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RELIABILITY MODELING WITH EXTENDSIM

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ABSTRACT

This paper will begin with an overview of ExtendSim. Some general reliability modeling concepts will be discussed. ExtendSim's unique toolset for simulating reliability will be presented. There will be a discussion of some reliability future features in upcoming releases of ExtendSim.

1 INTRODUCTION

ExtendSim is a powerful simulation application capable of modeling a wide variety of systems. These include manufacturing, healthcare, communications, logistics, military, service and more. While each of these areas have their own unique modeling requirements, reliability cuts across many of these applications. ExtendSim includes a variety of features and capabilities that help in modeling systems that include reliability factors. These include specific modeling components and architectural features.

2 EXTENDSIM STRUCTURE

An ExtendSim model is created by adding blocks to a model worksheet, connecting them together, and entering the simulation data. Each block has its own functionality, dialog, help, icon, and connections. Each instance of a block in the model has its own data. Blocks perform a number of functions in a simulation model including:

- Simulating the steps in a process (Queue, Activity)
- Performing a calculation (Math, Random Number, Equation)
- Interfacing with other applications or data storage (Read, Write)
- Providing a model utility (Find and Replace, Count Blocks)
- Plotting model results (Plotter, Histogram)
- Animating (Animate Value, 3D Scenery)
- Creating a user interface (Popup, Buttons)

The logical entity that moves through the system is referred to as an item. Items carry properties or attributes with them as they progress from one block to the next. Items are represented using data structures allowing large numbers to exist simultaneously within a model.

The source code for ExtendSim blocks is available and can be viewed or modified by the end user. New blocks can be created from existing blocks or created from scratch. This allows the modeler or developer to create their own libraries for specific modeling domains. Using this capability, a whole range of simulation products are based on the ExtendSim engine. These include applications for pulp and paper manufacturing, chemical process control, biological processes, and analytical chemistry.

Hierarchical help to organize the model. These blocks contain other blocks (either programmed or hierarchical) that form template models. Hierarchical blocks can be stored in a library and reused in the same or different models. ExtendSim has tools for creating an interface within the hierarchical block, making it easy for the modeler to expose important parameters and results.

ExtendSim's internal database is an integrated part of the model structure. Many of the modeling components are designed around the database to store and manage data. The database can also be used as part of the fabric of the simulation. As a database record value changes, interested blocks will receive a message notifying them of the change so that they can react accordingly. This powerful capability simplifies communication in complex models, eliminating cumbersome end-of-event status checks and event polling (Diamond, Krahl, Nastasi, and Tag 2010).

Complete information about ExtendSim can be found in the ExtendSim User Guide (Imagine That, 2013).

3 RELIABILITY MODELING

In reliability theory, reliability modeling can be broken up into three components: Reliability - the probability of a failure occurring over a specified time interval; Availability - a measure of something being in a state of readiness; and Maintainability - how a failed system is restored to readiness. Collectively, these are known as RAM. Typically, simulation modeling focuses on the availability component of these. A more advanced or focused simulation model would include maintainability by adding resources for repair and spares management.

3.1 Reliability (R in RAM)

Unfortunately, the term reliability is overloaded here. The Reliability (R) term in RAM is analyzed with dedicated software or with distribution fitting software. The result of the reliability (R) is often the input to a simulation model. The model would include the ubiquitous time between failure (TBF) and time to repair (TTR) distributions. Typically this analysis would be one of the major data sources for a discrete event simulation. In most cases this will be done by software that is dedicated to this purpose. The results would be in the form of random distributions describing the frequency and duration of failures throughout the system. Distribution fitting software that is commonly used with discrete event simulation software can also be used to transform the historical reliability data into statistical distributions.

3.2 Availability (A in RAM)

There are a number of factors that affect the availability of a system. These include:

- Random failures, possibly from multiple sources
- Maintenance
- "Off shift" time periods
- Availability of backup systems/equipment

These are not mutually exclusive factors. Maintenance may reset the "failure clock" postponing the expected time to the next failure. An off shift period may suspend the time to the next failure. And, a secondary piece of equipment may wear faster than a primary one. This is the "sweet spot" for typical discrete event simulation analysis. An ExtendSim model can effectively model a wide range of failure and repair scenarios.

3.2.1 The Shutdown Block

The heavy lifting for reliability modeling in ExtendSim is done by the Shutdown block. This deceptively simple modeling component is able to simulate a wide range of reliability scenarios. This block schedules an event at its next nearest failure or repair time. As it can simultaneously model multiple failure and repair events, it contains its own event calendar, posting the earliest event time to the Executive event calendar.

Figure 1: Shutdown Block

Figure 1 shows a Shutdown block. The input connectors (thinner squares) shown allow the modeler to specify the time between failures (TBF), time to repair (TTR), and the rate of wear for operating time based failures. Additional inputs (not shown) provide features such as cycle time based failure, control for the actual value of the downtime connector, and control of which item in a multi-capacity Activity will fail. Outputs (thicker squares) here are for the shutdown signal (unlabeled) and the total downtime (TD) so far. Additional outputs that are not currently shown provide more details about the accumulated downtime status and specific failure streams.

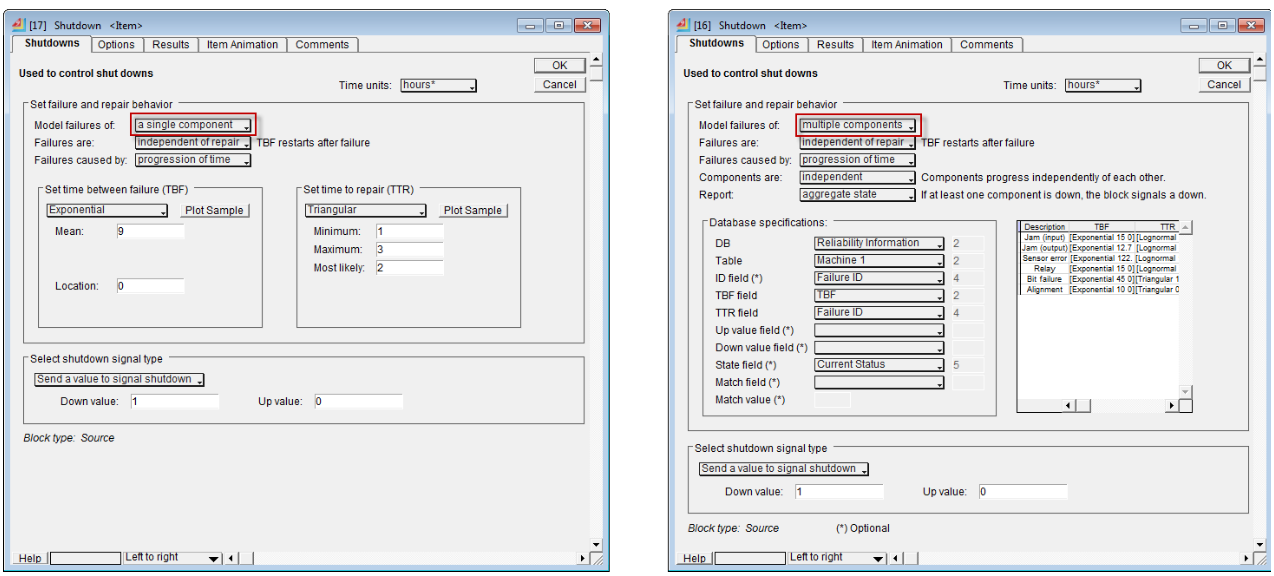

Figure 2: Dialog of Shutdown Block

While there are certainly many options in the Shutdown block for controlling the nature of the shutdowns, the most unique one is the ability to model multiple failure streams. Figure 2 shows the dialog of the shutdown block in single component (left) and multiple component failure modes. In the multiple component mode, a database table specifies the parameters for the failures.

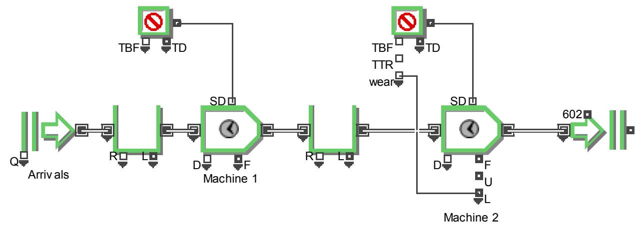

Figure 3: Simple Availability Model

Figure 3 shows a very simple manufacturing model with two types of failures. Machine 1 fails based on "clock" time the amount of elapsed time since the last failure. Machine 2 fails based on operating time. Because the length (L) connector on Machine 2 is connected to the "wear" connector on the Shutdown block, the time between failures will only accumulate when the Activity labeled Machine 1 contains an item.

The Shutdown block can also generate items as well as values. This allows the modeler to "target" an item in the Activity and shut it down individually. In this case, a matching attribute is specified and the same value for this attribute is set on the item from the Shutdown block and the item in the Activity.

3.2.2 The Shift Block

ExtendSim's Shift block is typically used to model scheduled time periods where a block or resource is unavailable. Shifts are often repeated over a set schedule. The Shutdown block can operate on a shift such that the accumulation of time and the actual failures do not occur when the Shutdown is "off shift".

3.2.3 Other Block Combinations

While the Shutdown block is the most common and convenient way to model failures, any number of other blocks can cause the entire Activity or an individual item in the Activity block to fail. For example if the shutdown occurred because of weather conditions, a submodel with this logic could be assembled and connected to the Shutdown (SD) connector on the Activity.

3.2.4 Unreliable Items

In some cases, it is more useful to model the unreliability of the items in the model rather than the blocks. This would be convenient in a simulation of spares management or fleet reliability. Figure 4 shows a model of aircraft reliability. Each plane is represented by an item that performs missions (mission model). The individual components that are subject to reliability are contained within a database table. As each aircraft completes its mission, the table is queried to determine whether any components failed. If a failure has occurred, the aircraft is taken out of service and is transferred to the lower network of blocks (repair model). Here, the failures are logged and once all of the failed components have been repaired, the aircraft returns to service.

Because of ExtendSim's integrated database, this model is scalable (Diamond, Krahl, Nastasi, and Tag 2010). Any number of aircraft and any number of components can be represented by changing the dimensions and data in the database table. At any point in the model the database contains the current status of the aircraft and all of its components. This is a simple model, but in a more complex form, this same concept is used by a variety of organizations to simulate equipment reliability.

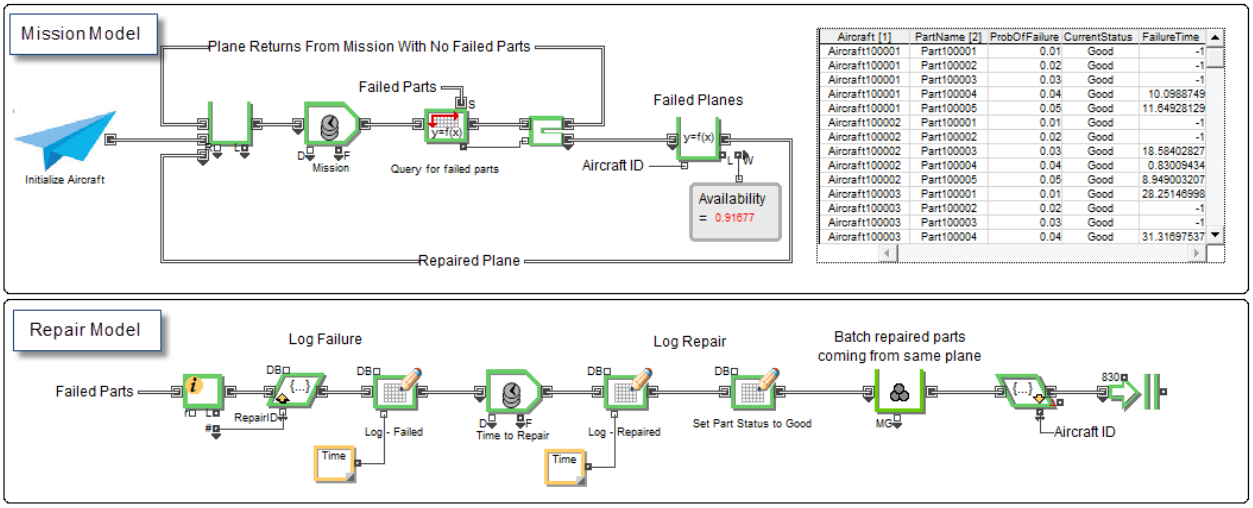

Figure 4: Aircraft Reliability

3.3 Maintainability (M in RAM)

In many cases simply specifying a time between failure and time to repair are insufficient to study the actual effects of downtime on a system. The repair may require resources, inventory, and system conditions for the process to proceed. Repairing offshore equipment may require certain weather conditions, personnel, vehicles, and timing. By using the item generation mode of the Shutdown block, an item is generated that can require resources or be routed or delayed based on system conditions. Utilizing a mechanic for a repair is shown in Figure 5. Here, when the failure occurs, an item goes into a Workstation block (labeled "Repair) and waits for a resource. When the mechanic resource is obtained, the failure item is delayed by the downtime and then releases the mechanic. As long as there is an item in the Workstation block, the Activity labeled "Machine 1" will remain shut down.

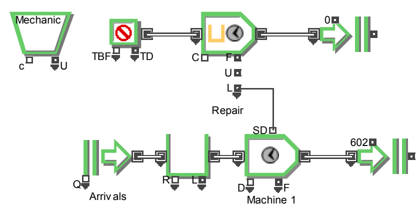

Figure 5: Adding Resource to Repair Process

Of course, the blocks modeling the shutdown process can be collapsed into a single hierarchical block. In this form it can be copied or saved in a library for reuse in another model. In Figure 6 the repair process is represented by a single hierarchical block. Any number of these can exist in the model. Because the mechanic resource is outside of the hierarchy, all of the repair processes will share the same resource.

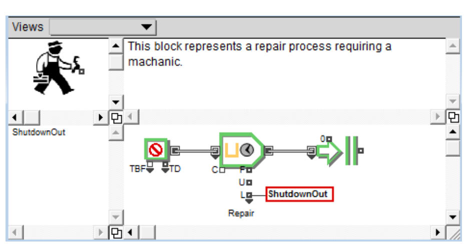

Figure 6: Repair Process Hierarchical Block

This type of analysis is where ExtendSim's unique architecture shines. A wide variety of blocks can be used to model virtually any type or configuration of repair processes. Additional features that can be added could include spares, part inventory, and any system conditions that would affect the repair. All of this can be done by connecting blocks together.

4 EVENT SCHEDULING ARCHITECTURE

Typically event calendars are optimized for finding the next scheduled event, but not for rescheduling events. Frequent shutdowns and adjustments to a scheduled failure or repair time can create performance issues with a traditional event calendar. This is because one of these events will require changing future events.

4.1 Rescheduling a Traditional Event Calendar

In the most common type of event calendar where each item has an entry when a failure occurs, a search must occur to locate each item affected by the failure. Once the item has been located, then it has to be removed from the calendar and either its repair time is rescheduled or it is put into an indefinite wait state until the repair has completed. The search and reschedule in a traditional calendar is inefficient.

4.2 Rescheduling in ExtendSim

ExtendSim uses a two-stage event calendar. Each block has a fixed position entry in the system event calendar. Within the block is a secondary calendar containing the future event times for the items within the block. The block posts the earliest of these event times on the system calendar. Then if the block is shutdown, there is a single assignment to reschedule its repair time. When the repair occurs, the Activity updates the completion time for its contained items. No searching is necessary as the Activity contains the list of just those items affected by the shutdown.

5 PUTTING IT ALL TOGETHER

All of the above features and components can be combined with discrete event and discrete rate models (Sharda and Bury, 2008). This provides a unique toolset for modeling entire systems where RAM analysis is required (Isaksen and Lilleheier, 2014). Models that incorporate both discrete event simulation and RAM are able to capture the additional detail required for large scale capital expenditures. Now, system availability can be accurately predicted taking into account not only the reliability of the individual and combined components, but also the effects of other system dynamics on those components. For example, a traditional RAM study might include the reliability of various on-shore components of a pipeline terminal. Adding a discrete event component to this can include the additional features of resource availability, delays from weather and port congestion, and ship configuration in the model. This more complete model give a more accurate and detailed assessment of operations.

6 IN THE FUTURE

A new library specifically designed for RAM analysis is in the works. This will allow modelers to create reliability block diagrams (RBD) and integrate them with their models. With this new library, RBDs such as the one in Figure 7 can be added to in discrete event models. This will be implemented such that a single RBD may be scaled up to represent any number of units.

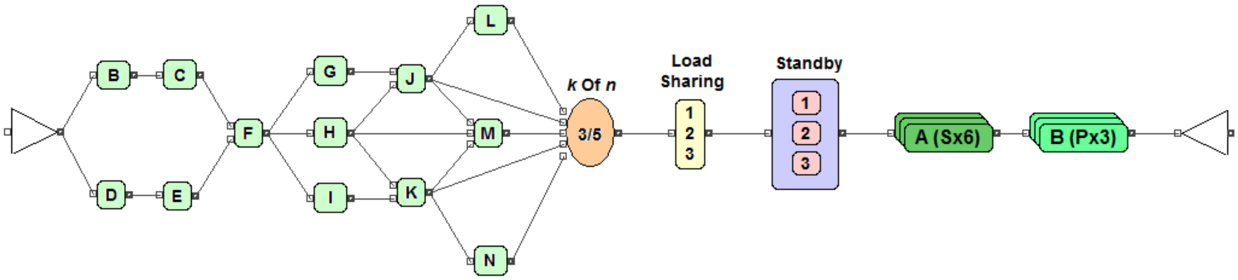

Figure 7: Reliability Block Diagram

7 CONCLUSIONS

ExtendSim can be used to model a wide variety of systems. Reliability is only one aspect of its capabilities. ExtendSim's flexible architecture provides significant advantages. This is particularly true when greater modeling detail or the combination of multiple technologies is required. All of this is done within ExtendSim's engaging interface.

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