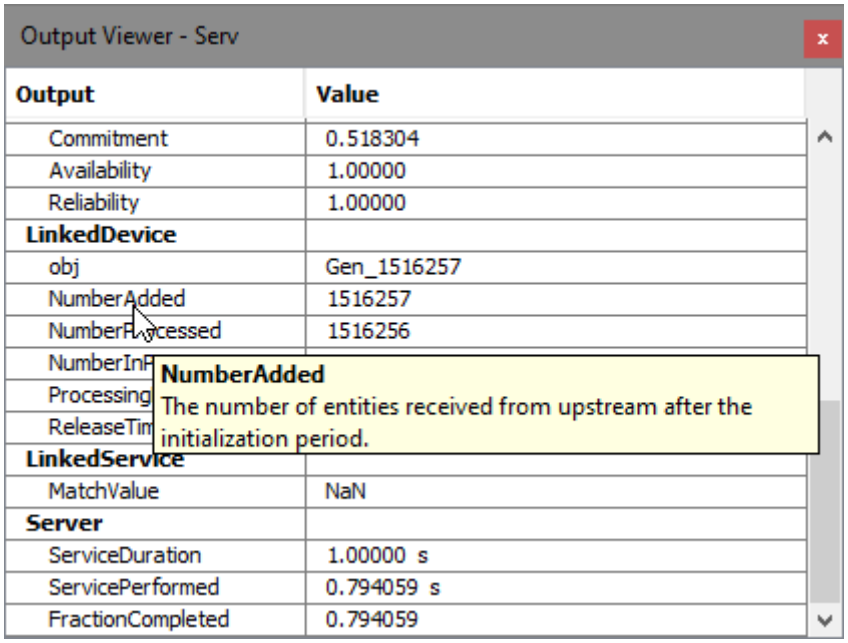
4.6 Output Viewer

The Output Viewer displays the available outputs for the selected object. The values in the Output Viewer are updated continuously as the simulation progresses.

Numerical outputs are normally shown in the appropriate SI unit, except for time which is shown in hours. When it is more convenient to view an output in another unit, the user can specify a set of preferred units using the Units entry in the Menu bar (see Section 4.1.1).

Hovering the cursor over an output name will display a tooltip containing a brief description of the output. The following figure shows the Output Viewer for the case of a Server being selected.

Figure 4-6 Output Viewer



5 Units

5.1 Unit Types

JaamSim performs all internal calculations in SI units (meters, kilograms, seconds, etc.). However, as it can sometimes be more convenient to specify quantities using other unit systems, JaamSim natively supports the units shown in the following table.

Table 5-1 Supported Unit Types and Units

Unit Type	Default Unit	Supported Units
DimensionlessUnit	not applicable	not applicable
TimeUnit	seconds (s)	ns, us, ms, s, min, h, d, w, y
DistanceUnit	meters (m)	mm, cm, m, km, nmi, in, ft, mi
SpeedUnit	meters per second (m/s)	m/s, km/h, knots, mph
AccelerationUnit	meters per squared second (m/s2)	m/s2, ft/s2
MassUnit	kilograms (kg)	kg, t, kt, Mt
MassFlowUnit	kilograms per second (kg/s)	(any mass unit)/(s, h, d, y)
VolumeUnit	cubic meters (m3)	m3, km3, bbl, mbbl, mmbbl
VolumeFlowUnit	cubic meters per second (m3/s)	(any volume unit)/(s, h, d, y)
AngleUnit	radians (rad)	rad, deg
AngularSpeedUnit	radians per second (rad/s)	rad/s, rad/h, deg/s, deg/h
EnergyUnit	joules (J)	J, kWh
EnergyDensityUnit	joules per cubic meter (J/m3)	J/m3, kWh/m³
SpecificEnergyUnit	joules per kilogram (J/kg)	J/kg, kWh/t
PowerUnit	watts (W)	W, kW, MW
CostUnit	dollars ($)	$
CostRateUnit	dollars per second ($/s)	$/s, $/h, $/d
LinearDensityUnit	kg/m	kg/m, t/m, kt/m
LinearDensityVolumeUnit	m3/m	m3/m
DensityUnit	kg/m3	kg/m3
PressureUnit	Pa	Pa, kPa, psi
ViscosityUnit	Pa-s	Pa-s, P, cP
AreaUnit	m2	m2, cm2, mm2, in2
RateUnit	/s	/ns, /us, /ms, /s, /min, /h, /d, /w, /y

Units are mandatory for most numerical inputs with the exception of pure numbers and ratios. Inputs that are pure numbers are indicated by the DimensionlessUnit type.

5.2 Defining a New Unit

In addition to the predefined units in JaamSim, new units can be specified using a Unit object. A new Unit object can be created by entering the appropriate Define statement in the configuration file (see Section 8). For example if a new TimeUnit called 'Fortnight' is required, then the define statement would be:

```
Define  TimeUnit  {  Fortnight  }
```

All Unit objects have the same input keyword:

Table 5-2 Unit Key Inputs

Keyword	Description
ConversionFactorToSI	Two numbers that specify the numerator and denominator, respectively, of the multiplicative factor to convert from the new Unit to SI base units.

For example, for the 'Fortnight' time unit (two weeks) defined above, the ConversionFactorToSI keyword should be set as follows:

```
Fortnight  ConversionFactorToSI  (  1209600  1  }
```

Once the new unit is defined in this way, it can be used with any input that requires that type of unit.

6 Expressions and User-Defined Variables

Most real-world models involve detailed rules and variables that are specific to that application. The variety and complexity of these rules make it impossible to accommodate every possibility in the keywords for a finite set of built-in objects. The expressions, attributes and custom outputs described in this section provide the model builder with the tools necessary to customize the built-in objects for his/her application.

6.1 Expressions

Expressions are mathematical statements that are evaluated by JaamSim. Many keywords that expect a number, string, or entity can also accept an expression that returns the appropriate type of object.

6.1.1 Syntax

Expressions can manipulate and return various types of objects:

- numbers (with or without units)
- strings
- objects
- arrays
- maps
- lambda functions

A map is similar to an array except that its entries are indexed by a key, such as a string, instead of an integer. The entries in an array or map can be numbers, strings, entities, or other arrays or maps.

A lambda function is an expression that takes one or more input variables and returns a number, string, object, array, map, or another lambda function. Lambda functions can be used with higher-order functions to perform complex calculations that would otherwise require a loop structure (see Section 6.1.6).

The rules for entering these objects in an expression are given in the following table.

Table 6-1 Types of Objects in Expressions

Entry	Rule	Examples
Number	If the number includes a unit, the unit must be enclosed by square brackets.	`1.0` `1[m]`
String	Strings are enclosed by double quotes.	`"Quick red fox"`
Object	Object names are enclosed by square brackets.	`[Server1]`

Array	Arrays are enclosed by curly braces, with individual entries separated by commas.	`{5, 6, 7}`
		`{5[m], 6[m], 7[m]}`
		`{"a", "b", "c"}`
		`{[Queue1], [Queue2]}`
		`{{1, 2}, {3, 4}}`

Map	The output "StateTimes" is the only map object used in JaamSim at present. Users cannot create new maps.	`[Server1].StateTimes`
Lambda Function	Input variables are enclosed by bars and separated by commas. The expression that generates the returned value is enclosed by brackets. Input variables can be a number, string, array, map, or another lambda function. The object returned can be any of these same types of objects.	`|x,y|(x + y)`

Mathematical expressions are entered using the following syntax:

Table 6-2 Syntax Rules for Expressions

Rule	Example	Result

If an expression includes spaces, curly brackets, or double quotes, it must be enclosed by a pair of single quotes. Spaces in an expression are ignored.	`1[m]+2[m]`
	`'1[m] + 2[m]'`
	`'{5,6,7}(2)+10'`
	`'{5, 6, 7}(2) + 10'`
	`'"abc"'`
		`3[m]`
		`3[m]`
		`16`
		`16`
		`abc`

Rules for mathematical order of operation are respected for the standard operators: +, -, *, /, and ^. Round brackets can be used to modify the order of operation.	`1+2*3`
	`(1+2)*3`
	`2*3^2`
	`(2*3)^2`
		`7`
		`9`
		`18`
		`36`

All calculations must respect units. Unit conversions are performed automatically.	`1[m]+2`
	`1[m]+2[m]`
	`1[m]/2[s]`
	`1[m]/2[m]`
	`1[m]*2[m]`
		`syntax error`
		`3[m]`
		`0.5[m/s]`
		`0.5`
		`2[m2]`

Outputs and attributes are referenced using a dot notation.	`[Queue1].QueueLength`	Number of entities in Queue1
The reserved string 'this' is used to refer to the object evaluating the expression.	`this.State`	State of the present entity.
Entries in an array are referenced by specifying an index. The index value can be either a constant or an expression that returns a dimensionless number. A non-integer value for the index will be truncated.	`[Queue1].QueueList(2)`	Entity that is second from the front of the queue.

Rule	Example	Result
Entities in a map are referenced by specifying a key (usually a string).	`[Server1].StateTimes("Idle")`	Total time Server1 has been in its Idle state.
Outputs can be chained using the dot notation.	`[Queue1].QueueList(1).State`	State of the entity at the front of the queue.
Entries in a nested array are referenced by providing multiple indices.	`'{{5,6}, {7,8}}(2)(1)'`	`7`
Strings can be concatenated using the + operator.	`'"abc" + "def"'`	`abcdef`

A lambda function can be evaluated by providing input values enclosed by brackets.	`|x|(2*x)(5)`
	`|x,y|(x+2*y)(1,2)`
	`|x,y|(x+y)("abc","def")`
		`10`
		`5`
		`abcdef`

A lambda function with multiple inputs can be turned into one with fewer inputs by providing one or more of the inputs	`|x,y|(x+2*y)(1)(2)`	`5`

When developing a complex expression it is usually best to prepare it separately in a text editor and copy it to the desired input. Expressions that return a number can be tested using an ExpressionEntity to ensure that correct value is returned.

6.1.2 Local Variables

To improve readability and to avoid repeated calculations, it is possible to define one or more local variables within an expression. A local variable can take the value of any valid type, i.e. a number, string, object, array, map, or lambda function.

The following syntax is used to define a local variable:

```
'<variable1> = <expression1>; … <variableN> = <expressionN>; <final expression>'
```

For example, the expression `'x = 1; y = 2; x + y'` would return the value 3.

6.1.3 Functions

The following mathematical functions can be used in expressions:

Table 6-3 Basic Mathematical and Logical Functions

Function	Description	Example	Result
PI	Mathematical constant 'pi'	`PI()`	`3.14159…`
E	Mathematical constant 'e'	`E()`	`2.71828…`
min	Smallest of a list of values	`'min(1[s], 2[s])'`	`1[s]`
max	Largest of a list of values	`'max(1[s], 2[s])'`	`2[s]`
indexOfMin	Position of the minimum in a list of values	`'indexOfMin(1[s], 2[s])'`	`1`
indexOfMax	Position of the maximum in a list of values	`'indexOfMax(1[s], 2[s])'`	`2`
abs	Absolute value	`'abs( -1[s] )'`	`1[s]`
ceil	Smallest (closest to negative infinity) integer that is greater than or equal to the argument	`'ceil( 5.2[s] )'`	`6[s]`
floor	Largest (closest to positive infinity) integer that is less than or equal to the argument	`'abs( 5.2[s] )'`	`5[s]`
signum	Zero if the argument is zero, 1.0 if the argument is greater than zero, and -1.0 if the argument is less than zero.	`'signum( 5.2[s] )'`	`1`
sqrt	Square root	`'sqrt( 4.0 )'`	`2.0`
cbrt	Cube root.	`'cbrt( 8.0 )'`	`2.0`
%	Modulus (remainder) operator. Used as an operator, not a function.	`'11.5 % 4'` `'11.5[s] % 4[s]'`	`3.5` `3.5[s]`
choose	Selects from a list using an index	`'choose(2, 1[s], 2[s])'`	`2[s]`

Table 6-4 Exponential and Trignometric Functions

Function	Description	Example	Result
exp	Exponential function	`'exp( 1 )'`	`2.71828…`
ln	Natural logarithm	`'ln( 2.71828 )'`	`0.999999`
log	Base-10 logarithm	`'log( 100 )'`	`2.0`
sin	Sine of an angle or dimensionless number	`'sin( 30[deg] )'`	`0.5`
cos	Cosine of an angle or dimensionless number	`'cos( 60[deg] )'`	`0.5`
tan	Tangent of an angle or dimensionless number	`'tan( 45[deg] )'`	`1`
asin	Arcsine function	`'asin( 0.5 )'`	`30[deg]`
acos	Arccosine function	`'acos( 0.5 )'`	`60[deg]`
atan	Arctangent function	`'atan( 1.0 )'`	`45[deg]`
atan2	Two-argument arctangent function. For Cartesian coordinates x and y, atan2(x,y) returns the angle for the corresponding polar coordinates.	`'atan2(1.0, -1.0)'`	`135[deg]`

Table 6-5 Functions of Arrays and Maps

Function	Description	Example	Result
size	Number of entries in an array or map.	`'size( {5,-1,2} )'`	3
minCol	Smallest entry in an array or map.	`'minCol( {5,-1,2} )'`	-1
maxCol	Largest entry in an array or map.	`'maxCol( {5,-1,2} )'`	5
indexOfMinCol	Index or key of the smallest entry in an array or map. If this value appears in several entries, the index of the first one is returned.	`'indexOfMinCol( {5,-1,2} )'`	2
indexOfMaxCol	Index or key of the largest entry in an array or map.	`'indexOfMaxCol( {5,-1,2} )''`	1
indexOfNearest	Index or key of the entry in an array or map that is closest to the specified value.	`'indexOfNearest( {5,-1,2}, 1.5 )'`	3

Table 6-6 Functions of Objects

Function	Description	Example	Result
notNull	Determines whether an entity exists. It can be used to test whether an output such as obj has been set.	`'notNull(this.obj)'`	0 or 1

When several entries in an array have the same value, the functions indexOfMinCol, indexOfMaxCol, and IndexOfNearest return the first index that satisfies the condition. When several entries in a map have the same value, the index returned by these functions is the first one that was entered in the map.

6.1.4 Logical Operations

Logical operations can also be performed in Expressions. All non-zero dimensionless values are interpreted as TRUE, while zero is interpreted as FALSE. The following are examples of syntactically valid logical Expressions:

```
'this.OutputA >= 1'
'(this.OutputA >= 1) && ([Entity1].OutputB == 0)'
```

The following logical operators are supported:

Table 6-7 Logical Operators

Operator	Description	Example	Result
==	Equal to	`'4.2 == 4.2'`	1
!=	Not equal to	`'3.5 != 4.2'`	1
<	Less than	`'3.5 < 4.2'`	1
<=	Less than or equal to	`'3.5 <= 3.5'`	1
>	Greater than	`'4.2 > 3.5'`	1
>=	Greater than or equal to	`'3.5 >= 3.5'`	1
&&	Logical AND operation	`'1 && 1'`	1
||	Logical OR operation	`'1 || 0'`	1
!	Logical NOT operation	`'! 0'`	1

The && and || operators use short-circuited evaluation, that is, the right-hand side of the operator is only evaluated when necessary. For example, if the left-hand side of the && operator is FALSE, then the result is FALSE regardless of the value of the right-hand side. Similarly, if the left-hand side of the || operator is TRUE, then the result is TRUE regardless of the right-hand side.

6.1.5 Conditionals

Conditional operations are implemented with the ternary operator, `?`, using the following syntax:

```
<condition_expression> ? <true_expression> : <false_expression>
```

The `?` operator uses short-circuited evaluation, that is, the `<true_expression>` is evaluated only when the `<condition_expression>` is TRUE and the `<false_expression>` is evaluated only when it is FALSE.

Examples of the conditional operator are:

```
'2>1 ? 5 : 4'
'this.OutputA >= 2 ? [Entity1].OutputB + 1 : 0'
```

Complex logical expressions can be constructed by chaining a series of ternary operators to form an "if, else-if" type structure, e.g.:

```
'this.OutputA <= 2 ? 2 : (this.OutputA <= 4 ? 4 : 6)'
```

Note that brackets were added to this expression to improve readability – they are not mandatory.

6.1.6 Higher-Order Functions

A function is considered to be higher-order if one or more of its arguments are lambda functions. Higher-order functions provide the expression system with the ability to carry out complex model logic in functional form, without needing a loop construct.

Table 6-8 Higher-Order and Related Functions

Function	Description	Example	Result
map	Applies a one-input lambda function to each element of an array and returns an array with the resulting values.	`map(|x|(2*x),{1,2})`	`{2,4)`
filter	Applies a one-input lambda function to each element of an array and returns an array with only the ones that return TRUE (i.e. a non-zero number).	`filter(|x|(x>2),{1,2,3,4})`	`{3,4}`

reduce	Applies the first input of a two-input lambda function to each element of an array. The second input to the reduce function is the initial value for an internal value maintained by the function during the calculation. The result of the calculation for each element is assigned to this internal value. After the last element is processed, the internal value is returned. The reduce function has three inputs: the function, the initial value to be assigned to the internal value, and the array to be processed.	`reduce(|x,accum|(x+accum), 0, {1,2,3})`
		`reduce(|x,accum|(max(x,accum)), 0, {1,2,3})`
		`reduce(|x,accum|(x||accum), 0, {0,1,0})`
			`6`
			`3`
			`1`

sort	Applies a two-input lambda function to the elements of an array and returns an array that has been re-ordered so that the lambda function returns TRUE (i.e. a non-zero number) for each adjacent pair of elements. The lambda function should return FALSE for entries that are equal.	`sort(|x,y|(x>y),{2,3,1})`	`{3,2,1}`

range	Generates an array of numerical values that can be used as an input to the higher-order functions.	`range(3)`
		`range(2,4)`
		`range(2,3,0.5)`
		`range(2,1)`
			`{1,2,3}`
			`{2,3,4}`
			`{2,2.5,3}`
			`{}`

6.2 User-Defined Variables

Users can define two types of variables for individual objects in a model:

- **Attribute**. A variable whose value can be changed be changed by one or more Assign objects in a model (see Section 14.11). Attributes are a useful way to add application-specific information to generated entities or to the permanent objects in a model. For example, if there are two types of customers in a model that require different service times, an attribute named "type" can be added to the generated customer objects and randomly assigned the value 1 or 2. When the customer arrives at the server, its service time can then be calculated based on its type attribute.

- **Custom Output**. A variable whose value is calculated on demand by evaluating a specified expression during the simulation run. Custom outputs are a way for the user to supplement

the JaamSim's built-in outputs or to avoid repeating a complicated calculation in more than one expression. Note that a custom output cannot use another custom output in its definition.

Attributes and custom outputs can have same types of values as expressions, i.e. numbers with or without units, strings, entities, arrays, maps, or lambda functions. They appear in the Output Viewer as outputs under the Entity heading.

The name for an attribute or custom output can be any alphanumeric text provided that no spaces are included.

Attributes and custom outputs can be defined for any of the objects in a model using the AttributeDefinitionList and CustomOutputList keywords described in the following table.

Table 6-9 Keywords for Attributes and Custom Outputs

Keyword	Description

AttributeDefinitionList	Defines one or more attributes for the object. The following format is used for the input:
	
	`{ <Name1> <InitValue1> } ... { <NameN> <InitValueN> }`
	
	where Name is the name of the attribute and InitValue is an expression that returns the initial value for the attribute. The expression is evaluated when the simulation is first started or re-started. Normally, the expression is a simple constant, such as `5[km]`. The attribute type (number, string, etc.) is determined by its initial value.
	
	The following example defines a series of attributes of various types:
	
	`{ A 1 } { B 9[km] } { C '"abc"' } { D [Server1] } { E '{5,3,7}' }`

CustomOutputList	Defines one or more custom outputs for the object. The following format is used for the input:
	
	`{ <Name1> <Exp1> <Unit1> } ... { <NameN> <ExpN> <UnitN> }`
	
	where Name is the name of the custom output, Exp is the expression to be evaluated on demand, and Unit is the unit type for the output.
	
	For example, the following example defines a custom output called TwiceSimTime, whose value is equal to two times the present simulation time:
	
	`{ TwiceSimTime '2 * this.SimTime' TimeUnit }`

7 Simulation Runs and Experiments

7.1 Simulation Object

The Simulation object is used to store inputs that define basic parameters of the model, such as run duration. The Simulation object is created automatically when a new model is started, and thus does not appear in the Model Builder.

Table 7-1 Simulation Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
RunDuration	Duration of the simulation run in which statistics will be recorded.
InitializationDuration	The initialization interval for the simulation run. The model will run for the InitializationDuration interval and then clear the statistics and execute for the specified RunDuration interval. The total length of the simulation run will be the sum of the InitializationDuration and RunDuration inputs.
PauseCondition	An optional expression that pauses the run when TRUE is returned.
ExitAtPauseCondition	If TRUE, the simulation run will be terminated when the PauseCondition expression returns TRUE. If multiple runs have been specified, then the next run will be started. If no more runs have been specified, the simulation will be paused or terminated depending on the input to the ExitAtStop keyword.
ExitAtStop	If TRUE, the program will be closed on completion of the last simulation run. Otherwise, the last run will be paused.
GlobalSubstreamSeed	Global seed that sets the substream for each probability distribution. Must be an integer >= 0. GlobalSubstreamSeed works together with each probability distribution's RandomSeed keyword to determine its random sequence. It allows the user to change all the random sequences in a model with a single input. To run multiple replications, set the appropriate inputs under the Multiple Runs tab and then set the GlobalSubstreamSeed input to the run number or to one of the run indices.
PrintReport	If TRUE, a full output report is printed to the file <configuration file name>.rep at the end of the simulation run.
ReportDirectory	The directory where output files will be written. The default location is the directory of the input configuration file.
UnitTypeList	A list of the unit types for the selected outputs specified by the RunOutputList keyword. Use DimensionlessUnit for a text output.
RunOutputList	One or more selected outputs to be printed at the end of each simulation run. Each output is specified by an expression. In script mode (-s tag), the selected outputs are printed to the command line (standard out). Otherwise, they are printed to the file <configuration file name>.dat.

TickLength	The smallest time increment for JaamSim's internal integer-based time keeping. The default value of 1 microsecond will support simulation runs of more than 100 years.
Multiple Runs	
RunIndexDefinitionList	Defines the number of run indices and the maximum value N for each index. When making multiple runs, each index will be iterated from 1 to N starting with the last index. One run will be executed for every combination of the run index values. For example, if three run indices are defined with ranges of 3, 5, and 10, then at total of 3*5*10 = 150 runs will be executed.
StartingRunNumber	The first run number to be executed. The value can be entered as either an integer or as the equivalent combination of run indices. For example, if there are three run indices with ranges of 3, 5, and 10, then run number 22 can be expressed as 1-3-2 because 22 = (1-1)*5*10 + (3-1)*10 + 2.
EndingRunNumber	The last run number to be executed. The value can be entered as either an integer or as the equivalent combination of run indices. For example, if there are three run indices with ranges of 3, 5, and 10, then run number 78 can be expressed as 2-3-8 because 78 = (2-1)*5*10 + (3-1)*10 + 8.
GUI	
DisplayedUnits	An optional list of units to be used for displaying model outputs.
SnapToGrid	If TRUE, a dragged object will be positioned to the nearest grid point.
SnapGridSpacing	The distance between snap grid points.
IncrementSize	The distance moved by the selected entity when the an arrow key is pressed.
RealTime	If TRUE, the simulation is executed a constant multiple of real time. Otherwise, the run is executed as fast as possible, limited only by processor speed.
RealTimeFactor	The target ratio of elapsed simulation time to elapsed real time.
PauseTime	The time at which the simulation will be paused.
ShowModelBuilder	If TRUE, the Model Builder tool is shown on startup.
ShowObjectSelector	If TRUE, the Object Selector tool is shown on startup.
ShowInputEditor	If TRUE, the Input Editor tool is shown on startup.
ShowOutputViewer	If TRUE, the Output Viewer tool is shown on startup.
ShowPropertyViewer	If TRUE, the Property Viewer tool is shown on startup.
ShowLogViewer	If TRUE, the Log Viewer tool is shown on startup.

7.2 Performing Multiple Simulation Runs

Multiple simulation runs can be executed automatically, one after another, using the keywords under the Multiple Runs tab for the Simulation object. The Simulation outputs RunNumber and RunIndex are used to change selected inputs between simulation runs. By default, the RunNumber output starts at 1 and is incremented by one with each simulation run that is performed. This output can be used to vary one or more inputs by referencing [Simulation].RunNumber in an expression. For example, setting the ServiceTime input for a Server to the following expression:

```
'1[s] + 0.1[s]*[Simulation].RunNumber'
```

assigns the service time to 1.1 s, 1.2 s, 1.3 s, etc., as the run number is incremented over multiple runs.

The RunIndex output is used when there are multiple inputs to test. This output contains an array of integers that are each incremented from 1 to N, where a separate value for N can be specified for each index. The number of run indices and the ranges over which they are incremented are determined by the RunIndexDefinitionList keyword.

For example, suppose there are two Servers and service times of 1.1 s, 1.2 s, and 1.3 s are to be tested for Server1 and service times of 2.1 s and 2.2 s are to be tested for Server2. Ten replications are to be made for each combination of service times. In this case, three run indices are needed – one for each variable that is to be changed. The run indices are defined by entering the values `3 2 10` to the RunIndexDefinitionList keyword. This input indicates that RunIndex(1) will be incremented over the range 1 to 3, RunIndex(2) will be incremented over 1 to 2, and that RunIndex(3) will be incremented over 1 to 10. The three run indices are used in the model inputs as follows:

- ServiceTime keyword for Server1: `'1[s] + 0.1[s]*[Simulation].RunIndex(1)'`
- ServiceTime keyword for Server2: `'2[s] + 0.1[s]*[Simulation].RunIndex(2)'`
- GlobalSubstreamSeed keyword for Simulation: `'[Simulation].RunIndex(3)'`

With these inputs, a total of sixty runs would be performed with the run indices incremented in the following sequence:

- `1-1-1, 1-1-2, … 1-1-10,`
- `1-2-1, 1-2-2, … 1-2-10,`
- `2-1-1, 2-1-2, … 2-1-10,`
- `2-2-1, 2-2-2, … 2-2-10,`
- `3-1-1, 3-1-2, … 3-1-10,`
- `3-2-1, 3-2-2, … 3-2-10,`

The notation `i-j-k` indicates run indices RunIndex(1) = i, RunIndex(2) = j, and RunIndex(3) = k.

It is not necessary to perform all the simulation runs defined by the run indices. The Simulation keywords StartingRunNumber and EndingRunNumber can be used to determine the runs that will be performed. To perform all sixty runs, the StartingRunNumber should be set to `1` (the default value) and the EndingRunNumber should be set to `60`.

Run indices are related to the run number by a mathematical equation that performs the necessary transformation. In the example given above, the RunNumber increases from 1 to 60, at the same time as the run indices increase from `1-1-1` to `3-2-10`. Run numbers and run indices in the `i-j-…-k`

notation can be used interchangeably for the StartingRunNumber and EndingRunNumber inputs. For example, to perform all sixty runs, the StartingRunNumber could be set to `1-1-1` and EndingRunNumber to `3-2-10` instead of `1` and `60`.

7.3 Customized Output Report

When making multiple runs, the output reports for the runs are appended one after another in a single file. If more than just a few runs are to be made, it is best to create a customized output report using the RunOutputList keyword for Simulation. This keyword allows the user to specify the set of outputs needed to analyse the results from the runs. Each output is entered as a separate expression enclosed by curly braces. For example, if the desired outputs are the simulation run number, average utilisation of Server1, and average waiting time for Queue1, then the input to the RunOutputList keyword would be as follows:

```
{ [Simulation].RunNumber } { [Server1].Utilisation } { [Queue1].AverageQueueTime }
```

It is best to prepare this input in a text editor and to copy each entry one-by-one to the Input Editor. This method allows errors to be located and corrected more easily.

Before entering the RunOutputList input, it is first necessary to specify the unit type for each output using the UnitTypeList keyword. For this example, the input would be:

```
DimensionlessUnit  DimensionlessUnit  TimeUnit
```

At the end of each run, the specified outputs are collected in a single output file with the name <configuration file name>.dat. The file has one row for each simulation run that was performed and is tab-delimited, which allows it to be imported directly into Excel for analysis.

The RunOutputList report can be generated with or without the main report, as specified by the PrintReport keyword.

8 Configuration File

The easiest way to create a simple model in JaamSim is to use the Graphical User Interface. However, once a model becomes more complex, it is often easier to edit the configuration file (CFG file) in a text editor. The configuration file is saved in plain text and has been designed to be human readable.

There are many advantages to a readable input file in plain text:

- Inputs can be easily reviewed and audited.
- Standard software for change control such as GIT can be used to track model inputs.
- Software for performing simulation experiments and optimisation can be developed by third-parties in other programming languages such as Python.

The recommended text editor is Notepad++, an open-source editor available for download at www.notepad-plus-plus.org.

8.1 Basic Structure

A JaamSim input configuration file consists of a series of lines, akin to a scripting language. Each line consists of a combination of object names, keywords, and values contained within braces. One or more spaces are used to separate these elements. Braces are also used to denote sets of arguments within the outer braces required for arguments in general. Blank lines are ignored by JaamSim.

Lines beginning with a hash mark ('#') can be used to create comments to document the input files. If a comment extends for several lines, each line must start with a hash mark.

8.2 Object Definitions

In JaamSim, an object is initialized by a Define statement. The statement contains Define followed by the object type, and the object name enclosed by braces. Multiple objects can be defined at the same time, provided that they are of the same type. For instance, the following two lines define respectively a single Arrow object and three Arrow objects.

```
Define Arrow  { SingleArrow }
Define Arrow  { Arrow1 Arrow2 Arrow3 }
```

Object instances can only be referenced after they have been defined.

8.3 Object Inputs

Once an object is defined, its keyword values can be set using a command of the following form:

```
<object name> <keyword> { <value1> <value2> … }
```

where value1, value2, … is the list of values for the keyword separated by one or more spaces. For instance, the following line sets the colour of the Arrow1 object to be black:

```
Arrow1 Colour { black }
```

Multiple parameters for an object can be set in one line containing the object name followed by keyword and value pairs.

```
Arrow1 Colour { black } Width { 2 }
```

Inner braces are used for keywords that accept multiple input values.

```
Arrow1 Points { { 0 0 0 m } { 1 1 1 m } }
```

8.4 Include Statements

The user can store input data in multiple files and then refer to these files in an input configuration file using Include statements. These statements refer to other input configuration files by filename and path, surrounded by single quotes:

```
Include  '..\Base File\InputFile.cfg'
```

Include statements are particularly useful when only a few inputs are varied across many simulation runs. Include statements can be used to create incremental configuration files for additional runs that contain a base case configuration file :

```
Include  '..\Base File\Basecase.cfg'
Arrow1 Width { 2.0 }
```

This example includes the contents of Basecase.cfg and modifies the already-defined object Arrow1's keyword Width value to 2.0. Note that the changes from the base case configuration must appear after the Include statement. These simple configuration files are useful because it is easy to tell exactly how the configuration differs from the base case configuration.

8.5 Groups

Group objects bundle multiple objects together to simplify inputs. Instead of referring to a long list of objects, a single Group can be used instead. The Group may be used to set the value for a keyword for all members instead of setting the value for each member of the Group. Certain keywords also accept Group objects as values.

Table 8-1 Group Inputs

Keyword	Description
List	A list of names of the objects included in this list, enclosed by braces.

The following example demonstrates the use of Groups:

```
Define     Arrow       { Arrow1 Arrow2 Arrow3 }
Define     Group       { ArrowList }
ArrowList  List        { Arrow1 Arrow2 Arrow3 }
ArrowList  Colour      { black }
```

In this example, a Group of three Arrow objects is created and each Arrow is set to the colour black.

By using the List keyword, a fourth Arrow can be added to the Group:

```
Define     Arrow       { Arrow4 }
ArrowList  List        { ArrowList Arrow4 }
ArrowList  Colour      { black }
```

8.6 RecordEdits Statement

The RecordEdits statement is used to preserve the organisation and formatting of a configuration file that has been prepared manually by the user.

It is usually best to construct a complex model manually using a text editor. These inputs are carefully formatted and organised, and include comments to document model design. However, once this material has been created, the easiest way to position the objects and to add graphics such as titles, labels, etc. is through the graphical user interface. If the model is then saved, all the formatting and comments would normally be lost.

JaamSim avoids this predicament with the RecordEdits statement. On saving, JaamSim copies all inputs before the RecordEdits statement line-by-line to the saved file, and then saves all the changes to the model using computer-written inputs. The following example illustrates this structure:

```
" Manually prepared inputs:
" - Everything before the RecordEdits statement is unchanged when JaamSim saves a
file.

RecordEdits

" Computer written inputs:
" - Everything that appears after the RecordEdits statement is written by the
computer.
```

The Save functionality in JaamSim is disabled when an input file is loaded without a RecordEdits statement. In this case, the Save As operation adds a RecordEdits statement to the end of the original configuration file and then writes out the new inputs.

8.7 Example Configuration File

The configuration file for the Basic Example described in Section 3 is given below.

```
RecordEdits

Define ColladaModel { Grid100x100  Axis }
Define DisplayEntity { XY-Grid  XYZ-Axis }
Define View { View1 }
Define TextModel { TitleTextModel  ClockTextModel }
Define OverlayText { Title }
Define OverlayClock { Clock }
Define SimEntity { Proto }
Define EntityGenerator { Gen }
Define EntityConveyor { GenToServ  ServToSink }
Define Server { Serv }
Define EntitySink { Sink }
Define Queue { ServQueue }
Define ExponentialDistribution { GenIATDist }

GenIATDist UnitType { TimeUnit }

Simulation Description { 'Simulation run control inputs' }
Simulation SnapToGrid { TRUE }
Simulation RealTime { TRUE }
Simulation RealTimeFactor { 2048 }
Simulation PauseTime {  }
Simulation ShowModelBuilder { TRUE }
Simulation ShowObjectSelector { TRUE }
```

```
Simulation ShowInputEditor { TRUE }
Simulation ShowOutputViewer { TRUE }
Simulation ShowPropertyViewer { FALSE }
Simulation ShowLogViewer { FALSE }

Grid100x100 ColladaFile { <res>/shapes/grid100x100.dae }

XY-Grid Description { 'Grid for the X-Y plane (100 m x 100 m)' }
XY-Grid Size { 100  100  m }
XY-Grid DisplayModel { Grid100x100 }
XY-Grid Movable { FALSE }

Axis ColladaFile { <res>/shapes/axis_text.dae }

XYZ-Axis Description { 'Unit vectors' }
XYZ-Axis Alignment { -0.4393409  -0.4410096  -0.4394292 }
XYZ-Axis Size { 1.125000  1.1568242  1.1266404  m }
XYZ-Axis DisplayModel { Axis }
XYZ-Axis Show { FALSE }
XYZ-Axis Movable { FALSE }

View1 Description { 'Default view window' }
View1 ViewCenter { -0.299610  -2.582932  2.866546  m }
View1 ViewPosition { -0.299610  -2.582933  11.526800  m }
View1 ShowWindow { TRUE }
View1 SkyboxImage { <res>/images/sky_map_2048x1024.jpg }

TitleTextModel Description { 'Text style for the Title' }
TitleTextModel FontColour { 150  23  46 }
TitleTextModel FontStyle { BOLD }

ClockTextModel Description { 'Text style for the Clock' }
ClockTextModel FontColour { 51  51  51 }
ClockTextModel FontStyle { ITALIC }

Title Description { 'Title for the simulation model' }
Title TextHeight { 18 }
Title Format { 'Getting Started with JaamSim' }
Title Position { 0.000000  0.000000  0.000000  m }
Title DisplayModel { TitleTextModel }
Title ScreenPosition { 15  15 }

Clock Description { 'Simulation date and time (no leap years or leap seconds)' }
Clock TextHeight { 10 }
Clock StartingYear { 2014 }
Clock DateFormat { 'yyyy-MMM-dd HH:mm:ss.SSS' }
Clock DisplayModel { ClockTextModel }
Clock ScreenPosition { 15  15 }
Clock AlignBottom { TRUE }

Proto Position { -4.400000  -0.600000  0.000000  m }
Proto Alignment { 0.0  0.0  -0.5 }

Gen NextComponent { GenToServ }
Gen InterArrivalTime { GenIATDist }
Gen PrototypeEntity { Proto }
Gen Position { -3.500000  -2.500000  0.000000  m }

GenToServ NextComponent { Serv }
GenToServ TravelTime { 1  s }
GenToServ Position { -2.500000  -2.500000  0.000000  m }
GenToServ Points { {  -2.500  -2.500  0.000  m  }  {  -1.500  -2.500  0.000  m  } }

Serv NextComponent { ServToSink }
Serv WaitQueue { ServQueue }
```

```
Serv ServiceTime { 1  s }
Serv Position { -0.500000  -2.500000  0.000000  m }

ServToSink NextComponent { Sink }
ServToSink TravelTime { 1.5  s }
ServToSink Position { 0.600000  -2.500000  0.000000  m }
ServToSink Points { {  0.600  -2.500  0.000  m  }  {  1.600  -2.500  0.000  m  } }

Sink Position { 2.500000  -2.500000  0.000000  m }

ServQueue Position { -0.500000  -4.500000  0.000000  m }

GenIATDist RandomSeed { 1 }
GenIATDist MaxValue { 10  s }
GenIATDist Mean { 2  s }
GenIATDist Position { -2.500000  -0.500000  0.000000  m }
```

9 Maintenance, Breakdowns, and Thresholds

A significant feature of JaamSim is its ability to model planned maintenance, breakdowns, and process blockages, and to record the total time the process spends in each state. This feature allows a JaamSim model to combine a full Reliability, Availability, and Maintainability (RAM) analysis, normally done separately with specialised software, with a typical logistics model.

9.1 Thresholds

Process blockages are modelled by Threshold objects that open and close according to various types of rules:

- TimeSeriesThreshold (Section 13.3). Opens and closes when the value provided by a TimeSeries object (Section 13.2) meets various conditions.
- ExpressionThreshold (Section 13.4). Opens and closes according to a specified expression that returns TRUE or FALSE.
- SignalThreshold (Section 14.18). Opens and closes when an entity is received by an EntitySignal object (Section 14.17).

All types of Threshold objects share the following inputs and outputs.

Table 9-1 Threshold Inputs

Keyword	Description
OpenColour	The colour of the threshold graphic when the threshold is open.
ClosedColour	The colour of the threshold graphic when the threshold is closed.
ShowWhenOpen	A Boolean value. If TRUE, the threshold is displayed when it is open.
ShowWhenClosed	A Boolean value. If TRUE, the threshold is displayed when it is closed.

Table 9-2 Threshold Outputs

Output Name	Description
Open	If open, then return TRUE. Otherwise, return FALSE.
OpenFraction	The fraction of total simulation time that the threshold is open.
ClosedFraction	The fraction of total simulation time that the threshold is closed.
OpenCount	The number of times the threshold's state has changed from closed to open.
ClosedCount	The number of times the threshold's state has changed from open to closed.

The respond of an object to the closure of one of its Thresholds depends on which one of the following keywords was used.

Table 9-3 Keywords that accept Thresholds

Keyword	Description
ImmediateThresholdList	A list of thresholds that must be satisfied for the object to operate. Operation is stopped immediately when one of the thresholds closes. If a threshold closes part way though processing an entity, the work is considered to be partly done and the remainder is completed once the threshold re-opens.
ImmediateReleaseThresholdList	A list of thresholds that must be satisfied for the object to operate. Operation is stopped immediately when one of the thresholds closes. If a threshold closes part way though processing an entity, the work is interrupted and the entity is released.
OperatingThresholdList	A list of thresholds that must be satisfied for the object to operate. If a threshold closes part way though processing an entity, the remaining work is completed and the entity is released before the object is closed.

A given Threshold can appear in only one of these keywords at a time. A single Threshold can be used by multiple objects.

9.2 Maintenance and Breakdowns

Planned maintenance and breakdowns are modelled using the DowntimeEntity (Section 13.9), which generates random or scheduled events based on either working time or calendar time. Normally, a maintenance activity is scheduled to occur at regular intervals based on calendar time. Breakdowns are normally modelled to occur randomly based on the working time for the object.

The object that will undergo the maintenance or breakdown has a series of keywords that determine how the object responds to a particular maintenance or breakdown event.

Table 9-4 Maintenance and Breakdowns Inputs

Keyword	Description
WorkingStateList	A list of states for which the entity is considered to be working.
ImmediateMaintenanceList	A list of DowntimeEntities representing planned maintenance that must be performed immediately, interrupting any work underway at present.
ForcedMaintenanceList	A list of DowntimeEntities representing planned maintenance that must begin as soon as task underway at present is finished.
OpportunisticMaintenanceList	A list of DowntimeEntities representing planned maintenance that can wait until task underway at present is finished and the queue of tasks is empty.
ImmediateBreakdownList	A list of DowntimeEntities representing unplanned maintenance that must be performed immediately, interrupting any work underway at present.
ForcedBreakdownList	A list of DowntimeEntities representing unplanned maintenance that must begin as soon as task underway at present is finished.
OpportunisticBreakdownList	A list of DowntimeEntities representing unplanned maintenance that can wait until task underway at present is finished and the queue of tasks is empty.

Only one breakdown or maintenance activity can occur at any given time. If multiple breakdown/maintenance activities are scheduled for the same time, they are performed sequentially.

It is possible under some circumstances for a breakdown or maintenance to occur while a threshold is closed. In this case, the state is set to the appropriate breakdown or maintenance state.

The outputs for maintenance, breakdowns, and thresholds are grouped together as follows.

Table 9-5 Maintenance, Breakdowns, and Thresholds Outputs

Output Name	Description
Open	Returns TRUE if all the thresholds specified by the OperatingThresholdList, ImmediateThresholdList, and ImmediateReleaseThresholdList keywords are open.
Working	Returns TRUE if work is being performed.
Maintenance	Returns TRUE if maintenance is being performed.
Breakdown	Returns TRUE if a breakdown is being repaired.
Utilisation	The fraction of calendar time (excluding the initialisation period) that this object is in the Working state.
Commitment	The fraction of calendar time (excluding the initialisation period) that this object is in any state other than Idle.
Availability	The fraction of calendar time (excluding the initialisation period) that this object is in any state other than Maintenance or Breakdown.
Reliability	The ratio of Working time to the sum of Working time and Breakdown time. All times exclude the initialisation period.

9.3 States

Objects implementing states have the following keywords and outputs.

Table 9-6 States Inputs

Keyword	Description
StateGraphics	A list of state/DisplayEntity pairs. For each state, the graphics will be changed to those for the corresponding DisplayEntity.

Table 9-7 States Outputs

Output Name	Description
State	The present state for this object, used for statistics collection. Typical states are: • **Working**. The object is performing its normal process. • **Idle**. The object is available for work, but has work to perform. • **Stopped**. One or more of the Thresholds are closed and there is no maintenance being performed or breakdown being repaired. • **Maintenance**. One of the DowntimeEntities entered to the Maintenance keywords is active. • **Breakdown**. One of the DowntimeEntities entered to the Breakdown keywords is active. Additional states can be defined for some objects.
WorkingState	Set to true if the present state is one of the pre-defined working states.
WorkingTime	Total time spent in any one of the working states.
StateTimes	Total time spent in each of the states.

10 Graphics

10.1 DisplayEntity

The DisplayEntity is the basic 3D graphical object in JaamSim. All JaamSim objects that have graphics are subclasses of DisplayEntity.

All objects intended for visualization in a model display window in JaamSim have a set of basic graphics keywords used to define their appearance. These are found in the Graphics tab of the Input Editor when the object is selected. For polyline type objects the inputs for Position, Alignment, Size, and Orientation are replaced by those for Points and CurveType.

Table 10-1 DisplayEntity Inputs

Keyword	Description
Normal Objects	
Position	The location of the object in {x, y, z} coordinates.
Alignment	The point within the object that is located at the coordinates of its Position input. Expressed with respect to a unit box centered about { 0 0 0 }.
Size	The size of the object in {x, y, z} coordinates. If only the x- and y-dimensions are given then the z-dimension is assumed to be zero.
Orientation	Euler angles defining the rotation of the object.
Polyline Type Objects	
Points	A list of points in {x, y, z} coordinates that define a polyline. When only two coordinates are given it is assumed that z = 0.
CurveType	The type of curve interpolation used for line type entities.
All Objects	
Region	If a Region is specified, the Position and Orientation inputs for the present object will be relative to the Position and Orientation of the specified Region. If the specified Region is moved or rotated, the present object with move to maintain it relative position and orientation.
RelativeEntity	If an object is specified, the Position input for the present object will be relative to the Position for the specified object. If the specified object is moved, the present object will move to maintain its relative position.
DisplayModel	The graphic representation of the object. If a list of DisplayModels is entered, each one will be displayed provided that its DrawRange input is satisfied. This feature allows the object's appearance to change with its distance from the View window's camera.
Show	If TRUE, the object is shown in the View windows.
Movable	If TRUE, the object will respond to mouse clicks and can be positioned by dragging with the mouse.

Table 10-2 DisplayEntity Outputs

Output Name	Description
Name	The unique input name for this entity.
ObjectType	The class of objects that this entity belongs to.
SimTime	The present simulation time.
User-defined attributes and custom outputs	The present values for each of the attributes and custom outputs that were defined for the DisplayEntity. (see Section 6.2)
Position	The present {x, y, z} coordinates of the DisplayEntity in its region.
Size	The present {x, y, z} components of the DisplayEntity's size.
Orientation	The present {x, y, z} Euler angles of the DisplayEntity's rotation.
Alignment	The present {x, y, z} coordinates of a point on the DisplayEntity that aligns direction with the position output. Each component should be in the range [-0.5, 0.5].

10.2 DisplayModel

The graphical appearance of a DisplayEntity and its subclasses is determined by its DisplayModel. The two objects work together to generate an object's display. In general, the DisplayEntity determines what is displayed, while its DisplayModel determines how it is displayed. A number of different subclasses of DisplayModel are available to match the various subclasses of DisplayEntity.

For example, the Text and TextModel objects work together to display text: the text to be displayed is determined by the Text object, while the style of the displayed text (font, bold, italics, colour, etc.) is determined by the TextModel. In this case, the TextModel plays the same role as a text style in word processing software. Users can ensure that the same text style is used for multiple Text objects by sharing the same TextModel between all these objects.

One DisplayModel can be shared between multiple DisplayEntities. This is an essential feature for the case of complex 3D content built from millions of triangles. In this case, a ColladaModel (a subclass of DisplayModel) stores 3D information that can be shared between multiple DisplayEntities. The 3D content is loaded and stored only once, even though it is displayed many times in various locations. Even in the case of animated 3D content, only one ColladaModel is needed to display a different animation state in each location.

Although DisplayModels determine the appearance of a DisplayEntity, the DisplayModel has no graphics itself and therefore cannot be dragged and dropped in the normal manner. To create a new DisplayModel, simply duplicate an existing DisplayModel. JaamSim starts with a pre-defined example of each type of DisplayModel that can be used for this purpose. Duplicate an existing DisplayModel by right-clicking its entry in the Object Selector and selecting Duplicate, then edit its keyword values and name as necessary.

A selection of DisplayModels can be found in the Display Models palette in the Object Selector. Each type of DisplayModel is intended for specific types of DisplayEntities.

Table 10-3 Types of DisplayModel

DisplayModel	Description	Usage
ColladaModel	An imported 3D object.	DisplayEntity and all its sub-classes.
ImageModel	An imported picture.	DisplayEntity and all its sub-classes.
ShapeModel	A flat geometric object such as a circle or rectangle.	DisplayEntity and all its sub-classes.
PolylineModel	A series of line segments connected by nodes.	Selected sub-classes of DisplayEntity such as EntityConveyor and EntityDelay.
TextModel	A text style (font, colour, etc.).	Text, OverlayText, BillboardText, and OverlayClock objects.
ArrowModel	Similar to PolylineModel except that the last line terminates in an arrowhead.	Arrow object.
GraphModel	Formatting inputs for graphs.	Graph object.

All of these DisplayModel objects have the same Graphics keywords that control optional rendering and scaling at different drawing ranges.

Table 10-4 DisplayModel Inputs

Keyword	Description
VisibleViews	A list of Views for which this DisplayModel is shown. If empty, the model appears on all Views.
DrawRange	A list of two values for the minimum and maximum distance from the camera this object is visible.
ModelScale	A list of three multiplicative factors by which to scale the model in the x, y and z dimensions respectively.

10.2.1 ColladaModel

ColladaModel objects are used to display custom 3D graphics in a simulation model. The COLLADA file format (.DAE) is an interchange file format used for 3D graphics. Any 3D object such as a DisplayEntity and most of its sub-classes can accept a ColladaModel as its DisplayModel.

A number of other 3D formats can be used in addition to Collada. At the present time, JaamSim supports DAE, OBJ, and JSB formats as well as zipped versions of these files (ZIP). The JSB format is specific to JaamSim:

The JSB format is a binary format that allows complex 3D objects to be loaded much faster than is possible with the DAE and OBJ formats. A JSB file can be exported by right clicking on a ColladaModel in the Object Selector and selecting "Export 3D Binary File (*.jsb)". Note that the exported JSB will look for the same textures as the DAE file and that these should be located in the same relative position to the JSB file as they were to the DAE file.

Managing 3D assets can be complicated because of the large file sizes and the need to provide separate files for the textures. It is recommended that the user place each 3D asset and its texture files in its own ZIP file. This approach greatly reduces the number and size of the files being handled, and ensures that the files can be moved between computers without breaking the file paths.

Note that it is often necessary to edit the DAE file with a text editor, such as Notepad++, to convert any absolute file paths for texture files to relative ones.

Table 10-5 ColladaModel Inputs

Keyword	Description
ColladaFile	A file path to the DAE, OBJ, or JSB file to be used for this display model. A ZIP file containing one of these files and its related texture files can also be used, and is the recommended option for this input. The file path must be enclosed in single quotes if it contains spaces.
Actions	A list of animation Actions and the object outputs to which they are to be connected, in the format { Action1 Output1 } { Action2 Output2 }. In this example, the actions Action1 and Action2 must be available for the graphical asset specified by the ColladaFile input. The outputs Output1 and Output2 must be valid outputs for the entity to which this ColladaModel is assigned.

10.2.2 ImageModel

ImageModel objects are used to display custom 2D graphics in a simulation model, such as a picture or a map. Both DisplayEntity and OverlayImage can accept an ImageModel object as an input. Image file types currently supported by JaamSim include BMP, GIF, JPG, PCX and PNG files, or a ZIP file containing any one of these file types.

Table 10-6 ImageModel Inputs

Keyword	Description
ImageFile	A file path to the image file to be used for this display model. Must be enclosed in single quotes if the path contains spaces.
Transparent	If TRUE, transparency is enabled for supported image types (GIF and PNG).
CompressedTexture	If TRUE, image compression is applied to alleviate memory issues with large images.

10.2.3 TextModel

TextModel objects specify the general appearance of Text objects and of overlay objects that display text (OverlayText, OverlayClock, and BillboardText). A TextModel object can therefore be used as a style class, with all instances of these Text objects that have the same style sharing the same TextModel.

Table 10-7 TextModel Inputs

Keyword	Description
FontName, FontColour, FontStyle, DropShadow, DropShadowColour, DropShadowOffset	Same as the keywords used by Text (see Table 11-6).

10.2.4 Polyline Model

The PolylineModel is used to determine the graphics for entities that appear as a single-segment or multi-segment line, such as EntityConveyor and EntityDelay. It cannot be used by other objects such as a DisplayEntity intended for 3D or 2D graphics.

PolylineModel has no inputs other than the standard ones for DisplayModels.

10.2.5 ArrowModel

The ArrowModel is used to determine the graphics for the Arrow object. It has no inputs other than the standard ones for DisplayModels.

10.2.6 GraphModel

The GraphModel is used to determine the presentation style and proportions for various types of Graph objects. To make the Graph scalable to any size, all length measurements are specified as a fraction of the Graph's total height.

Table 10-8 GraphModel Inputs

Keyword	Description
TitleTextHeight	Text height for the Graph title.
XAxisTitleTextHeight	Text height for the x-axis title.
YAxisTitleTextHeight	Text height for the y-axis title.
LabelTextHeight	The text height for both x-axis and y-axis labels.
TitleGap	The gap between the Graph title and the top of the Graph.
XAxisTitleGap	The gap between the x-axis labels and the x-axis title.
XAxisLabelGap	The gap between the x-axis and its labels.
YAxisTitleGap	The gap between the y-axis labels and the y-axis title.
YAxisLabelGap	The gap between the y-axis and its labels.
TopMargin	Size of the gaps between the respective edges of the outer pane and the Graph. Expressed as a fraction of the Graph's total height.
BottomMargin	
LeftMargin	
RightMargin	
TitleTextModel	The TextModel used to determine the font, colour, and style for the Graph title. The dropshadow settings are ignored. Black Verdana text is used if this input is left blank.
AxisTitleTextModel	The TextModel used to determine the font, colour, and style for the x-axis and y-axis titles. The dropshadow settings are ignored. Black Verdana text is used if this input is left blank.
LabelTextModel	The TextModel used to determine the font, colour, and style for the labels next to the x-axis and y-axis tick marks. The dropshadow settings are ignored. Black Verdana text is used if this input is left blank.
GraphColor	The colour of the Graph background.

BackgroundColor	The colour of the outer pane background.
BorderColor	The colour of the Graph border.

10.2.7 ShapeModel

ShapeModel objects are used to display a 2D object whose geometry and colour can be adjusted.

Table 10-9 ShapeModel Inputs

Keyword	Description
Shape	The graphical appearance of the object, chosen from a selection of predefined shapes.
FillColour	The colour of the filled part of the DisplayModel, defined by a colour name or RGB values.
OutlineColour	The colour of the outline of the DisplayModel, defined by a colour name or RGB values.
Filled	If TRUE, the DisplayModel will appear with a solid colour fill. Otherwise, the DisplayModel will appear hollow.
Bold	If TRUE, the DisplayModel outline will appear thicker than normal.

10.3 Importing a 3D Object or Image

The easiest way to create a new DisplayEntity for a 3D object or an image is to use the Import function provided in the Control Panel under File. This method creates a new DisplayEntity that is connected to a new DisplayModel with the imported 3D object or image.

10.4 View Window

The View object is used to hold the position and direction of the camera that creates the 3D image in a View window. A new View can be created by clicking on the View item in the Menu bar. An existing View can be selected for editing by click anywhere in its windows that does not land on an entity.

Table 10-10 View Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Graphics	
Region	The Region this View is within.
ViewCenter	The position the view camera is looking at.
ViewPosition	The position the view camera is looking from.
WindowSize	The size of the window in pixels (width, height).
WindowPosition	The position of the upper left corner of the window in pixels measured from the top left corner of the screen.
TitleBarText	Text to place in the title bar of the View window. The window must be closed and re-opened manually after changing the title.
ShowWindow	If TRUE, the View window is displayed on-screen.
Movable	A Boolean indicating whether the view can be panned or rotated.
FollowEntity	The (optional) entity for this view to follow. Setting this input makes the view ignore ViewCenter and interprets ViewPosition as a relative offset to this entity.
ScriptedViewPosition	The (optional) scripted curve for the view position to follow.
ScriptedViewCenter	The (optional) scripted curve for the view center to follow.
SkyboxImage	The image file to use as the background for this view.

11 Graphics Objects Palette

Graphics Objects are used to create 3D objects, pictures, text, graphs, arrows, and other graphical components needed to visualise and monitor a simulation. The following objects are included in the Graphics Objects palette.

Table 11-1 Graphics Objects Palette

Object	Description
Region	Local coordinate system.
DisplayEntity	Graphical object displaying either a 3D shape or a 2D picture.
Text	Text that appears in the 3D model universe.
EntityLabel	Text that labels another object. An EntityLabel can only be created by selecting the "Show Label" option in an object's context menu. Since they cannot be dragged and dropped, EntityLabel does not appear in the Model Builder.
InputBox	Text that provides an input value for the model.
BarGauge	Gauge that displays the value of an expression.
OverlayImage	Picture that appears in a fixed position in the display window.
OverlayText	Text that appears in a fixed position in the display window.
OverylayClock	Time and date display that appears in a fixed position in the display window.
BillboardText	Text that follows a 3D position but is always upright on the screen.
Arrow	Line that terminates in an arrow head.
Graph	Chart that shows model outputs as they change in time.
MimicEntity	Graphical object that copies the appearance of another DisplayEntity.
View	Display window showing view of the 3D model universe. A View can only be created using the Views menu in the Menu Bar.
VideoRecorder	Object that makes a video recording of the model.

11.1 Region

The Region object is used to define a local coordinate system. When a Region is specified for an object, its inputs for position and orientation are relative to the position and orientation of its Region. The global coordinate system is the default for objects that do not reference a specific Region.

The Position and Orientation keywords are used to define the origin for the coordinate system and the angles for its coordinate axes. Once these inputs have been set, it is advised to set the inputs for Show and Movable to FALSE so the Region object is no longer visible and cannot be moved accidentally.

Table 11-2 Region Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-3 Region Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.2 DisplayEntity

The DisplayEntity object is used to add an image or static 3D content in a model. Normally, a DisplayEntity is created automatically when a 3D object or an image is imported through the File > Import menu item.

A DisplayEntity can also be created by drag and drop from the Model Builder. The default appearance of a DisplayEntity is a grey cube. Its appearance can be changed by right-clicking the DisplayEntity and selecting "Change Graphics". The user can then select between the available DisplayModels or can create a new DisplayModel by importing a file in one of the supported 3D graphics formats.

Table 11-4 DisplayEntity Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-5 DisplayEntity Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.3 Text

The Text object is used to show static or dynamic text in a model. Text objects are used for labelling various parts of the model and for monitoring the status of the model.

The output displayed by the Text object is determined primarily by its Format keyword. Dynamic text can be introduced by including a Java format code such as %s in the Format keyword and specifying the value to be displayed with the DataSource keyword. Some typical Java format codes are %s, which can display both text and numbers, and %.6f, which displays a numeric value with six decimal places.

If the variable text is a number with units, the value can be converted from SI to a specified unit through the Unit keyword.

The easiest way to modify the contents of a Text object is to edit it directly in the view window. Double-click on the object to place it in edit mode. In this mode, text can be entered, deleted, inserted, and highlighted using the same conventions as a typical text editor. Text can be copied from and pasted to the clipboard using Ctrl-C and Ctrl-V. Press the Return key or click on another object to save the changes and return the Text object to its normal mode.

The appearance and style of the text is determined by the keywords under the Font tab, including FontName, FontColour, etc. If no inputs are provided to these keywords, the appearance of the text is determined by the TextModel entered for the DisplayModel keyword. The default TextModel is set to the black Verdana font.

TextModels can be used in the same way as the Text Styles in Microsoft Word. A new TextModel can be created through the following steps:

1. In the Object Selector, right-click on the TextModelDefault object and select Duplicate.
2. Rename the new TextModel object by clicking on its name in the Object Selector, entering the new name.
3. Use the Input Editor to specify the characteristics for the new TextModel, such as font, font style, colour, etc.
4. Use the Input Editor to select the new TextModel for the Text object's DisplayModel keyword.

Table 11-6 Text Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
TextHeight	The height of the font as displayed in the view window.
Format	The fixed and variable text to be displayed. If spaces are included, enclose the text in single quotes. If variable text is to be displayed using the DataSource keyword, include the appropriate Java format in the text. For example, `%s` will display a text output and `%.6f` will display a number with six decimals of accuracy.
UnitType	The unit type for the numerical value to be displayed as variable text. Set to DimensionlessUnit if the variable text is non-numeric such as the state of a Server.
Unit	The unit in which to express an expression that returns a numerical value. For example, if the UnitType input has been set to DistanceUnit, then the output value could be displayed in kilometres, instead of meters, by entering km to this keyword.
DataSource	An expression that returns the variable text to be displayed. The expression can return a number that will be formatted as text or it can return text directly, such as the state of a Server.
FailText	The text to display if there is any failure while formatting the variable text or while evaluating the expression.
Font	
FontName	The font to be used for the text.
FontColour	The colour of the text, specified by a colour keyword or RGB values.
FontStyle	The font styles to be applied to the text, e.g. Bold, Italic.
DropShadow	If TRUE, then a drop shadow appears for the text.
DropShadowColour	The colour for the drop shadow, specified by a colour keyword or RGB values.
DropShadOffset	The { x, y, z } coordinates of the drop shadow's offset, expressed as a decimal fraction of the text height.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-7 Text Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.4 EntityLabel

The EntityLabel object is a special version of a Text object that is used to display the name of a selected object. The only way to create an EntityLabel is to right-click on the object to be labelled and select “Show Label”. It cannot be dragged and dropped from the Model Builder.

An EntityLabel moves automatically with the object and is destroyed when the object is destroyed. An object can have only one EntityLabel at a time.

An object name can be changed by editing its EntityLabel in the view window. Double-click on the EntityLabel to enter edit mode and revise the name as desired. Press the Return key or click on another object to accept the new name.

The appearance of all the EntityLabels in a model can be changed by editing the inputs for the EntityLabelModel (under Display Models > TextModel in the Object Selector). The standard colour, font and style (bold and/or italics) for all EntityLabels can be selected in this way.

An EntityLabel has the same inputs and outputs as Text, with the exception of the

Table 11-8 EntityLabel Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
TextHeight	Keywords for Text (see Table 11-6).
Font	
FontName, FontColour, FontStyle, DropShadow, DropShadowColour, DropShadowOffset	Keywords for Text (see Table 11-6).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-9 EntityLabel Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.5 InputBox

1.0

The InputBox object is a special version of a Text object that is used to allow a user to enter a model input directly in the view window, without using the Input Editor. The input value can be modified by double-clicking on the displayed value to enter edit mode. After editing is complete, press the Return key or click on another object to accept the new value.

The function of an InputBox object is similar to that of an InputValue object (see Section 13.1). The difference is that InputBox can be used to assign both numerical and non-numerical inputs, while InputValue is restricted to numerical inputs.

Table 11-10 InputBox Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
TextHeight	Keywords for Text (see Table 11-6).
TargetInput	The names of the Entity and Keyword that will receive the input.
Font	
FontName, FontColour, FontStyle, DropShadow, DropShadowColour, DropShadowOffset	Keywords for Text (see Table 11-6).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-11 InputBox Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.6 BarGauge

The BarGauge object is used to provide a graphical display of the numerical value returned by an expression.

Table 11-12 BarGauge Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DataSource	Height of the bar expressed as a value between 0 and 1. Values outside this range will be truncated.
Colour	Colour of the bar.
BackgroundColour	Colour of the gauge's body.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-13 BarGauge Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
BarGauge	
Value	Value displayed by the gauge.

11.7 Overlay Objects (OverlayImage, OverlayText, OverlayClock)

Overlay objects are special versions of other objects that are used for graphical display in a simulation model. Unlike other display objects, the position of overlay objects is referenced to the corner of a view window, and so the object does not move when the View is panned or zoomed. These objects are useful for labelling View windows or displaying the model name and company logos. Examples of overlay objects are the default Title and Clock that are provided automatically when a new model is opened.

There are three types of overlay objects, each corresponding to a different graphical object type. The relationship between each overlay object, its parent object type, and its usage is summarized in the following table.

Table 11-14 Overlay Object and Usage Summary

Overlay Object	Parent Object	Usage
OverlayImage	DisplayEntity	Static image (Logos, other graphics)
OverlayText	Text	Static or dynamic text (Model name, states, rates)
OverlayClock	Text	Current time in the simulation model.

Apart from graphics inputs, each type of overlay object has the same keywords as its parent object. The graphics inputs for overlay objects are shown in the following table.

Table 11-15 Overlay Objects Graphics Inputs

Keyword	Description
ScreenPosition	A list of two numbers specifying the spacing, in pixels, between the left and top corner of the View window and the object.
AlignRight	If TRUE, the horizontal alignment is referenced to the right side of the View window instead of the left.
AlignBottom	If TRUE, the vertical alignment is referenced to the bottom side of the View window instead of the top.

11.8 BillboardText

A BillboardText object is similar to a Text object, except that the text is always oriented towards the View window and its height is given in pixels instead of metres. BillboardText retains its coordinates in space and in this way differs from the OverlayText object. Both static and dynamic text can be displayed by a BillboardText object using the same keywords as Text objects.

BillboardText is commonly used to label 3D objects. The advantage of using BillboardText is that the label is visible and readable from all view angles.

The keywords for BillboardText are identical to those for Text objects and have the same meaning, except for the TextHeight keyword, which now gives the height of the text in pixels instead of metres. At the present time, this input must include the units of metres (m) even though it is interpreted as pixels. This will be corrected in a future version of the software.

11.9 Arrow

An Arrow object consists of a line, which can be composed of multiple segments, and an arrowhead.

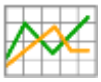
Table 11-16 Arrow Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Graphics	
Points, CurveType, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).
Width	The width of the Arrow line segments in pixels.
ArrowSize	A set of { x, y, z } numbers that define the size of the arrowhead in those directions at the end of the connector.
Colour	The colour of the arrow, defined using a colour keyword or RGB values.

Table 11-17 Arrow Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.10 Graph



The Graph object is a real-time visual representation of one or more quantities, showing their values over a specified time period.

The following figure illustrates the meanings of the keywords that are used to format a Graph.

Figure 11-1 Sample Graph with Formatting Keywords Defined Graphically

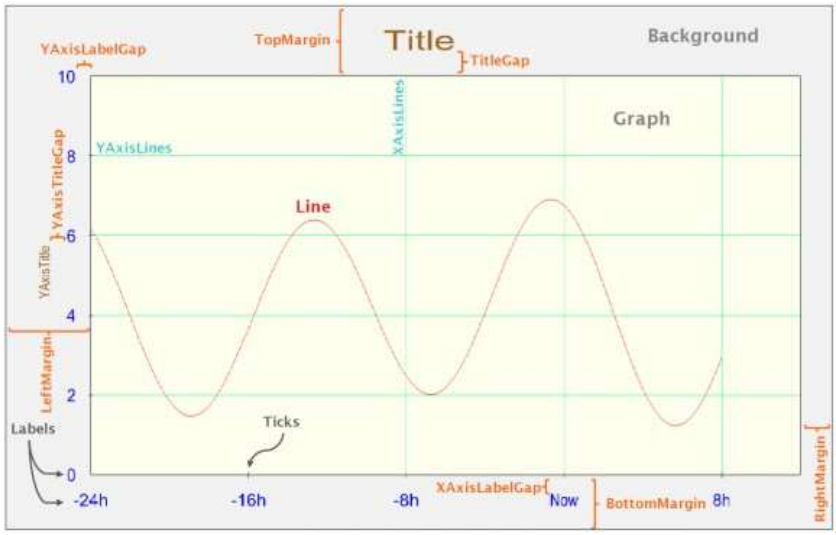


Table 11-18 Graph Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Title	Text for the graph title, enclosed in single quotes if it contains spaces.
NumberOfPoints	The number of data points to be displayed on the Graph. This determines the resolution of the graph.
UnitType	The type of units for each line specified by the DataSource input. Must be specified before the DataSource input and the Y-Axis inputs.
DataSource	One or more sources of data to be graphed against the primary y-axis. Specified as a series of Expressions, each enclosed by braces.
LineColours	A list of colours for the data series to be displayed. For multiple colours, each colour must be enclosed in braces as each colour can be itself defined as a list of RGB values.
LineWidths	A list of widths, in pixels, for the data series to be displayed.
SecondaryUnitType	The type of units for each line specified by the SecondaryDataSource input. Must be specified before the SecondaryDataSource input and the Secondary Y-Axis inputs.

SecondaryDataSource	One or more sources of data to be graphed against the secondary y-axis. Specified as a series of Expressions, each enclosed by braces.
SecondaryLineColours	A list of colours for the data series to be displayed. For multiple colours, each colour must be enclosed in braces as each colour can be itself defined as a list of RGB values.
SecondaryLineWidths	A list of widths, in pixels, for the data series to be displayed.
X-Axis	
XAxisTitle	Title text for the x-axis.
XAxisUnit	The unit to be used for the x-axis.
XAxisStart	The minimum value for the x-axis.
XAxisEnd	The maximum value for the x-axis.
XAxisInterval	The interval between x-axis labels.
XAxisLabelFormat	The Java format to be used for the tick mark values on the x-axis. For example, the format %.1f would display the value 5 as 5.0.
XLines	A list of time values between XAxisStart and XAxisEnd where vertical gridlines are inserted.
XLinesColor	Colour of the vertical gridlines, or a list corresponding to the colour of each gridline defined in XLines, defined using a colour name or RGB values.
Y-Axis	
YAxisTitle	Title text for the primary y-axis.
YAxisUnit	The unit to be used for the primary y-axis.
YAxisStart	The minimum value for the primary y-axis, in units of the DataSource.
YAxisEnd	The maximum value for the primary y-axis.
YAxisInterval	The interval between primary y-axis labels.
YAxisLabelFormat	The Java format to be used for the tick mark values on the primary y-axis. For example, the format %.1f would display the value 5 as 5.0.
YLines	A list of values at which to insert horizontal gridlines.
YLinesColor	Colour of the horizontal gridlines, defined using a colour name or RGB values.
Secondary Y-Axis	
SecondaryYAxisTitle	Title text for the secondary y-axis.
SecondaryYAxisUnit	The unit to be used for the secondary y-axis.
SecondaryYAxisStart	The minimum value for the secondary y-axis.
SecondaryYAxisEnd	The maximum value for the secondary y-axis.
SecondaryYAxisInterval	The interval between secondary y-axis labels.
SecondaryYAxisLabelFormat	The Java format to be used for the tick mark values on the secondary y-axis.

Graphics	
Points, CurveType, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-19 Graph Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.11 MimicEntity

The MimicEntity is used to copy the display of another entity, usually as part of a control panel for a model. The entity whose display is to be copied is specified by the input to the SourceEntity keyword. This input can be the name of a specific entity or an expression that returns an entity.

Table 11-20 MimicEntity Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
SourceEntity	The entity whose graphics are to be copied.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-21 MimicEntity Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

11.12 VideoRecorder

The VideoRecorder object is used to create a short video of a model in operation.

The AVI file created by the VideoRecorder is encoded using the VP8 codec, which is NOT supported by Windows Media Player. Furthermore, the present encoding algorithm is quite inefficient making the file size much larger than necessary. Both problems can be solved by re-encoding the video using free open-source software such as HandBrake (www.handbrake.fr).

The original AVI file in VP8 codec can be viewed with the VLC video player (www.videolan.org).

Table 11-22 VideoRecorder Key Inputs

Keyword	Description
Key Inputs	
CustomOutputList	Keyword for User-Defined Variables (see Table 6-9).
CaptureStartTime	Simulation time at which to capture the first frame.
CaptureInterval	Simulation time between captured frames.
CaptureFrames	The total number of frames to capture for the video. The recorded video assumes 30 frames per second. Therefore, if a 2 minute video is required, the number of frames should be set to 120 x 30 = 3600.
CaptureArea	The size of the video/image, expressed as the number of horizontal and vertical pixels. The top left-hand corner of the captured frames will be the same as the top left-hand corner of the image on the monitor. If the specified image size is larger than the monitor resolution, then the image will be extended beyond the bottom and/or right sides of the monitor.
CaptureViews	The list of View windows to be captured.
VideoBackgroundColor	The background colour for the captured frames. Only the 3D view portion of the specified windows will be captured. The remainder of the frame, such as the Control Panel or any gaps between the view windows, will be replaced by the background colour.
VideoName	A label to append to the run name when the AVI file is saved. The saved file will be named <run name>_<VideoName>.avi.
SaveImages	If TRUE, an individual PNG file will be saved for each frame.
SaveVideo	If TRUE, an AVI file containing the video will be saved.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 11-23 VideoRecorder Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

12 Probability Distributions Palette

The Probability Distributions palette provides a selection of standard theoretical probability distributions as well as user-defined probability distributions.

Table 12-1 Probability Distributions

Distribution Name	Description
UniformDistribution	Generates samples with a constant probability between minimum and maximum values.
TriangularDistribution	Generates samples from a triangular probability distribution between minimum and maximum values. The distribution peaks at its mode.
NormalDistribution	Generates samples from a normal probability distribution.
ExponentialDistribution	Generates samples from a negative exponential probability distribution.
NonStatExponentialDist	Generates samples from a time-varying negative exponential probability distribution. The correct 'non-stationary Poisson process' algorithm is used.
ErlangDistribution	Generates samples from an Erlang probability distribution.
GammaDistribution	Generates samples from a Gamma probability distribution.
BetaDistribution	Generates samples from a Beta probability distribution.
WeibullDistribution	Generates samples from a Weibull probability distribution.
LogNormalDistribution	Generates samples from a Log-Normal probability distribution.
LogLogisticDistribution	Generates samples from a Log-Logistic probability distribution.
DiscreteDistribution	Generates samples from a discrete set of values.
ContinuousDistribution	Generates samples over a continuous range of values.
BooleanSelector	Randomly selects true/false with a user-selectable probability of true.

Most probability distributions use the following inputs and outputs.

Table 12-2 Distribution Inputs

Keyword	Description
UnitType	The unit type for the value returned by the distribution, e.g. TimeUnit. To keep the units consistent for other inputs, this input must be set first.
RandomSeed	Seed for the random number generator. Must be an integer greater than or equal to zero. The RandomSeed keyword works together with the GlobalSubstreamSeed under the Simulation object to determine the random sequence. The GlobalSubstreamSeed keyword allows the user to change all the random sequences in a model with a single input.
MinValue	The minimum value that can be returned by the distribution. A value less than the minimum is rejected and the distribution is re-sampled.
MaxValue	The maximum value that can be returned by the distribution. A value greater than the maximum is rejected and the distribution is re-sampled.

Table 12-3 Distribution Outputs

Output Name	Description
Value	The last value sampled from the distribution. When used in an expression, this output returns a new sample every time the expression is evaluated.
CalculatedMean	The mean value for the distribution calculated directly from the inputs. Ignores the values entered for the MinValue and MaxValue keywords.
CalculatedStandardDeviation	The standard deviation for the distribution calculated directly from the inputs. Ignores the values entered for the MinValue and MaxValue keywords.
NumberOfSamples	The total number of samples returned by the Probability Distribution.
SampleMean	The average of the samples returned by the Probability Distribution.
SampleStandardDeviation	The standard deviation of the samples returned by the Probability Distribution.
SampleMin	The minimum of the samples returned by the Probability Distribution.
SampleMax	The maximum of the samples returned by the Probability Distribution.

The Probability Distributions were coded using algorithms adapted from "Simulation Modeling & Analysis", 4th Edition, by Averill M. Law. Random numbers for these distributions are generated by the Multiple Recursive Generator developed by L'Ecuyer ("Good Parameters and Implementations for Combined Multiple Recursive Random Number Generators", Operations Res., 47: 159-164 (1999a)).

12.1 Changing the Random Seed

Each Probability Distribution has the RandomSeed keyword, which generates a different pseudo-random sequence of values for each Probability Distribution. Often, a simulation model is executed multiple times, called 'replications', using different random seeds to determine the statistical accuracy of the output parameters.

One way to achieve multiple replications is to change the RandomSeed for each Probability Distribution. However, this can be impractical when large numbers of distributions are used in a model. The GlobalSubstreamSeed keyword for the Simulation object simplifies this process. Changing the input for this keyword causes all Probability Distributions in the model to generate a different random sequence. In effect, the seed for each Probability Distribution is the combination of the inputs to the RandomSeed and GlobalSubstreamSeed keywords.

When multiple objects behave according to a Probability Distribution with the same characteristics, it is advisable to have a unique instance of the Probability Distribution for each object. This avoids any cross-correlation effects arising from the order in which a single distribution may be sampled.

12.2 UniformDistribution

The UniformDistribution object generates random samples with a constant probability between specified minimum and maximum values.

Table 12-4 UniformDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-5 UniformDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.3 TriangularDistribution

The TriangularDistribution object generates random samples from a triangular probability distribution between specified minimum and maximum values. The distribution peaks at its mode.

Table 12-6 TriangularDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Mode	The mode of the triangular distribution, i.e. the value with the highest probability.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-7 TriangularDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.4 NormalDistribution

The NormalDistribution object generates random samples from a normal probability distribution.

Table 12-8 NormalDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Mean	The mean of the normal distribution (ignoring the MinValue and MaxValue keywords).
StandardDeviation	The standard deviation of the normal distribution (ignoring the MinValue and MaxValue keywords).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-9 NormalDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.5 ExponentialDistribution

The ExponentialDistribution object generates random samples from a negative exponential probability distribution.

Table 12-10 ExponentialDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Mean	The mean of the exponential distribution.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-11 ExponentialDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.6 NonStatExponentialDist

The NonStatExponentialDist object generates random samples from a time-varying negative exponential probability distribution. The correct "non-stationary Poisson process" algorithm is used.

Table 12-12 NonStatExponentialDist Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
ExpectedArrivals	A time series containing the expected cumulative number of arrivals as a function of time.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-13 NonStatExponentialDist Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.7 ErlangDistribution

The ErlangDistribution object generates random samples from an Erlang probability distribution.

Table 12-14 ErlangDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Mean	The scale parameter for the Erlang distribution.
Shape	The shape parameter for the Erlang distribution. An integer value >= 1. Shape = 1 gives the Exponential distribution. For Shape > 10 it is better to use the Gamma distribution.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-15 ErlangDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.8 GammaDistribution

The GammaDistribution object generates random samples from a Gamma probability distribution.

Table 12-16 GammaDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Mean	The mean of the Gamma distribution.
Shape	The shape parameter for the Gamma distribution. A decimal value > 0.0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-17 GammaDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.9 BetaDistribution

The BetaDistribution object generates random samples from a Beta probability distribution.

Table 12-18 BetaDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
AlphaParam	The alpha tuning parameter.
BetaParam	The beta tuning parameter.
Scale	The scale parameter for the distribution. This scales the value of the distribution so it return values between 0 and scale.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-19 BetaDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.10 WeibullDistribution

The WeibullDistribution object generates random samples from a Weibull probability distribution.

Table 12-20 WeibullDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Scale	The scale parameter for the Weibull distribution.
Location	The location parameter for the Weibull distribution.
Shape	The shape parameter for the Weibull distribution. A decimal value > 0.0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-21 WeibullDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.11 LogNormalDistribution

The LogNormalDistribution generates random samples from a Log-Normal probability distribution.

Table 12-22 LogNormalDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Scale	The scale parameter for the Log-Normal distribution.
NormalMean	The mean of the dimensionless normal distribution (not the mean of the lognormal).
NormalStandardDeviation	The standard deviation of the dimensionless normal distribution (not the standard deviation of the lognormal).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-23 LogNormalDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.12 LogLogisticDistribution

The LogLogisticDistribution object generates random samples from a Log-Logistic probability distribution.

Table 12-24 LogLogisticDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
Scale	The scale parameter for the Log-Logistic distribution.
Shape	The shape parameter for the Log-Logistic distribution. A decimal value > 0.0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-25 LogLogisticDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.13 DiscreteDistribution

The DiscreteDistribution object generates random samples from a discrete set of values.

Table 12-26 DiscreteDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
ValueList	The list of discrete values that can be returned by the distribution. The values can be any positive or negative and can be listed in any order. No interpolation is performed between these values.
ProbabilityList	The list of probabilities corresponding to the discrete values in the ValueList. Must sum to 1.0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-27 DiscreteDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.14 ContinuousDistribution

The ContinuousDistribution object generates random samples over a continuous range of values.

Table 12-28 ContinuousDistribution Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType, RandomSeed, MinValue, MaxValue	Keywords for Distribution (see Table 12-2).
ValueList	The list of values for the user-defined cumulative probability distribution.
CumulativeProbabilityList	The list of cumulative probabilities corresponding to the values in the ValueList. The cumulative probabilities must be given in increasing order. The first value must be exactly 0.0. The last value must be exactly 1.0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-29 ContinuousDistribution Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Distribution	
Value, CalculatedMean, CalculatedStandardDeviation, NumberOfSamples, SampleMean, SampleStandardDeviation, SampleMin, SampleMax	Outputs inherited from Distribution (see Table 12-3).

12.15 BooleanSelector

The BooleanSelector returns a randomly-selected value of TRUE or FALSE based on a user-specified probability.

Table 12-30 BooleanSelector Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
RandomSeed	Keyword for Distribution (see Table 12-2).
TrueProbability	The probability of the Selector returning true.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 12-31 BooleanSelector Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
BooleanSelector	
Value	The last value sampled from the distribution. When used in an expression, this output returns a new sample every time the expression is evaluated.

13 Basic Objects Palette

The Basic Objects palette contains a number of objects that can be used in many types of simulation models. The following objects are provided in the Basic Objects palette.

Table 13-1 Basic Objects Palette

Object	Description
InputValue	Provides a way to enter a numerical value directly into the simulation model screen.
TimeSeries	Provides a floating point number that changes in simulated time following a series of input values.
TimeSeriesThreshold	Specifies a range of values from a TimeSeries for which an activity is permitted.
ExpressionThreshold	Specifies a logical condition for which an activity is permitted.
BooleanIndicator	Circular entity that changes colour to indicate TRUE and FALSE.
ExpressionLogger	Records the values for one or more expressions to a log file at regular intervals.
EntitlementSelector	Selects an index on the basis of entitlement from a given set of proportions.
ExpressionEntity	Calculates the value for a specified expression.
DowntimeEntity	Provides Breakdown and Maintenance controls.
ValueSequence	Generates a repeating sequence of numerical values.
EventSchedule	Generates a sequence of inter-arrival times from a list of event times.
FileToVector	Populates a one-dimensional array with numeric data from a specified file.
FileToMatrix	Populates a two-dimensional array with numeric data from a specified file.
ScriptEntity	Changes model inputs during a simulation run.

13.1 InputValue

1.0

The InputValue object is a special version of a Text object that is used to allow a user to enter a numerical input directly in the view window, without using the Input Editor. The input value can be modified by double-click on the displayed value to enter edit mode. After editing is complete, press the Return key or click on another object to accept the new value.

The present value for an InputValue object can be accessed by the inputs to the keywords for other objects either through an expression, e.g. [InputValue1].Value, or by simply entering the name of the InputValue.

The function of an InputValue object is similar to that of an InputBox object (see Section 11.5) except that it is restricted to numerical keywords that can accept an expression or an object that returns a number. In contrast, the InputBox object can be used with any input, both numeric and non-numeric.

Table 13-2 InputValue Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
TextHeight, UnitType	Keywords for Text (see Table 11-6).
Value	The numerical value for the input.
Font	
FontName, FontColour, FontStyle, DropShadow, DropShadowColour, DropShadowOffset	Keywords for Text (see Table 11-6).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-3 InputValue Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
InputValue	
Value	The present value for this input.

13.2 TimeSeries

The TimeSeries object simulates a numerical value that varies with time.

Many JaamSim keywords are structured to accept a constant value, a Probability Distribution, a TimeSeries, or an Expression, which makes TimeSeries a powerful and flexible component for building simulation models.

The data for the object consists of a series of time stamps and values specified by the Value keyword. The time stamps can be irregularly spaced and it is possible to repeat the time series over and over again during the simulation using the CycleTime keyword.

The value returned by a TimeSeries object has a specific unit type indicated by the UnitType keyword. To maintain consistency, the UnitType must be specified prior to any other input.

Table 13-4 TimeSeries Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the time series. The UnitType input must be specified before the Value input.
Value	A list of time series records with format { time value }, where: 'time' is the time stamp for the record and 'value' is the time series value. Records are entered in order of increasing simulation time. The appropriate units should be included with both the time and value inputs. The first time stamp MUST be zero simulation time or January 1 00:00:00 of an arbitrary year. If a non-zero year is entered, e.g. '2010-01-01 00:00:00', then the TimeSeries considers this date to be time zero of the simulation and all other timestamps are offset accordingly.
CycleTime	The time at which the time series will repeat from the start.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-5 TimeSeries Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
TimeSeries	
PresentValue	The time series value for the present time.

Timestamps can be entered in the normal fashion, such as 0 s, 5 h, etc., or in various year/month/day formats (see Table 4-12).

The first timestamp must always be zero seconds (i.e. 0 s) or January 1, 00:00 of an arbitrary year. If a non-zero year is used, for example 2010-01-01, then the TimeSeries considers this date to be time zero of the simulation and all other timestamps are offset accordingly.

The value for the TimeSeries is constant between one timestamp and the next. If the simulation time is greater than the CycleTime, the TimeSeries will repeat from the beginning of the Value list.

For time series with more than a few entries, it is best to put the Value inputs in a separate file and use the Include feature described in Section 8.4. This will require manual editing of the configuration file (see Section 8). In the following example, the include file, TimeSeries1.inc, contains the following entries:

```
TimeSeries1  Value {
{   0 d  0.00  km/h  }
{   2 d  0.76  km/h  }
{  10 d  0.24  km/h  }
}
```

Assuming that the include-file is located in the same directory as the configuration file, the inputs to the configuration file would be:

```
Define  TimeSeries  { TimeSeries1 }
TimeSeries1  UnitType  { SpeedUnit }
Include '.\TimeSeries1.inc'
TimeSeries1  CycleTime  { 14 d }

RecordEdits
```

Note that all the inputs associated with TimeSeries1 appear at the beginning of the configuration file before the RecordEdits statement (see Section 8.6). This position will allow editing of the model in the Input Editor and saving the results without changing the Include file arrangement.

In the example, TimeSeries1 takes on a new value (0.76 km/h) on when simulation time reaches 24 hours and another new value (0.24 km/h) at 240 hours. After 14 days, the TimeSeries completes a cycle and takes on the original value (0 km/h). This 14-day cycle would repeat until the end of the simulation run.

The following inputs in year/month/day format are equivalent to those for the example given above.

```
TimeSeries1  Value {
{  2014-01-01T00:00:00  0.00  km/h  }
{  2014-01-03T00:00:00  0.76  km/h  }
{  2014-01-11T00:00:00  0.24  km/h  }
}
```

13.3 TimeSeriesThreshold

The TimeSeriesThreshold object varies its state between open and closed depending on the present value for a TimeSeries object.

The TimeSeries to be monitored is specified by the TimeSeries keyword. Trigger levels are determined by the MinOpenLimit and MaxOpenLimit keywords. For the TimeSeriesThreshold to be open, the present value for the TimeSeries must be within the range specified by these two keywords.

The LookAhead and Offset keywords provide additional flexibility:

- If a non-zero value is specified for the LookAhead keyword, then the present value for the TimeSeries must be within the range specified by the MinOpenLimit and MaxOpenLimit keywords over the entire LookAhead duration, starting from the present time.
- If a non-zero value is specified for the Offset keyword, then the above rule is modified so that the LookAhead duration begins at the present time plus the offset.

Table 13-6 TimeSeriesThreshold Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the threshold (e.g. DistanceUnit, TimeUnit, MassUnit).
TimeSeries	The TimeSeries object whose values are to be tested.
MaxOpenLimit	The largest TimeSeries value for which the threshold is open. The threshold is closed for TimeSeries values greater than MaxOpenLimit.
MinOpenLimit	The smallest TimeSeries value for which the threshold is open. The threshold is closed for TimeSeries values smaller than MinOpenLimit.
LookAhead	The length of time over which the TimeSeries values must be >= MinOpenLimit and <= MaxOpenLimit. The threshold is open if the TimeSeries values x(t) satisfy MinOpenLimit <= x(t) <= MaxOpenLimit for simulation times t from (SimTime + Offset) to (SimTime + Offset + LookAhead).
Offset	The amount of time that the threshold adds on to every time series lookup.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).
OpenColour, ClosedColour, ShowWhenOpen, ShowWhenClosed	Keywords for Thresholds (see Table 9-1).

Table 13-7 TimeSeriesThreshold Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
Threshold	
Open, OpenFraction, ClosedFraction, OpenCount, ClosedCount	Outputs inherited from Threshold (see Table 9-2).

13.4 ExpressionThreshold

The ExpressionThreshold object varies its state between open and closed depending on the value returned by an expression.

The expression to be evaluated is specified by the OpenCondition keyword. It is re-evaluated with every time advance of the model, and on demand when the Open output is tested by another Expression.

Normally, an ExpressionThreshold is open when the OpenCondition is TRUE and IS closed when it is FALSE. However, it is possible to specify a separate expression to close the ExpressionThreshold using the CloseCondition keyword. When this keyword is specified, the threshold remains open until the CloseCondition expression is TRUE.

The CloseCondition keyword introduces some special cases to be addressed:

- If the two conditions conflict by both returning TRUE, then the threshold is considered to be open.
- If both conditions are FALSE, then the threshold's previous open or closed state is retained.
- If both conditions are FALSE at the start of the simulation run, then InitialOpenValue keyword determines whether the threshold is open or closed.

Expression thresholds CANNOT be used in some circumstances. The expressions entered to the OpenCondition and CloseCondition keywords are tested only when an event occurs in the model such as the arrival of an entity or the completion of processing a Server. Normally, this restriction has no effect on a discrete event simulation since every change of the model's state is associated with an event. However, it is possible to enter an expression that changes between TRUE and FALSE without an event occurring. This can occur when simulation time is used explicitly in an expression, e.g. `'this.SimTime > 5[s]'`. An ExpressionThreshold will detect this condition becoming TRUE at the first event that occurs after 5 seconds. The correct way to model this type of condition is to use a TimeSeries and a TimeSeriesThreshold.

The ShowPendingStates keyword is used to detect situations where an ExpressionThreshold is being used inappropriately. A "pending state" is the situation where the present values for the OpenCondition and CloseCondition expressions are inconsistent with the present state of the ExpressionTheshold. This situation can be detected when the ExpressionTheshold is visible in the View window because the OpenCondition and CloseCondition expressions are re-evaluated every time the computer screen is refreshed.

Table 13-8 ExpressionThreshold Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
OpenCondition	The logical condition for the ExpressionThreshold to open.
CloseCondition	The logical condition for the ExpressionThreshold to close. If not specified, the CloseCondition defaults to the opposite of the OpenCondition. If the OpenCondition and CloseCondition are both TRUE, then the ExpressionThreshold is set to open.
InitialOpenValue	The initial state for the ExpressionThreshold: TRUE = Open, FALSE = Closed. This input is only relevant when the CloseCondition input is used and both the OpenCondition and CloseCondition are FALSE at the start of the simulation run. Otherwise, the initial state is determined explicitly by the OpenCondition and CloseCondition.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).
OpenColour, ClosedColour, ShowWhenOpen, ShowWhenClosed	Keywords for Thresholds (see Table 9-1).
PendingOpenColour	The colour of the ExpressionThreshold graphic when the threshold condition is open, but the gate is still closed.
PendingClosedColour	The colour of the ExpressionThreshold graphic when the threshold condition is closed, but the gate is still open.
ShowPendingStates	A Boolean value. If TRUE, the ExpressionThreshold displays the pending open and pending closed states.

Table 13-9 ExpressionThreshold Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
Threshold	
Open, OpenFraction, ClosedFraction, OpenCount, ClosedCount	Outputs inherited from Threshold (see Table 9-2).
ExpressionThreshold	
Open	If open, then return TRUE. Otherwise, return FALSE.

13.5 BooleanIndicator

The BooleanIndicator allows the state of a specified Expression returning TRUE or FALSE to be displayed.

Table 13-10 BooleanIndicator Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DataSource	An expression returning a boolean value: zero = FALSE, non-zero = TRUE.
TrueColour	The colour of the indicator when the DataSource expression is TRUE.
FalseColour	The colour of the indicator when the DataSource expression is FALSE.
TrueText	The string returned by the Text output when the DataSource expression is TRUE.
FalseText	The string returned by the Text output when the DataSource expression is FALSE.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-11 BooleanIndicator Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
BooleanIndicator	
Text	If the DataSource expression is TRUE, then return TrueText. If it is FALSE, then return FalseText.

13.6 ExpressionLogger

The ExpressionLogger object provides the ability to record the value for one or more expressions whenever the object is triggered during the simulation run. An ExpressionLogger can be triggered by one or more types of events:

- At regular time intervals,
- Whenever an object changes state, and
- Whenever the value of an expression changes.

Logging at regular intervals is handled by the keywords in the Key Inputs tab. State and value tracing is handled by the keywords in the Tracing tab.

Table 13-12 ExpressionLogger Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Interval	A fixed interval at which entries will be written to the log file. This input is optional if state tracing or value tracing is specified.
UnitTypeList	The unit types for the quantities being logged. Use DimensionlessUnit for text entries.
DataSource	One or more sources of data to be logged. Each source is specified by an Expression. Also acceptable are: a constant value, a Probability Distribution, TimeSeries, or a Calculation Object.
IncludeInitialization	If TRUE, entries are logged during the initialization period.
StartTime	The time for the first log entry.
EndTime	The latest time at which to make an entry in the log.
Tracing	
StateTraceList	A list of entities whose states will be traced. An entry in the log file is made every time one of the entities changes state. Each entity's state is written automatically to the log file - it is not necessary to add an expression to the DataSource keyword's input.
ValueUnitTypeList	The unit types for the values being traced.
ValueTraceList	One or more sources of data whose values will be traced. An entry in the log file is made every time one of the data sources changes value. Each data source's value is written automatically to the log file - it is not necessary to add an expression to the DataSource keyword's input. Each source is specified by an Expression. Also acceptable are: a constant value, a Probability Distribution, TimeSeries, or a Calculation Object.
ValuePrecisionList	The number of decimal places to show for each value in valueTraceList. If only one number is given, then that number of decimal places is used for all values.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-13 ExpressionLogger Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

13.7 EntitlementSelector

The EntitlementSelector object is similar to the DiscreteDistribution object in that it returns an index in some range, except that instead of returning a random selection based on probabilities it makes its choice using an entitlement algorithm based on proportions. The entitlement algorithm chooses the index that minimizes the difference between the actual number returned for each index and the expected number based on the proportions.

The ProportionList keyword is used to specify the relative proportions for the N choices.

Table 13-14 EntitlementSelector Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
ProportionList	A list of N numbers equal to the relative proportion for each of the N indices. Must sum to 1.0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-15 EntitlementSelector Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
EntitlementSelector	
Value	The last index that was selected.
NumberOfSamples	The total number of times that an index has been selected.
SampleCount	The number of times each of the N indices has been selected.
SampleDifference	The difference between the number of times each index has been selected and the expected number calculated from the proportions.

13.8 ExpressionEntity

The ExpressionEntity is used to evaluate an expression. It is useful when a complicated expression is used in several different places. Instead of entering the expression several times, it is better to use an ExpressionEntity to evaluate the expression and then use its output Value to pass the result to other expressions.

Table 13-16 ExpressionEntity Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the value returned by the expression.
Expression	The expression to be evaluated.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-17 ExpressionEntity Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
ExpressionEntity	
Value	The present value for the expression.

13.9 DowntimeEntity

The DowntimeEntity object is used to generate planned and unplanned maintenance events for various types of objects. The DowntimeEntity generates the downtime events and their durations, but the objects that use one or more DowntimeEntities must provide their own logic for halting operations.

Table 13-18 DowntimeEntity Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
FirstDowntime	The calendar or working time for the first planned or unplanned maintenance event. If an input is not provided, the first maintenance event is determined by the input for the Interval keyword. A number, an object that returns a number, or an expression can be entered.
IntervalWorkingEntity	The object whose working time determines the occurrence of the planned or unplanned maintenance events. Calendar time is used if the input is left blank.
DurationWorkingEntity	The object whose working time determines the completion of the planned or unplanned maintenance activity. Calendar time is used if the input is left blank.
Interval	The calendar or working time between the start of the last planned or unplanned maintenance activity and the start of the next maintenance activity. A number, an expression, or an object that returns a number can be entered.
Duration	The calendar or working time required to complete the planned or unplanned maintenance activity. A number, an expression, or an object that returns a number can be entered.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-19 DowntimeEntity Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
DownTimeEntity	
StartTime	The time that the most recent downtime event started.
EndTime	The time that the most recent downtime event finished or will finish.
CalculatedDowntimeRatio	The value calculated directly from model inputs for: (avg. downtime duration)/(avg. downtime interval)
Availability	The fraction of calendar time (excluding the initialisation period) during which this type of downtime did not occur.

13.10 ValueSequence

The ValueSequence object is used to generate a specified sequence of numbers. It can be used instead of a Probability Distribution when a model is to be validated against recorded data. It can also be used to specify an interval or duration for a planned maintenance activity.

The next value in the sequence is returned every time the ValueSequence is referenced. The values are recycled after the last value in the list is returned.

Table 13-20 ValueSequence Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the generated values.
ValueList	The sequence of numbers to be generated. Note that the appropriate unit for the numbers must be entered in the last position.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-21 ValueSequence Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
ValueSequence	
Index	The position of the last value returned in the list.
Value	The last value returned by the ValueSequence. When used in an expression, this output returns a new value every time the expression is evaluated.

13.11 EventSchedule

The EventSchedule object is similar to the ValueSequence object in that a specified sequence of values is returned. The difference is that an EventSchedule returns the inter-arrival times for a specified sequence of event times. When applied to the InterArrivalTime keyword for an EntityGenerator, it generates a specified sequence of entities at the simulation times provided to the EventSchedule.

Table 13-22 EventSchedule Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
TimeList	A sequence of monotonically-increasing simulation times at which to generate events. If entered in date format, an input of '0000-01-01 00:00:00' corresponds to zero simulation time.
CycleTime	Defines when the event times will repeat from the start.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-23 EventSchedule Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
ValueSequence	
Index	The position of the event time in the list for the last inter-arrival time that was returned.
Value	The last inter-arrival time returned from the sequence. When used in an expression, this output returns a new value every time the expression is evaluated.

13.12 FileToVector and FileToMatrix

The FileToVector and FileToMatrix objects read numerical data contained in a file. The data must be delimited by either spaces or tabs (but NOT commas). The data is made available to the model through an output named Value. The two objects differ in the type of data returned by this output:

- For FileToVector, the Value output returns a single array combining all the records in the file.
- For FileToMatrix, the Value output returns an array of arrays, with one internal array for each record that was read.

The data file is first read when the model is loaded. It is re-read and the Value output updated whenever the object receives an entity.

Table 13-24 FileToVector and FileToMatrix Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
DataFile	A file containing numerical data, delimited by spaces or tabs.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-25 FileToVector and FileToMatrix Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).
FileToVector or FileToMatrix	
Value	The numerical data contained in the file.

13.13 ScriptEntity

Originally developed for video capture, a ScriptEntity can be used to change window Views, to create automatic zooming and panning, and to toggle video capture during a run. Furthermore, keywords defined in the script file can be used to modify simulation and object parameters initially defined in the input configuration file.

At present, the ScriptEnity cannot be dragged and dropped into a model. It can only be created by editing the configuration file (see Section 8).

The ScriptEntity object takes only one keyword, which is the path to a script (.scr) file.

Table 13-26 ScriptEntity Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Script	Path to the file containing the scripting instructions to be loaded
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 13-27 ScriptEntity Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

The script file contains sets of model inputs preceded by the Time keyword under the ScriptEntity object.

Table 13-28 Inputs for .scr file

Keyword	Description
Time	The simulated time at which the subsequent inputs are executed.

For example, the following inputs can be entered into a .scr file and then referenced by a ScriptEntity object to slow down the model at a given point in the simulation run:

```
ScriptEntity1 Time            { 24.0 h }
Simulation    RealTime        { TRUE }
Simulation    RealTimeFactor  { 1200 }

ScriptEntity1 Time            { 30.0 h }
Simulation    RealTime        { FALSE }
```

14 Process Flow Palette

The Process Flow palette contains all the objects needed to create process flow type models. These models are characterized by a passive entity that is passed from one object to another following a process flow diagram. These types of models are often used to simulate a manufacturing process where the entities represent parts that are moved between processing stations. The following objects are provided in the Process Flow palette.

Table 14-1 Process Flow Palette

Object	Description
SimEntity	The basic entity for use in a process flow type model.
EntityGenerator	Creates copies of a prototype entity at specified intervals.
EntitySink	Destroys any entity it receives.
Server	Processes a received entity over a specified duration.
Queue	Stores received entities until they are needed.
EntityConveyor	Transports a received entity along a specified path at a fixed speed.
EntityDelay	Delays a received entity by a specified duration.
Resource	Set of identical resource units that can be seized and released by various processes.
Seize	Seizes one or more units of a Resource.
Release	Releases one or more units of a Resource.
Assign	Assigns new values to attributes.
Branch	Directs a received entity to a selected destination.
Duplicate	Sends copies of the received entity to a set of destinations.
Combine	Matches entities from multiple queues. The entity from the first queue is passed on while the other entities are destroyed.
SetGraphics	Changes the appearance of the received entity.
EntityGate	Blocks received entities from progressing further until the EntityGate is opened by one or more Thresholds.
EntitySignal	Opens or closes a specified SignalThreshold when an entity is received.
SignalThreshold	Threshold that is opened and closed directly by an EntitySignal object.
Assemble	Combines sub-components to create an assembled part.
EntityContainer	An entity that can hold one or more entities.
Pack	Inserts entities in a new EntityContainer.
Unpack	Removes all the entities from an EntityContainer which is subsequently destroyed.
AddTo	Add entities to an existing EntityContainer.
RemoveFrom	Removes some or all of the entities from an EntityContainer.
EntityLogger	Records the outputs and state data for a generated entity in an output log.

Object	Description
Statistics	Collects statistics from the received entities.

Many of the objects in the Process Flow palette use the inputs and outputs shown in the following tables.

Table 14-2 LinkedComponent Inputs

Keyword	Description
DefaultEntity	The default value for the output obj. Normally, obj is set to the last entity received by this object. Prior to receiving its first entity, obj is set to the object provided by DefaultEntity. If an input for DefaultEntity is not provided, then obj is set to null until the first entity is received.
NextComponent	The next object to which the processed entity is passed.
StateAssignment	The state to be assigned to an entity when it is first received by this object. The state name can be chosen freely by the user. The entity's state is unchanged if the value for this keyword is blank.

Table 14-3 LinkedComponent Outputs

Output Name	Description
obj	The entity that was received most recently.
NumberAdded	The number of entities received from upstream after the initialization period.
NumberProcessed	The number of entities processed by this component after the initialization period.
NumberInProgress	The number of entities that have been received but whose processing has not been completed yet.
ProcessingRate	The number of entities processed per unit time by this component after the initialization period.
ReleaseTime	The time at which the last entity was released.

14.1 SimEntity

The SimEntity object is the basic entity that is passed through a process flow type model. The main feature of SimEntity is that its state can be assigned at various stages of the process flow. The time spent in each state can be accessed using the StateTimes output. Process Flow objects that can receive a SimEntity, such as Server and Queue, can assign a state to the received SimEntity using their StateAssignment keyword.

Table 14-4 SimEntity Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultStateList	A list of states that will always appear in the output report, even if no time is recorded for this state.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-5 SimEntity Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).

14.2 EntityGenerator

The EntityGenerator object creates a series of entities that are passed to the next object in a process.

The PrototypeEntity keyword identifies the entity to be copied. This entity can be any type of object, no matter how complex. Either a specific object or an expression that returns an object can be entered. Copies retain both the graphics of the prototype as well as the values of all its inputs.

The rate at which entities are generated is determined by the InterArrivalTime and FirstArrivalTime keywords. These inputs have units of time and can be a constant value, an object that returns a number with units of time (e.g. TimeSeries or Probability Distribution), or an expression that returns such a number.

Table 14-6 EntityGenerator Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	A list of state/DisplayEntity pairs. For each state, the graphics will be changed to those for the corresponding DisplayEntity.
NextComponent	The next object to which a generated entity is passed.
FirstArrivalTime	The time at which the first entity is to be generated. Can be a constant value, a TimeSeries, a Probability Distribution, or an Expression.
InterArrivalTime	The elapsed time between one generated entity and the next. Can be a constant value, a TimeSeries, a Probability Distribution, or an Expression.
EntitiesPerArrival	The number of entities to be generated for each arrival time. Can be a constant value, a TimeSeries, a Probability Distribution, or an Expression.
PrototypeEntity	The entity to be copied by the EntityGenerator.
MaxNumber	The maximum number of entities to be generated.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-7 EntityGenerator Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	Inherited output that is not relevant for EntityGenerator.
EntityGenerator	
NumberGenerated	The total number of entities generated, including the initialization period.
PresentIAT	The total working time required before the next entity is created.
ElapsedTime	The working time that has been completed towards the creation of the next entity.
FractionCompleted	The portion of the total working time towards the creation of the next entity that has been completed.

14.3 EntitySink

The EntitySink object destroys incoming entities.

Table 14-8 EntitySink Key Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-9 EntitySink Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).

14.4 Server

The Server object processes an incoming entity and then passes it to the next object.

Entities that are waiting to be processed are held by a Queue object identified by the keyword WaitQueue. All entities received by the Server first pass through this Queue object, even if the Server is Idle.

Entities can also be sent directly to the Queue. Whenever an entity is added to a Queue, all the Servers that specified this Queue as its WaitQueue will be notified. The first Server that is available will then remove the entity for processing.

The rate at which entities are processed is determined by the ServiceTime keyword. This input has units of time and accepts a constant value, a TimeSeries, a Probability Distribution, or an Expression.

The Server can be stopped under various circumstances using the OperatingThresholdList keyword, which specifies a list of threshold objects such as SignalThreshold, TimeSeriesThreshold, or ExpressionThreshold. All of the specified threshold objects must be open for the Server to operate. However, if a threshold closes while the Server is processing an entity, it will complete its work on that entity before ceasing further operation.

Table 14-10 Server Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the processor.
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
ServiceTime	The time required to process the incoming entity. Can be a constant value, a TimeSeries, a Probability Distribution, or an Expression.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).

Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-11 Server Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.
Server	
ServiceDuration	The total working time required for the present service activity.
ServicePerformed	The working time that has been completed for the present service activity.
FractionCompleted	The portion of the total service time for the present service activity that has been completed.

14.5 Queue

A Queue object defines a location for simulation entities to wait for processing by other entities.

Unlike many other objects in this palette, an entity received by a Queue is not passed automatically to the next object. It must wait in the Queue until it is removed by some other object. Queues are used in this way by the Server, Seize, EntityGate, Assemble, Combine, Pack, Unpack, AddTo, and RemoveFrom objects. Whenever an entity is added to a Queue, all the objects that use this Queue are notified that a new entity is available. The first available object will remove the entity from the Queue and start processing it.

Queued entities can be sequenced by an optional priority value specified by the Priority keyword. In most cases, the Priority is specified by an Expression that is evaluated when the entity first arrives at the Queue. Priority is integer valued and decimal values will be truncated, which means, for example, that priority values of 3.2 and 3.6 are identical (i.e. truncated to 3).

Entities with the same priority values can be sequenced in either the default first-in-first-out (FIFO) order, or in last-in-first-out order (LIFO).

Lastly, a queued entity can be provided with an optional identification number using the Match keyword. Objects that use Queues, such as a Server, can request its Queue to provide the first entity with a specified value for the Match keyword. As with the Priority keyword, in most cases the Match value is specified by an Expression that is evaluated when the entity first arrives at the Queue. The Match variable is integer valued, and if a decimal value is provided, it will be truncated.

Table 14-12 Queue Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateAssignment	Keyword for LinkedComponent (see Table 14-2).
Priority	The priority for positioning a received entity in the Queue. Priority is integer valued and a lower numerical value indicates a higher priority. Priority is normally specified by an Expression,; however, a dimensionless number or an object that returns a dimensionless number such as a TimeSeries or a Probability Distribution can also be used.
Match	An integer value that can be used to label the queued entities. Match is normally specified by an Expression; however, a dimensionless number or an object that returns a dimensionless number such as a TimeSeries or a Probability Distribution can also be used.
FIFO	The order in which entities are placed in the queue. TRUE indicates first-in-first-out order (FIFO). FALSE indicates last-in-first-out order (LIFO).
RenegeTime	The time an entity will wait in the queue before deciding whether or not to renege. Evaluated when the entity first enters the queue. A constant value, a distribution to be sampled, a time series, or an expression can be entered.

RenegeCondition	A logical condition that determines whether an entity will renege after waiting for its RenegeTime value. Note that TRUE and FALSE are entered as 1 and 0, respectively. A constant value, a distribution to be sampled, a time series, or an expression can be entered.
RenegeDestination	The object to which an entity will be sent if it reneges.
Spacing	The amount of graphical space between objects in the Queue.
MaxPerLine	Maximum number of objects in each row of the Queue.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-13 Queue Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).
Queue	
QueueLength	The present number of objects in the Queue.
QueueList	The entities in the queue.
QueueTimes	The waiting time for each entity in the queue.
PriorityValues	The Priority expression value for each entity in the queue.
MatchValues	The Match expression value for each entity in the queue.
QueueLengthAverage	The average number of objects in the Queue.
QueueLengthStandardDeviation	The standard deviation of the number of objects in the Queue.
QueueLengthMinimum	The fewest number of objects in the Queue.
QueueLengthMaximum	The largest number of objects in the Queue.
QueueLengthTimes	The total time that the queue has length 0, 1, 2, etc.
AverageQueueTime	The average time each entity waited in the Queue. Calculated as total accumulated queue time divided by the number of entities added to the Queue.
MatchValueCount	The present number of unique match values in the queue.
NumberReneged	The number of entities that reneged from the queue.
QueuePosition	The position in the queue for an entity undergoing the RenegeCondition test. First in queue = 1, second in queue = 2, etc.

14.6 EntityConveyor

The EntityConveyor object moves an incoming entity along a path at a fixed speed, and then passes it to the next object.

The travel time for the EntityConveyor is determined by the TravelTime keyword. If a variable travel time is specified through an expression, the conveyor's speed is updated whenever an entity is added to the conveyor or an entity reaches the end of the conveyor.

Table 14-14 EntityConveyor Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
TravelTime	The time required to convey an entity from the start to the end.
Width	The width of the line representing the EntityConveyor in pixels.
Color	The colour of the line representing the EntityConveyor.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Points, CurveType, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-15 EntityConveyor Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	Not used by EntityConveyor.

14.7 EntityDelay

The EntityDelay object delays an incoming entity by a variable duration before passing it to the next object.

The delay is represented as motion along a line that is similar in appearance to the EntityConveyor object. It differs, however, in that the entities moving along the line can pass one another due to their different delay times.

The duration of each entity's delay is determined by the Duration keyword. This input has units of time and accepts a constant value, a TimeSeries, a Probability Distribution, or an Expression.

Table 14-16 EntityDelay Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
Duration	The time required to process the incoming entity. Can be a constant value, a TimeSeries, a Probability Distribution, or an Expression.
Animation	If TRUE, entities are moved along the specified path to represent their progression through the delay activity.
Width	The width of the line representing the EntityDelay in pixels.
Color	The colour of the line representing the EntityDelay.
Graphics	
Points, CurveType, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-17 EntityDelay Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).

14.8 Resource

The Resource object is used to represent a pool of identical equipment or processor units. Resource units can be seized and released by the Seize and Release objects.

The number of resource units is specified using the Capacity keyword, which can accept a constant value or an expression. If the number of units is allowed to vary, it is possible for the number of units in use to be greater than the present value for Capacity. If this situation occurs, the model continues normally and takes resource units out of service one-by-one as they are released. If the Capacity increases, the Resource attempts to make use of the additional capacity immediately.

Table 14-18 Resource Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Capacity	The number of equivalent resource units that are available. The input can be a constant value, a time series, or an expression.
StrictOrder	If TRUE, the next entity to seize the resource will be chosen strictly on the basis of priority and waiting time. If this entity is unable to seize the resource because of other restrictions such as an OperatingThreshold input or the unavailability of other resources it needs to seize at the same time, then other entities with lower priority or shorter waiting time will NOT be allowed to seize the resource. If FALSE, the entities will be tested in the same order of priority and waiting time, but the first entity that is able to seize the resource will be allowed to do so.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-19 Resource Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Resource	
Capacity	The total number of resource units that can be used.
UnitsInUse	The number of units that are in use.
AvailableUnits	The number of resource units that are not in use.
UnitsSeized	The number of units that have been seized.
UnitsReleased	The number of units that have been released.
UnitsInUseAverage	The average number of units that have been in use.
UnitsInUseStandardDeviation	The standard deviation of the number of units that have been in use.
UnitsInUseMinimum	The minimum number of units that have been in use.
UnitsInUseMaximum	The maximum number of units that have been in use.
UnitsInUseTimes	The total time that the number of resource units in use was 0, 1, 2, etc.

14.9 Seize

The Seize object allocates one or more units of a specified set of Resources on receiving an incoming entity.

If any of the Resources have insufficient units available, the received entity is directed to a Queue object identified by the WaitQueue keyword. All entities received by the Seize object first pass through this Queue object, even if sufficient units of the Resources are available.

Entities can be sent directly to the Queue specified by the WaitQueue keyword. Whenever an entity is added to the Queue, all the Seize objects that specified this Queue as their WaitQueue will be notified. The first Seize block that has sufficient resource units available will then remove the entity for processing.

Entities waiting for the same Resources at more than one Seize object are processed in order of the priority assigned to them by the input to their Queue's Priority keyword. If the entities in two or more Queues have the same priority value, then the one that has waited the longest is chosen.

All of the specified Resources for the selected entity must be available before any are seized. Once all of them are available, they are seized simultaneously.

Table 14-20 Seize Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
Resource	A list of Resources to be seized.
NumberOfUnits	A list containing the number of units of each Resource to be seized. Each entry can be a constant value, a TimeSeries, a Probability Distribution, or an Expression. A decimal input will be truncated to an integer by the internal logic.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-21 Seize Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.
Seize	
SeizedUnits	The number of resource units seized by the last entity.

14.10 Release

The Release object de-allocates one or more units of a specified set of Resources on receiving an incoming entity. All of the Resources are released simultaneously.

On release of the Resources, the entities waiting for these Resources are processed in order of the priority assigned to them by the input to their Queue's Priority keyword. If the entities in two or more Queues have the same priority value, then the one that has waited the longest is chosen.

Table 14-22 Release Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
Resource	The Resource(s) to be released.
NumberOfUnits	The number of units to release from the Resource(s).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-23 Release Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).

14.11 Assign

The Assign object performs one or more Attribute assignments whenever it receives an incoming entity. Once the assignments have been performed, the received entity is passed to the next object without delay.

The Assign object is the only place where an Attribute's value can be modified. The Assign object can modify the value of any attribute in the model: its own attributes, the received entity's attributes, or any other object's attributes.

The attribute assignments to be performed are specified by the input to the AttributeAssignmentList keyword. Each assignment has the following form:

```
{ <left-hand side expression> = <right-hand side expression> }
```

The right side of each assignment equation is an expression to be evaluated. The left side is an expression that identifies the attribute whose value is to be modified. For example, if object Assign1 has a dimensionless numerical attribute A, then the following input to its AttributeAssignmentList keyword causes the attribute to be increased by 1:

```
{ 'this.A = this.A + 1' }
```

The Assign object attribute obj can be used to access the attributes of the received entity. For example, if the received entity has an attribute B whose value is a string, then the following input to the AttributeAssignmentList keyword causes this attribute to take the value `'New String'`:

```
{ 'this.obj.B = [[New String]]' }
```

If another object, say Server1, has an attribute C whose value is a number with units of distance, then the following input to the AttributeAssignmentList keyword causes this attribute to be increased by 1 kilometre:

```
{ '[Server1].C = [Server1].C + 1[km]' }
```

An unlimited number of assignments can be performed by one Assign object.

Table 14-24 Assign Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
AttributeAssignmentList	A list of attribute assignments that are triggered when an entity is received.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-25 Assign Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).

14.12 Branch

The Branch object directs an incoming entity to a destination that is chosen from a list of alternatives.

The value for the Choice keyword determines the destination that is chosen: 1 = first branch, 2 = second branch, etc. The input to Choice can be a constant value, a DiscreteDistribution, a TimeSeries, or an Expression. The use of an Expression allows the choice to be made based on the Attributes of the incoming entity.

Table 14-26 Branch Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
NextComponentList	A list of possible objects to which the processed DisplayEntity can be passed.
Choice	A number that determines the choice of next component: 1 = first branch, 2 = second branch, etc.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-27 Branch Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).

14.13 Duplicate

The Duplicate object sends copies of the received entity to one or more objects.

Table 14-28 Duplicate Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
TargetComponentList	A list of the objects to which a copy of the received entity will be sent.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-29 Duplicate Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).

14.14 Combine

The Combine object takes one entity each from multiple queues and passes on a single entity to the next object. Each of the entities must have the same match value calculated by the input to Match keyword for its Queue. Entities are combined when each queue has at least one entity with the same Match value as the other Queues. When a match is found, the entity in the first Queue is passed to the object specified by the NextComponent keyword, while the entities from the other Queues are destroyed.

Table 14-30 Combine Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the position of the Combine object.
ServiceTime	The time required to process the incoming entity. Can be a constant value, a TimeSeries, a Probability Distribution, or an Expression.
WaitQueueList	A list of Queue objects that hold the entities waiting to be combined.
RetainAll	If TRUE, all the matching entities are passed to the next component. If FALSE, only the entity in the first queue is passed on.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-31 Combine Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.

14.15 SetGraphics

The SetGraphic object is used to change the graphical appearance of a specified entity.

Table 14-32 SetGraphics Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
TargetEntity	The entity whose graphics are to be changed. Defaults to the entity that was received.
GraphicsList	List of entities whose graphics can be chosen for assignment to the target entity.
Choice	A number that determines the choice of entities from the GraphicsList: 1 = first entity's graphics, 2 = second entity's graphics, etc. A constant value, a distribution to be sampled, or a time series can be entered.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-33 SetGraphics Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).

14.16 EntityGate

The EntityGate object allows incoming entities to be blocked temporarily.

When the EntityGate is open and the Queue is empty, incoming entities pass through without delay. When it is closed, incoming entities are directed to a Queue where they are held until the EntityGate becomes Open. When the EntityGate opens, the queued entities are released one at time, separated by a delay determined by the ReleaseDelay keyword. This delay does not apply to entities that arrive when the EntityGate is open. However, if queued entities are still being released, an incoming entity is placed at the end of the Queue even though the EntityGate is Open.

The EntityGate's state, either Open or Closed, is determined by the input to the OperatingThresholdList keyword, which specifies a list of threshold objects such as SignalThreshold, TimeSeriesThreshold, or ExpressionThreshold. All of the specified threshold objects must be open for the EntityGate to become Open.

Table 14-34 EntityGate Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the processor.
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
ReleaseDelay	The time required to remove each entity from the Queue.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-35 EntityGate Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.

14.17 EntitySignal

The EntitySignal object sets the state of a SignalThreshold object when it receives an incoming entity.

The SignalThreshold and its new state are specified by the TargetSignalThreshold and NewState keywords, respectively.

Table 14-36 EntitySignal Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
TargetSignalThreshold	The SignalThreshold object whose state will be changed by this EntitySignal.
NewState	The state to be set for the SignalThreshold: TRUE if it is open, FALSE if it is closed.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-37 EntitySignal Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).

14.18 SignalThreshold

The SignalThreshold object varies its state between open and closed when instructed to do so by one or more EntitySignal objects.

SignalThreshold has no internal logic of its own for changing state.

Table 14-38 SignalThreshold Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
InitialState	The initial state for the SignalThreshold at the start of the run. TRUE = open, FALSE = closed.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).
OpenColour, ClosedColour, ShowWhenOpen, ShowWhenClosed	Keywords for Thresholds (see Table 9-1).

Table 14-39 SignalThreshold Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
Threshold	
Open, OpenFraction, ClosedFraction, OpenCount, ClosedCount	Outputs inherited from Thresholds (see Table 9-2).

14.19 Assemble

The Assemble object combines a number of sub-components into an assembled part.

Sub-components waiting for processing are collected into a series of Queue objects, identified by the WaitQueueList keyword, one for each type of sub-component.

Incoming sub-components must be sent directly to the appropriate queue, not to the Assemble object itself. If necessary, a Branch object can be used to direct incoming entities to the various queues.

The assembly process begins when there is at least one sub-component entity in each of the Queues. When this occurs, the first sub-component in each Queue is removed and destroyed, and a new assembled part is created by copying the object specified by the PrototypeEntity keyword. The time required to complete the assembly process is given by the ServiceTime keyword.

Table 14-40 Assemble Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the position of the Assemble object.
ServiceTime	The service time required to perform the assembly process.
WaitQueueList	A list of Queue objects in which to place the arriving sub-component entities.
NumberRequired	The number of entities required from each queue for the assembly process to begin. The last value in the list is used if the number of queues is greater than the number of values.
MatchRequired	If TRUE, the all entities used in the assembly process must have the same Match value. The match value for an entity determined by the Match keyword for each queue. The value is calculated when the entity first arrives at its queue.
PrototypeEntity	The prototype for entities representing the assembled part.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).

Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-41 Assemble Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.

14.20 EntityContainer

The EntityContainer object is used to store a collection of entities for subsequent processing as a unit.

EntityContainer is a sub-class of SimEntity and consequently includes the State output. It can be passed to any object that can accept a SimEntity. The Pack object is used to place entities in generated EntityContainers. The Unpack object is used to remove the entities and to destroy the EntityContainer.

Table 14-42 EntityContainer Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
DefaultStateList	A list of states that will always appear in the output report, even if no time is recorded for this state.
PositionOffset	The position of the first entity in the container relative to the container.
Spacing	The amount of graphical space shown between entities in the container.
MaxPerLine	The number of entities in each row inside the container.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-43 EntityContainer Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
EntityContainer	
Count	The present number of entities in the EntityContainer.
EntityList	The entities contained by the EntityContainer.

14.21 Pack

The Pack object is used to generate EntityContainers and fill them with incoming entities.

EntityContainers are created automatically on demand by the Pack object. The number of entities to be packed in each EntityContainer is determined by the NumberOfEntities keyword. Once the specified number of entities is available in the Queue, the entities are packed one by one in the EntityContainer in the same order as the Queue. The time to pack each entity is specified by the ServiceTime keyword.

Table 14-44 Pack Key Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the processor.
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
PrototypeEntityContainer	The prototype for EntityContainers to be generated. The generated EntityContainers will be copies of this entity.
NumberOfEntities	The number of entities to pack into the container.
ServiceTime	The service time required to pack each entity in the container.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-45 Pack Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.
Pack	
Container	The EntityContainer that is being filled.

14.22 Unpack

The Unpack object is used to remove the entities from incoming EntityContainers.

Entities are unpacked one by one from the EntityContainer in the same order as they were packed. The time to unpack each entity is specified by the ServiceTime keyword. The received EntityContainer is destroyed once it has been unpacked.

Table 14-46 Unpack Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the processor.
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
ServiceTime	The service time required to unpack each entity.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-47 Unpack Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.

14.23 AddTo

The AddTo object is used to add a given number of entities to a received EntityContainer.

The number of entities to be added to each EntityContainer is determined by the NumberOfEntities keyword. Once the specified number of entities is available in the WaitQueue and there is an EntityContainer waiting in the ContainerQueue, the entities are added one by one to the EntityContainer in the same order as they appeared in the WaitQueue. The time to add each entity is specified by the ServiceTime keyword. EntityContainers are filled in the order in which they appear in the ContainerQueue.

When an input to the Match keyword is provided, only the entities in the WaitQueue that have the same Match value are added to the EntityContainer. The Match keyword for the ContainerQueue is not used by this logic.

Table 14-48 AddTo Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the processor.
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
NumberOfEntities	The number of entities to pack into the container.
ServiceTime	The service time required to pack each entity in the container.
ContainerQueue	The Queue in which the arriving EntityContainers are stored while they wait for processing.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).

Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-49 AddTo Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.
Pack	
Container	The EntityContainer that is being filled.

14.24 RemoveFrom

The RemoveFrom object is used to remove a given number of entities from an incoming EntityContainer.

Entities are removed one by one from the EntityContainer in the same order as they were packed. The time to unpack each entity is specified by the ServiceTime keyword. EntityContainers are passed to another object once the specified number of entities have been unpacked.

Table 14-50 RemoveFrom Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
StateGraphics	Keyword for StateEntity (see Table 9-6).
DefaultEntity, NextComponent, StateAssignment	Keywords for LinkedComponent (see Table 14-2).
ProcessPosition	The position of the entity being processed relative to the processor.
WaitQueue	The queue in which the waiting DisplayEntities will be placed.
Match	An expression returning a dimensionless integer value that can be used to determine which of the queued entities is eligible for processing.
ServiceTime	The service time required to unpack each entity.
NumberOfEntities	The maximum number of entities to remove from the container.
NextForContainers	The next object to which the processed EntityContainer is passed.
Thresholds	
ImmediateThresholdList, ImmediateReleaseThresholdList, OperatingThresholdList	Keywords for Thresholds (see Table 9-3).
Maintenance	
WorkingStateList, ImmediateMaintenanceList, ForcedMaintenanceList, OpportunisticMaintenanceList, ImmediateBreakdownList, ForcedBreakdownList, OpportunisticBreakdownList	Keywords for Maintenance and Breakdowns (see Table 9-4).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-51 RemoveFrom Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
StateUserEntity	
Open, Working, Maintenance, Breakdown, Utilisation, Commitment, Availability, Reliability	Outputs inherited from StateUserEntity (see Table 9-5).
LinkedDevice	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedDevice (see Table 14-3).
LinkedService	
MatchValue	The present value to be matched to an entity in the queue.

14.25 EntityLogger

The EntityLogger object records the outputs, attributes, and state data for each entity that it receives.

The output log file is created automatically when the simulation run begins. The output file is named <configuration file name>-<EntityLogger name>.log to ensure that it is unique for the simulation run. For example, if the configuration file is named "run1.cfg" and the EntityLogger's name is EntityLogger1, then the name of the log file will be "run1-EntityLogger1.log". A pre-existing file with this name will be overwritten once the simulation run is started.

Table 14-52 EntityLogger Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitTypeList	The unit types for the quantities being logged. Use DimensionlessUnit for text entries.
DataSource	One or more sources of data to be logged. Each source is specified by an Expression. Also acceptable are: a constant value, a Probability Distribution, TimeSeries, or a Calculation Object.
IncludeInitialization	If TRUE, entries are logged during the initialization period.
StartTime	The time for the first log entry.
EndTime	The latest time at which to make an entry in the log.
NextComponent	Keyword for LinkedComponent (see Table 14-2).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-53 EntityLogger Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
Logger	
LogTime	The simulation time at which the last log entry was made.
EntityLogger	
obj	The entity that was received most recently.

14.26 Statistics

The Statistics object collects statistical information on the entities it receives.

The quantity to be tracked is specified using the SampleValue keyword, which accepts an Expression. Some example inputs are:

- 'this.obj.A' - the sample value is the Attribute 'A' carried by the received entity
- 'this.SimTime - this.obj.t' - the sample value is the simulation time that has elapsed since the Attribute 't' for the received entity was set to the simulation time at some earlier point in the model

Table 14-54 Statistics Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
NextComponent	Keyword for LinkedComponent (see Table 14-2).
UnitType	The unit type for the variable whose statistics will be collected.
SampleValue	The variable for which statistics will be collected.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 14-55 Statistics Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
StateEntity	
State, WorkingState, WorkingTime, StateTimes	Outputs inherited from StateEntity (see Table 9-7).
LinkedComponent	
obj, NumberAdded, NumberProcessed, NumberInProgress, ProcessingRate, ReleaseTime	Outputs inherited from LinkedComponent (see Table 14-3).
Statistics	
SampleMinimum	The smallest value that was recorded.
SampleMaximum	The largest value that was recorded.
SampleAverage	The average of the values that were recorded.
SampleStandardDeviation	The standard deviation of the values that were recorded.
StandardDeviationOfTheMean	The estimated standard deviation of the sample mean.
TimeAverage	The average of the values recorded, weighted by the duration of each value.
TimeStandardDeviation	The standard deviation of the values recorded, weighted by the duration of each value.

15 Calculation Objects Palette

The Calculation Objects Palette contains objects for building continuous type models and mixed discrete-event/continuous models. As the name suggests, a continuous model changes state continuously as time advances. JaamSim is able to model this type of behaviour very efficiently using outputs, Attributes, and Expressions. The following objects are provided in the Calculation Objects palette.

Table 15-1 Calculation Objects Palette

Object	Description
Controller	Signals the updating of each component in the specified sequence.
WeightedSum	Calculates the weighted sum of the input values.
Polynomial	Evaluates a polynomial function of the input value.
Integrator	Integrates the input value over time.
Differentiator	Differentiates the input value over time.
PIDController	Proportional-Integral-Differential controller.
Lag	Calculates the LAG operation for the input value.
MovingAverage	Calculates a moving average of the input value over a specified range of time.
SineWave	Generates a sinusoidal wave.
SquareWave	Generates a square wave.
UnitDelay	Delays the input value by one Controller time step.

Many calculation objects use the following inputs and outputs.

Table 15-2 Calculation Object Inputs

Keyword	Description
Controller	The Controller object that signals the updating of the calculation.
SequenceNumber	The sequence number used by the Controller to determine the order in which calculations are performed. A calculation with a lower value is executed before one with a higher value.
UnitType	The unit type for the input value(s) to the calculation.
InputValue	The input value for the present calculation.

Table 15-3 Calculation Object Outputs

Output Name	Description
Value	The result of the calculation at the present time.

15.1 Controller

The Controller object generates the update signals for the individual objects in a continuous type model that are managed by this Controller.

Table 15-4 Controller Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
SamplingTime	Interval between update signals to the objects managed by this Controller.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-5 Controller Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

15.2 WeightedSum

The WeightedSum object adds two or more input values. A set of dimensionless constants can be provided to multiply each input value prior to addition.

$$y = C_1*x_1 + C_2*x_2 + \ldots + C_N*x_N, \text{ if the coefficients } C_i \text{ are specified}$$
$$= x_1 + x_2 + \ldots + x_N \quad , \text{ if the coefficients } C_i \text{ are not specified}$$

where:

y = present output value for the weighted sum
x_i = present value for the i^{th} input to the weighted sum
C_i = i^{th} entry in the **CoefficientList** input
N = number of inputs to the weighted sum

The value returned by the WeightedSum is calculated on demand.

Table 15-6 WeightedSum Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the inputs to the weighted sum and for the value returned.
InputValueList	The list of inputs to the weighted sum. All inputs must have the same unit type.
CoefficientList	The list of dimensionless coefficients to be applied to the input values. If left blank, the input values are simply added without applying any coefficients.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-7 WeightedSum Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
WeightedSum	
Value	The calculated value for the weighted sum.

15.3 Polynomial

The Polynomial object evaluates a specified polynomial for the present input value:

$$y = C_0 + C_1*x + C_2*x^2 + \ldots + C_N*x^N$$

where:

y = present output value for the polynomial
x = present input to the polynomial
C_i = i^{th} entry in the **CoefficientList** input

The value returned by the Polynomial is calculated on demand.

Table 15-8 Polynomial Key Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
InputValue	The dimensionless input value to the polynomial
CoefficientList	The list of dimensionless coefficients for the polynomial function. The number of coefficients provided determines the number of terms in the polynomial. For example, inputs c0, c1, c2 specifies the second order polynomial P(x) = c0 + c1*x + c2*x^2.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-9 Polynomial Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
WeightedSum	
Value	The calculated value for the polynomial.

15.4 Integrator

The Integrator object integrates the input value with respect to time using the trapezoidal rule:

```
y = Y + (t - T)*0.5*(x + X)
```

where:

```
y = present output value for the integrator
x = present input to the integrator
t = present simulation time
Y = output value for the integrator at the last update time
X = input to the integrator at the last update time
T = simulation time at the last update
```

The value returned by the Integrator is calculated on demand. The update signal received from the Controller is used only to record the values Y, X, and T used in the calculation.

Table 15-10 Integrator Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber, UnitType, InputValue	Keywords for Calculation Objects (see Table 15-2).
InitialValue	The initial value for the integral at time = 0.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-11 Integrator Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
DoubleCalculation	
Value	Output inherited from Calculation Object.

15.5 Differentiator

The Differentiator object calculates the time derivative of the input value:

```
y = (x - X)/(t - T), for t > T
  = Y              , for t = T
```

where:

```
y = present output value for the differentiator
x = present input to the differentiator
t = present simulation time
Y = output value for the differentiator at the last update time
X = input to the differentiator at the last update time
T = simulation time at the last update
```

The value returned by the Differentiator is calculated on demand. The update signal received from the Controller is used only to record the values Y, X, and T used in the calculation.

Table 15-12 Differentiator Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber, UnitType, InputValue	Keywords for Calculation Objects (see Table 15-2).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-13 Differentiator Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
DoubleCalculation	
Value	Output inherited from Calculation Object.

15.6 PIDController

The PIDController object simulates the Proportional-Integral-Differential (PID) type controller that is widely used in electronic control systems.

```
error = SetPoint - x
integral = INTEGRAL + (error - ERROR)*(t - T)
derivative = (error - ERROR)/(t - T)

y' = ProportionalGain/SetPointScale * (error + integral/IntegralTime +
                 derivative*DerivativeTime)

y = min( max( y', OutputLow ), OutputHigh )
```

where:

```
y = present output value for the PID controller
x = present ProcessVariable input to the PID controller
t = present simulation time
Y = output value for the PID controller at the last update time
X = ProcessVariable input to the PID controller at the last update time
T = simulation time at the last update
ERROR = value for error at the last update time
INTEGRAL = value for integral at the last update time
```

The value returned by the PIDController is calculated on demand. The update signal received from the Controller is used only to record the values Y, X, T, ERROR, and INTEGRAL used in the calculation.

Table 15-14 PIDController Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber, UnitType	Keywords for Calculation Objects (see Table 15-2).
SetPoint	The set point for the PIDController. The unit type for the set point is given by the UnitType keyword. The set point can be a constant value or any entity that returns a number, such as a calculation object, a TimeSeries, a Probability Distribution, or an Expression.
ProcessVariable	The process variable feedback to the PIDController. The unit type for the process variable is given by the UnitType keyword. The process variable can be a constant value or any entity that returns a number, such as a calculation object, a TimeSeries, a Probability Distribution, or an Expression.
ProcessVariableScale	A constant with the same unit type as the process variable and the set point. The difference between the process variable and the set point is divided by this quantity to make a dimensionless variable.
OutputUnitType	The unit type for the output from the PID controller.
ProportionalGain	The coefficient applied to the proportional feedback loop. The unit type for the proportional gain is given by the OutputUnitType keyword.
IntegralTime	The coefficient applied to the integral feedback loop.
DerivativeTime	The coefficient applied to the differential feedback loop.
OutputLow	The lower limit for the output signal.
OutputHigh	The upper limit for the output signal.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-15 PIDController Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
DoubleCalculation	
Value	Output inherited from Calculation Object.
PIDController	
ProportionalValue	The proportional component of the output value.
IntegralValue	The integral component of the output value.
DerivativeValue	The derivative component of the output value.

15.7 Lag

The Lag object calculates the lag operation used in electronic control systems.

```
y = Y + (t - T)*(x - Y)/LagTime
```

where:

```
y = present output value for the Lag object
x = present input to the Lag object
t = present simulation time
Y = output value for the Lag object at the last update time
X = input to the Lag object at the last update time
T = simulation time at the last update
```

The value returned by the Lag object is calculated on demand. The update signal received from the Controller is used only to record the values Y, X, and T used in the calculation.

Table 15-16 Lag Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber, UnitType, InputValue	Keywords for Calculation Objects (see Table 15-2).
LagTime	A value with units of time used in the lag calculations.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-17 Lag Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
DoubleCalculation	
Value	Output inherited from Calculation Object.
Lag	
Error	The value for (InputValue - Value).

15.8 MovingAverage

The MovingAverage object calculates the average value of the input over a given time interval.

$$y = \{ x + \sum_{(i = M \text{ to } M-N-2)} X(i) \} / N$$

where:

y = present output value for the MovingAverage object
x = present input to the MovingAverage object
N = **NumberOfSamples**
M = number of updates that have been performed previously
X(i) = input to the MovingAverage object at the i^{th} update time

The value returned by the MovingAverage object is calculated on demand. The update signal received from the Controller is used only to record the values X(i) used in the calculation.

Table 15-18 MovingAverage Key Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber, UnitType, InputValue	Keywords for Calculation Objects (see Table 15-2).
NumberOfSamples	The number of input values over which to average.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-19 MovingAverage Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
DoubleCalculation	
Value	Output inherited from Calculation Object.

15.9 SineWave

The SineWave object generates a sine wave output:

$$y = \mathbf{Offset} + \mathbf{Amplitude} * \sin(2\pi\ t/\mathbf{Period} + \mathbf{PhaseAngle})$$

where:

```
y = present output value for the SineWave object
t = present simulation time
```

The value returned by the SineWave is calculated on demand.

Table 15-20 SineWave Key Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the value returned by the wave.
Amplitude	Amplitude of the generated wave.
Period	Period of the generated wave.
PhaseAngle	Initial phase angle of the generated wave.
Offset	Offset added to the output of the generated wave.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-21 SineWave Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
WaveGenerator	
Value	The present value for the wave.

15.10 SquareWave

The SquareWave object generates a square wave output:

```
y = Offset + Amplitude, if sin(2π t/Period + PhaseAngle) >= 0
  = Offset - Amplitude, if sin(2π t/Period + PhaseAngle) < 0
```

where:

```
y = present output value for the SquareWave object
t = present simulation time
```

The value returned by the SquareWave is calculated on demand.

Table 15-22 SquareWave Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
UnitType	The unit type for the value returned by the wave.
Amplitude	Amplitude of the generated wave.
Period	Period of the generated wave.
PhaseAngle	Initial phase angle of the generated wave.
Offset	Offset added to the output of the generated wave.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-23 SquareWave Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
WaveGenerator	
Value	The present value for the wave.

15.11 UnitDelay

The UnitDelay object holds the value from the last update time. It is used to prevent an infinite loop from occurring when a modelled calculation includes a feedback loop.

$$y = \mathbf{x}$$

where:

```
y = present output value for the UnitDelay object
X = input to the UnitDelay at the last update time
```

Table 15-24 UnitDelay Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber, UnitType, InputValue	Keywords for Calculation Objects (see Table 15-2).
InitialValue	The value for the UnitDelay function at simulation time equal to zero.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 15-25 UnitDelay Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
UnitDelay	
Value	The result of the calculation at the present time.

16 Fluid Objects Palette

The Fluid Objects Palette contains objects for building dynamic models of hydraulic flow involving tanks, pipes, pumps, etc. The flow rate in the system is calculated by solving the unsteady Bernoulli equation.

The following objects are provided in the Fluid Objects palette.

Table 16-1 Fluid Objects Palette

Object	Description
Fluid	Defines a specific fluid and its properties.
FluidFlow	Computed flow of a specified fluid between a source and a destination.
FluidFixedFlow	Constant flow to/from a specified tank.
FluidTank	Cylindrical vessel for storing fluid.
FluidPipe	Cylindrical conduit for transporting fluid.
FluidCentrifugalPump	Type of pump with a rotating impeller.

Many fluid objects use the following inputs and outputs.

Table 16-2 Fluid Object Inputs

Keyword	Description
Previous	The upstream component that feeds this component.
Diameter	The hydraulic diameter of the component. Equal to the inside diameter of a pipe with a circular cross-section.

Table 16-3 Fluid Object Outputs

Output Name	Description
FlowArea	The cross-sectional area of the component.
Velocity	The velocity of the fluid within the component.
ReynoldsNumber	The Reynolds Number for the fluid within the component. Equal to (velocity)(diameter)/(kinematic viscosity).
DynamicPressure	The dynamic pressure of the fluid flow. Equal to (0.5)(density)(velocity^2).
InletPressure	The static pressure at the component's inlet.
OutletPressure	The static pressure at the component's outlet.

16.1 Fluid

The Fluid object defines the basic properties of the fluid.

Table 16-4 Fluid Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Density	The density of the fluid (default = water).
Viscosity	The dynamic viscosity of the fluid (default = water).
Colour	The colour used to represent the fluid.
Gravity	The acceleration of gravity to be used in the fluid flow calculations.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 16-5 Fluid Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).

16.2 FluidFlow

The FluidFlow object calculates the flow rate between a source and a destination by solving the unsteady Bernoulli equation.

Table 16-6 FluidFlow Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber	Keywords for Calculation Objects (see Table 15-2).
Fluid	The Fluid being moved by the flow.
Source	The source object for the flow.
Destination	The destination object for the flow.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 16-7 FluidFlow Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
FluidFlowCalculation	
FlowRate	The volumetric flow rate for the system.
FluidFlow	
FlowAcceleration	The time derivative of the volumetric flow rate.
FlowInertia	The sum of (density)(length)/(flow area) for the hydraulic components in the route.

16.3 FluidFixedFlow

The FluidFixedFlow object moves Fluid between a source and a destination at a fixed volumetric flow rate.

Table 16-8 FluidFixedFlow Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Controller, SequenceNumber	Keywords for Calculation Objects (see Table 15-2).
Fluid	The Fluid being moved by the flow.
Source	The source object for the flow.
Destination	The destination object for the flow.
FlowRate	The constant volumetric flow rate from the source to the destination.
Width	The width of the pipe segments in pixels.
Colour	The colour of the pipe.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 16-9 FluidFixedFlow Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
FluidFlowCalculation	
FlowRate	The volumetric flow rate for the system.

16.4 FluidTank

The FluidTank object represents a cylindrical storage tank containing Fluid. FluidTanks are modelled as large diameter FluidPipes so that the velocity and inertia of the Fluid are preserved in calculations.

Table 16-10 FluidTank Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Previous, Diameter	Keywords for Fluid Objects (see Table 16-2).
Capacity	The total volume of fluid that can be stored in the tank.
InitialVolume	The volume of fluid in the tank at the start of the simulation.
AmbientPressure	The atmospheric pressure acting on the surface of the fluid in the tank.
InletHeight	The height of the flow feeding the tank. Measured relative to the bottom of the tank.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 16-11 FluidTank Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
FluidComponent	
FlowArea, Velocity, ReynoldsNumber, DynamicPressure, InletPressure, OutletPressure	Outputs inherited from Fluid Objects (see Table 16-5).
FluidTank	
FluidVolume	The volume of the fluid stored in the tank.
FluidLevel	The height of the fluid from the bottom of the tank.

16.5 FluidPipe

The FluidPipe object represents a cylindrical pipe for transporting Fluid.

Table 16-12 FluidPipe Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Previous, Diameter	Keywords for Fluid Objects (see Table 16-2).
Length	The length of the pipe.
HeightChange	The height change over the length of the pipe. Equal to (outlet height - inlet height).
Roughness	The roughness height of the inside pipe surface. Used to calculate the Darcy friction factor for the pipe.
PressureLossCoefficient	The pressure loss coefficient or 'K-factor' for the pipe. The factor multiplies the dynamic pressure and is applied as a loss at the pipe outlet.
Width	The width of the pipe segments in pixels.
Colour	The colour of the pipe.
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 16-13 FluidPipe Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
FluidComponent	
FlowArea, Velocity, ReynoldsNumber, DynamicPressure, InletPressure, OutletPressure	Outputs inherited from Fluid Objects (see Table 16-5).
FluidPipe	
DarcyFrictionFactor	The Darcy Friction Factor for the pipe.

16.6 FluidCentrifugalPump

The FluidCentrifugalPump object models the performance of a centrifugal pump.

Table 16-14 FluidCentrifugalPump Inputs

Keyword	Description
Key Inputs	
AttributeDefinitionList, CustomOutputList	Keywords for User-Defined Variables (see Table 6-9).
Previous, Diameter	Keywords for Fluid Objects (see Table 16-2).
MaxFlowRate	Maximum volumetric flow rate that the pump can generate.
MaxPressure	Maximum static pressure that the pump can generate (at zero flow rate).
MaxPressureLoss	Maximum static pressure loss for the pump (at maximum flow rate).
SpeedController	The CalculationEntity whose output sets the rotational speed of the pump. The output value is ratio of present speed to maximum speed (0.0 - 1.0).
Graphics	
Position, Alignment, Size, Orientation, Region, RelativeEntity, DisplayModel, Show, Movable	Keywords for Graphics (see Table 10-1).

Table 16-15 FluidCentrifugalPump Outputs

Output Name	Description
Entity and DisplayEntity	
Name, ObjectType, SimTime, Attributes, Custom Outputs, Position, Size, Orientation, Alignment	Outputs inherited from Entity and DisplayEntity (see Table 10-2).
FluidComponent	
FlowArea, Velocity, ReynoldsNumber, DynamicPressure, InletPressure, OutletPressure	Outputs inherited from Fluid Objects (see Table 16-5).

Appendix A - Named Colours

This section provides the names and respective RGB values for the pre-defined colours built into JaamSim.

Colour Name	Colour	R	G	B
lavenderblush		255	240	245
pink		255	192	203
lightpink		255	182	193
palevioletred		219	112	147
hotpink		255	105	180
deeppink		255	20	147
violetred		208	32	144
mediumvioletred		199	21	133
raspberry		135	38	87
thistle		216	191	216
plum		221	160	221
orchid		218	112	214
violet		238	130	238
magenta		255	0	255
purple		128	0	128
mediumorchid		186	85	211
darkorchid		153	50	204
darkviolet		148	0	211
blueviolet		138	43	226
indigo		75	0	130
mediumpurple		147	112	219
lightslateblue		132	112	255
mediumslateblue		123	104	238
slateblue		106	90	205
darkslateblue		72	61	139
ghostwhite		248	248	255
lavender		230	230	250
blue		0	0	255
darkblue		0	0	139
navy		0	0	128
midnightblue		25	25	112
cobalt		61	89	171
royalblue		65	105	225

Colour Name	Colour	R	G	B
chocolate		210	105	30
rawsienna		199	97	20
sienna		160	82	45
brown		138	54	15
lightsalmon		255	160	122
darksalmon		233	150	122
salmon		250	128	114
lightcoral		240	128	128
coral		255	114	86
tomato		255	99	71
orangered		255	69	0
red		255	0	0
crimson		220	20	60
firebrick		178	34	34
indianred		176	23	31
burntumber		138	51	36
maroon		128	0	0
sepia		94	38	18
white		255	255	255
gray99		252	252	252
gray98		250	250	250
gray97		247	247	247
gray96		245	245	245
gray95		242	242	242
gray94		240	240	240
gray93		237	237	237
gray92		235	235	235
gray91		232	232	232
gray90		229	229	229
gray89		227	227	227
gray88		224	224	224
gray87		222	222	222
gray86		219	219	219

Colour Name	Colour	R	G	B
cornflowerblue		100	149	237
lightsteelblue		176	196	222
lightslategray		119	136	153
slategray		112	128	144
dodgerblue		30	144	255
aliceblue		240	248	255
powderblue		176	224	230
lightblue		173	216	230
lightskyblue		135	206	250
skyblue		135	206	235
deepskyblue		0	191	255
peacock		51	161	201
steelblue		70	130	180
darkturquoise		0	206	209
cadetblue		95	158	160
azure		240	255	255
lightcyan		224	255	255
paleturquoise		187	255	255
cyan		0	255	255
turquoise		64	224	208
mediumturquoise		72	209	204
lightseagreen		32	178	170
manganeseblue		3	168	158
teal		0	128	128
darkslategray		47	79	79
turquoiseblue		0	199	140
aquamarine		127	255	212
mintcream		245	255	250
mint		189	252	201
seagreen		84	255	159
mediumspringgreen		0	250	154
springgreen		0	255	127
emeraldgreen		0	201	87
mediumseagreen		60	179	113
cobaltgreen		61	145	64
darkseagreen		143	188	143
honeydew		240	255	240

Colour Name	Colour	R	G	B
gray85		217	217	217
gray84		214	214	214
gray83		212	212	212
gray82		209	209	209
gray81		207	207	207
gray80		204	204	204
gray79		201	201	201
gray78		199	199	199
gray77		196	196	196
gray76		194	194	194
gray75		191	191	191
gray74		189	189	189
gray73		186	186	186
gray72		184	184	184
gray71		181	181	181
gray70		179	179	179
gray69		176	176	176
gray68		173	173	173
gray67		171	171	171
gray66		168	168	168
gray65		166	166	166
gray64		163	163	163
gray63		161	161	161
gray62		158	158	158
gray61		156	156	156
gray60		153	153	153
gray59		150	150	150
gray58		148	148	148
gray57		145	145	145
gray56		143	143	143
gray55		140	140	140
gray54		138	138	138
gray53		135	135	135
gray52		133	133	133
gray51		130	130	130
gray50		127	127	127
gray49		125	125	125

Colour Name	Colour	R	G	B
palegreen		152	251	152
lawngreen		124	252	0
greenyellow		173	255	47
limegreen		50	205	50
forestgreen		34	139	34
sapgreen		48	128	20
green		0	128	0
darkgreen		0	100	0
darkolivegreen		85	107	47
olivedrab		107	142	35
olive		128	128	0
ivory		255	255	240
lightyellow		255	255	224
lightgoldenrodyellow		250	250	210
cornsilk		255	248	220
lemonchiffon		255	250	205
beige		245	245	220
yellow		255	255	0
khaki		240	230	140
lightgoldenrod		255	236	139
palegoldenrod		238	232	170
darkkhaki		189	183	107
banana		227	207	87
gold		255	215	0
goldenrod		218	165	32
darkgoldenrod		184	134	11
brick		156	102	31
floralwhite		255	250	240
seashell		255	245	238
oldlace		253	245	230
linen		250	240	230
antiquewhite		250	235	215
papayawhip		255	239	213
blanchedalmond		255	235	205
eggshell		252	230	201
bisque		255	228	196
moccasin		255	228	181

Colour Name	Colour	R	G	B
gray48		122	122	122
gray47		120	120	120
gray46		117	117	117
gray45		115	115	115
gray44		112	112	112
gray43		110	110	110
gray42		107	107	107
gray41		105	105	105
gray40		102	102	102
gray39		99	99	99
gray38		97	97	97
gray37		94	94	94
gray36		92	92	92
gray35		89	89	89
gray34		87	87	87
gray33		84	84	84
gray32		82	82	82
gray31		79	79	79
gray30		77	77	77
gray29		74	74	74
gray28		71	71	71
gray27		69	69	69
gray26		66	66	66
gray25		64	64	64
gray24		61	61	61
gray23		59	59	59
gray22		56	56	56
gray21		54	54	54
gray20		51	51	51
gray19		48	48	48
gray18		46	46	46
gray17		43	43	43
gray16		41	41	41
gray15		38	38	38
gray14		36	36	36
gray13		33	33	33
gray12		31	31	31

Colour Name	Colour	R	G	B
navajowhite		255	222	173
wheat		245	222	179
peachpuff		255	218	185
tan		210	180	140
burlywood		222	184	135
melon		227	168	105
sandybrown		244	164	96
cadmiumyellow		255	153	18
carrot		237	145	33
orange		255	128	0
flesh		255	125	64
cadmiumorange		255	97	3

Colour Name	Colour	R	G	B
gray11		28	28	28
gray10		26	26	26
gray9		23	23	23
gray8		20	20	20
gray7		18	18	18
gray6		15	15	15
gray5		13	13	13
gray4		10	10	10
gray3		8	8	8
gray2		5	5	5
gray1		3	3	3
black		0	0	0