GoldSim:
Simulation Software to Support
Risk Analysis and Strategic Planning
In the Energy Industry

White Paper

Abstract

GoldSim is a powerful and flexible Windows-based computer program for carrying out probabilistic simulations of complex systems to support management and decision-making in engineering, science and business. The program is highly graphical, highly extensible, able to directly represent uncertainty, and allows you to create compelling presentations of your model. GoldSim can be used to solve a wide variety of complex problems, and is particularly well-suited to applications in the energy and power industry. It allows you to create realistic models of engineered and environmental systems in order to carry out risk analyses, evaluate potential environmental impacts, support strategic planning, evaluate the reliability of engineered systems, and evaluate alternative policies and plans. This short paper provides a brief overview of GoldSim, with special emphasis on applications in the energy industry.

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Introduction

The Challenge of Strategic Planning and Risk Management in the Energy Industry. One of the greatest challenges for the energy industry is to quantitatively evaluate alternative approaches for carrying out projects and to identify and manage the associated risks. The outcomes of these projects are often inherently risky and uncertain, since they typically involve systems made up of many component parts that are interrelated, and in some cases poorly characterized. In most situations, the system is highly dynamic (i.e., it constantly evolves over time, often in a complex way) and involves uncertain processes, parameters, and events.

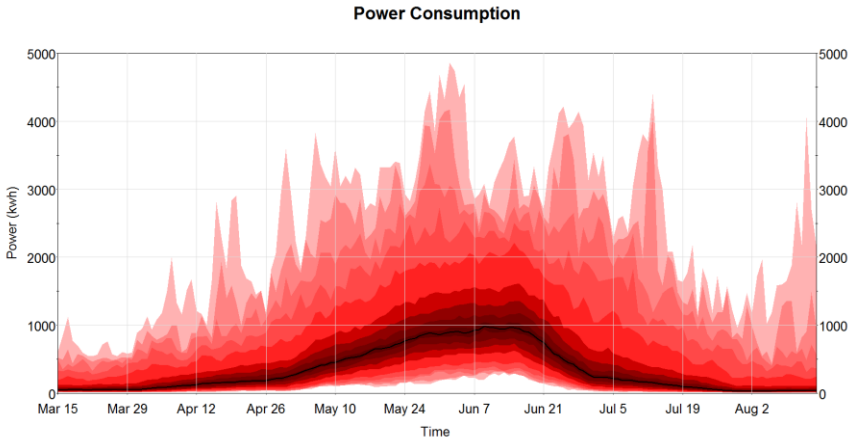
The challenge when evaluating such systems is to find an approach that can incorporate all the knowledge available to analysts and management into a quantitative framework that can be used to predict the outcome of alternative approaches. For many complex systems, this can only be addressed by developing a computer simulation model of the system.

The Solution. The GoldSim Technology Group has addressed this problem by developing a dynamic probabilistic simulation tool, GoldSim, which can be used to help organizations realistically model complex systems and thereby improve the financial performance of their operations. As used here, simulation is defined as the process of creating a model (i.e., an abstract representation or facsimile) of an existing or proposed system in order to identify and understand those factors that control the system and/or to predict (forecast) the future behavior of the system. Almost any system that can be quantitatively described using equations and/or rules can be simulated. The objective in modeling such a system is to understand the different ways it could evolve, to project its performance (financial, environmental, etc.), and to determine what can be done to influence the outcome.

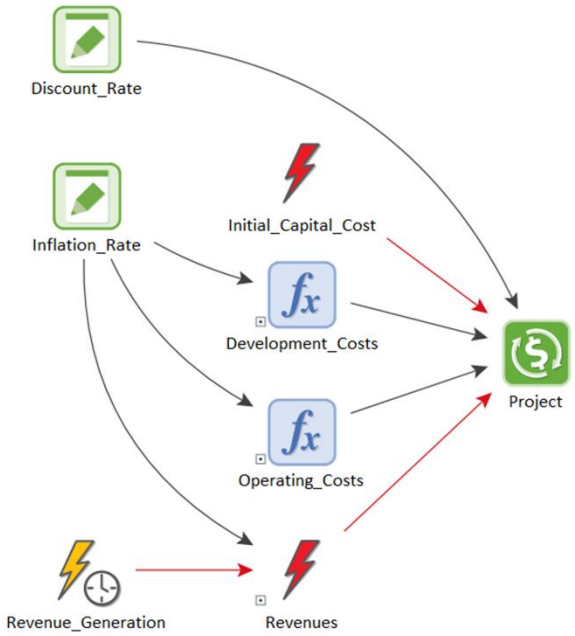
Traditionally, many parts of a complex system or project are considered separately and independently. If important interrelationships or feedbacks are missing, it is difficult or impossible to gain a diagnostic understanding of the system or to identify the most important processes/issues to consider when evaluating alternatives. System simulation is a powerful and important tool because it provides a framework and methodology for consistently integrating the various components of a system, while explicitly representing the interrelationships, feedback mechanisms and uncertainties about the components and processes involved.

Overview of the GoldSim Simulation Framework

GoldSim is a powerful and flexible platform for visualizing and numerically simulating nearly any kind of physical, financial or organizational system. In a sense, GoldSim is like a "visual spreadsheet" that allows you to visually create and manipulate data and equations. Unlike spreadsheets, however, GoldSim allows you to readily evaluate how systems evolve over time, and predict their future behavior.



The GoldSim simulation environment is highly graphical and completely ***object-oriented***. That is, you create, document, and present models by creating and manipulating graphical objects (referred to as *elements*) representing data and relationships between the data. Based on how the various objects in your model are related, GoldSim automatically indicates their influences and interdependencies by visually connecting them in an appropriate manner.

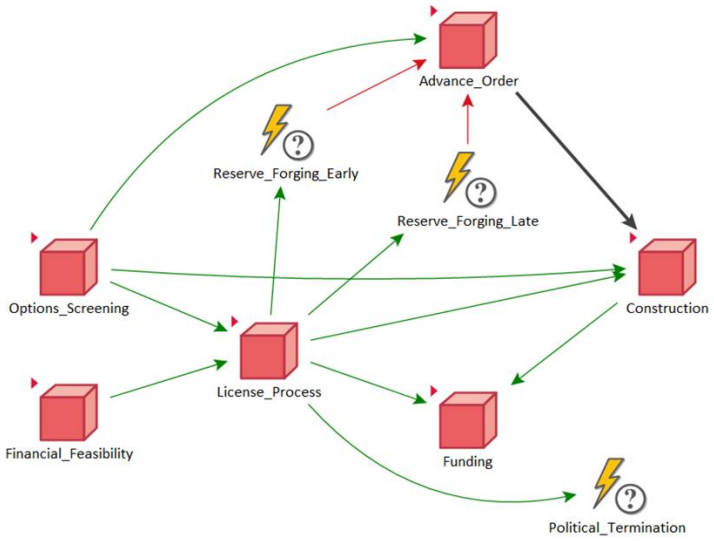


Because simulation can be such a powerful tool for understanding and managing complex systems, a number of simulation tools currently exist. The following combination of features, however, makes the GoldSim approach unique:

GoldSim allows models to be built and modified very rapidly. The time savings over programming an equivalent model "from scratch" is typically ten-fold or more. Moreover, GoldSim's built-in configuration management tools (such as the ability to record the changes made to a model over time) ensures that modifications are made in a traceable and organized manner. As a result, an iteration of a GoldSim model can be carried out within a timescale of hours or days, rather than the weeks required for many other modeling frameworks.

GoldSim is extremely flexible, allowing it to be applied to nearly any kind of system. GoldSim is a generic, probabilistic simulation framework. As such, it can be (and has been) applied to a wide variety of systems, ranging from engineering systems to financial or organizational systems. As a result, for example, the same tool can be used to simultaneously model not only the reliability and engineering performance of a facility, but also nearly any other aspect of the facility operations, including waste management, material management and financial analysis.

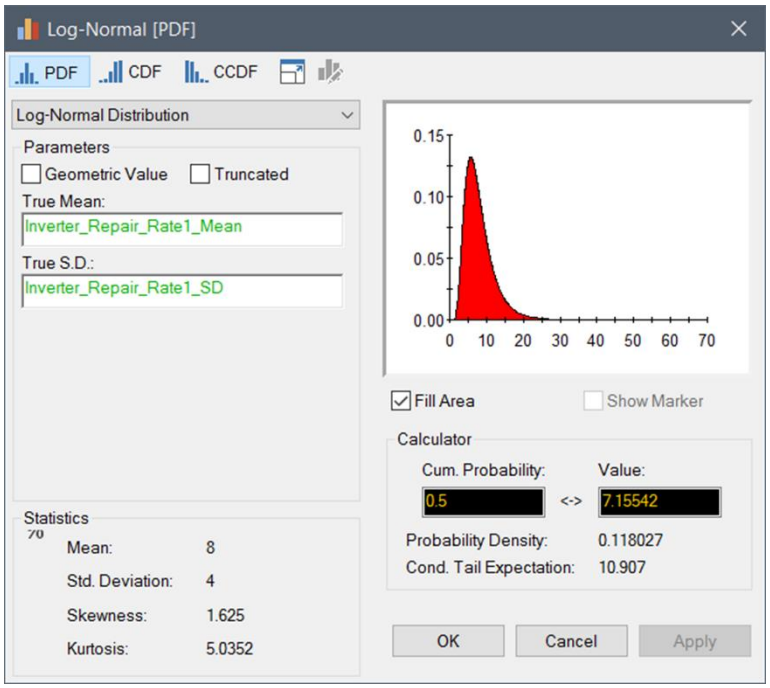
GoldSim supports creation of hierarchical, modular models, and this facilitates the reuse and sharing of models across an organization. GoldSim models can be built in a hierarchical and modular manner, by creating and linking together subsystems (sub models). The sub models can include custom (legacy) codes that can be linked dynamically into GoldSim. These sub models, after being built for one application or project, are often readily transferable with only minor modifications to another application.



The GoldSim framework is designed to allow sub models to be saved (and perhaps posted to an internal website), and then re-used in other models for other projects within the organization. Sharing and re-using sub models in this manner can result in significant cost savings by eliminating the need to "reinvent the wheel". In effect, GoldSim acts as a framework to share knowledge and experience across the organization. Not only does this reduce redundant efforts,

it promotes consistency in the assumptions and approach to modeling within the organization.

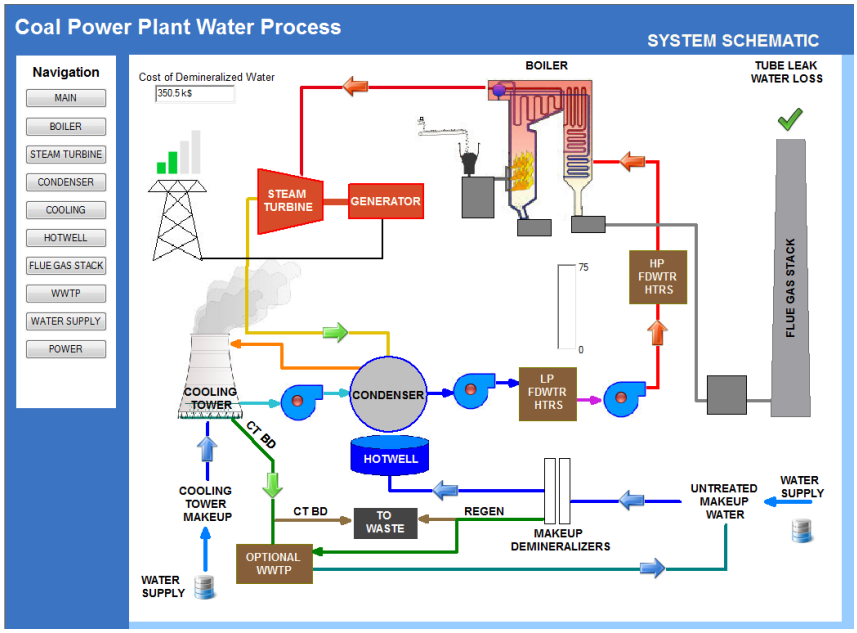
Uncertainty in processes, parameters and future events can be explicitly represented. Uncertainty in processes and parameters can be represented by specifying model inputs as probability distributions. This capability makes it relatively easy to generate stochastic records of electricity demand, weather related variables (e.g., temperature and precipitation) and other system drivers. The impact of uncertain events (e.g., accidents, regulatory or economic changes) can also be directly represented by specifying the occurrence rates and consequences of such "disruptive events". GoldSim uses Monte Carlo simulation to propagate uncertainty through the model.



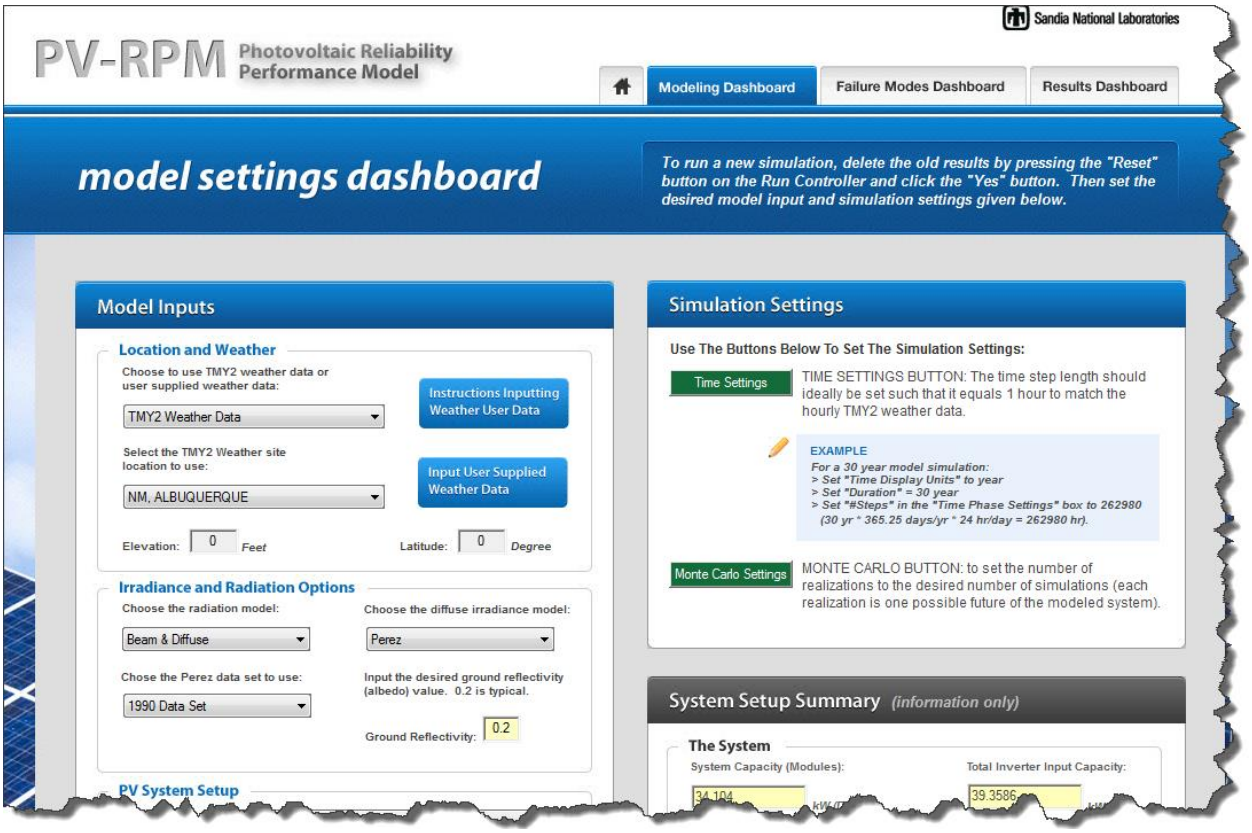
GoldSim is highly extensible. GoldSim provides a wide variety of built-in objects ("elements") from which you can construct your models, and, if desired, you can program your own custom objects, and link them seamlessly into the GoldSim framework. In particular, you can dynamically link your own custom external programs or spreadsheets directly into your GoldSim model. In addition, GoldSim was specifically designed to support the addition of customized modules (program extensions) to address specialized applications.

GoldSim allows you to create compelling presentations of your model, and therefore facilitates effective interaction with stakeholders. A model that cannot be easily explained is a model that will not be used or believed. GoldSim was specifically designed to allow you to effectively document, explain and present your model. You can add graphics, explanatory text, notes and hyperlinks to your model, and organize it in a hierarchical manner such that it can be presented at an appropriate level of detail to multiple target audiences. The ability to create hierarchical, top-down models, coupled with GoldSim's powerful documentation features, allows you to design transparent, highly-graphical models that can be effectively explained to any audience at an appropriate level of detail. Moreover, GoldSim facilitates real-time model experimentation (e.g., the ability to answer stakeholder "What If?" questions

during a meeting). Transparent, easy to understand models and real-time model experimentation promote effective interaction with regulators and other stakeholders, and help to build trust. This ultimately can help you avoid costly delays and requests for additional (and technically unnecessary) modeling studies or data collection.



GoldSim provides a specialized set of tools that allow you to create custom interfaces, or "dashboards" for your models to make them accessible to non-technical users. Models created using the GoldSim Authoring tools can be saved and subsequently viewed and run using the free GoldSim Player. The interfaces can be designed to include buttons, input fields, sliders and result displays, and the author can embed text, tool-tips and graphics to provide instructions on the use of the model. Such an interface allows a model to be easily used by someone without requiring them to be familiar with either the GoldSim modeling environment or the details of the specific model. In effect, this allows you to use GoldSim as a high-level programming language to create custom simulation applications for distribution to end users who may not necessarily be modelers.



Example GoldSim Applications in the Energy Industry

GoldSim has been used for a wide range of diverse applications. The following short descriptions provide a number of example applications from within the energy industry, and provide a good indication of the diversity of applications, ranging from long-term strategic planning to modeling detailed engineering processes.

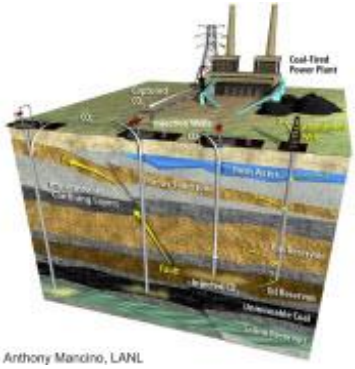
Evaluating the Reliability and Performance of a Photovoltaic System. Accurately predicting the performance of photovoltaic (PV) systems can be a challenging undertaking, but a necessary one in order to assess the financial viability of the system. PV system energy production can be affected by numerous factors including the choice of location, component technology, and system design. While these modeling factors are generally considered by most PV performance models, other factors are typically not, including: 1) solar resource variability, 2) degradation due to environmental conditions (humidity, temperature swings, UV exposure, wind, salt spray, rodent damage, etc.), 3) component reliability (failure rates of inverters, modules, trackers, etc.), and 4) operations and maintenance (O&M) strategies. Engineers at Sandia National Laboratories are using GoldSim to develop an analytical, scenario-based predictive modeling tool that can be used to help owners, operators, risk managers, and financiers simulate planned PV projects to avoid costly system weaknesses prior to development.

Management of Coal Combustion Products at a Coal-Fired Power Plant. Proactive planning for the beneficial utilization and cost efficient disposal of coal combustion products (CCPs) is required due to constantly evolving CCP markets (CCPs can be utilized as construction materials), plant operational requirements, and changing regulatory requirements. At Great River Energy's (GRE) Coal Creek Station generating facility in North Dakota, management recognized that these issues will likely impact the marketability, disposal practices, environmental aspects, and economic issues associated with CCPs, and ultimately affect power costs to its rate payers. GRE and Golder Associates, an international engineering consulting firm, collaborated to evaluate this complex interdependent dynamic system. A process of planning, modeling and engineering activities were carried out to evaluate the economic and environmental impacts associated with various CCP management scenarios at the Coal Creek Station. GoldSim was key to this evaluation, and allowed for the dynamic and probabilistic modeling of various interconnected systems, enabling for the prediction of future behavior of a number of CCP management scenarios with respect to both material and financial implications. Results of the modeling effort led to the development of a long-term comprehensive CCP management plan, which will minimize the impacts on power cost for GRE's rate payers.

Forecasting Electricity Demand from Iron Ore Mines. GoldSim was used to forecast electricity demand from new iron ore mines in the Mid-West region of Western Australia. An accurate forecast was required to estimate the size of new demand from greenfield iron ore mines and assist in demonstrating the need for a new 330 kV transmission line. Regulation required that the cost analysis be conducted using discounted cash flow model. Traditionally, this would be implemented in a spreadsheet using the net present value (NPV) approach; however, the spreadsheet soon became so complex that it was very difficult to audit and quite cumbersome to use. By contrast, using GoldSim, the model was substantially easier to understand and follow. Moreover, GoldSim's advanced functionality is substantially more sophisticated than available in a spreadsheet. For example, the Monte Carlo functionality in GoldSim allowed the modeling to explicitly recognize uncertainty.

Coal Seam Brine Management. Coal seam gas (CSG) is a natural gas consisting primarily of methane extracted from underground coal seams. CSG "production water" contains varying levels of salts. CSG water management focuses on the beneficial use of CSG water and the beneficial uses of salt. GoldSim was used to develop an adaptive brine management strategy for the collection (sizing of brine contaminant ponds) and proper management of brine / salt for ultimate disposal / sequestration or beneficial use. GoldSim supported dynamic modelling of salt transport processes within and between CSG water ponds, as well as the salt composition from different CSG well fields, transport media (water) and transport pathways (e.g. reverse osmosis plant, brine concentrator, concentrated brine ponds, crystallizers). As a result, the GoldSim model facilitated the examination of the various brine management options for efficient brine treatment, beneficial use and disposal of the solid salts produced by brine treatment.

Long-Term Plan for Managing Spent Nuclear Fuel in South Korea. By 2030, South Korea intends for nearly 60% of the country's power generation to come from nuclear reactors. This commitment to expanding its use of nuclear energy will result in an increase of Spent Nuclear Fuel (SNF). To manage this, the Korea Atomic Energy Research Institute (KAERI) used GoldSim to develop an "integration model" that predicts the generation, storage, transport, shipping, reprocessing and disposal of SNF and associated wastes over the course of the next 100 years. The model is designed to evaluate various options including: constructing a repository for SNF and high-level waste, storing SNF at reactor sites or at centralized storage facilities, or using offshore or domestic SNF reprocessing facilities. It enables researchers to ask "what if" questions by evaluating various scenarios and determining the short and long-term implications. This innovative approach enables stakeholders, engineers and researchers to rapidly evaluate possible options and communicate their findings to all necessary stakeholders.



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Evaluating Risks Associated with Geological Carbon Sequestration. The global warming due to increase of CO_2 in the atmosphere is one of most urgent issues that we face today. Los Alamos National Laboratory has developed a system-level model for geologic sequestration that tracks the fate of CO_2 sequestered in geologic reservoirs and is designed to include all associated risks. The system-level CO_2 sequestration model, called CO2-PENS (Predicting Engineered Natural Systems) uses GoldSim as the upper level platform. Initially, CO2 – PENS provides a screening tool to identify appropriate storage sites. Once a site is selected, the model adapts to individual locations as detailed site-specific information and data, such as geologic make-up and atmospheric conditions, emerge. By simulating carbon's behavior from its initial capture through site injection and storage, while simultaneously predicting the likelihood of leakage to the surface, scientists can gauge the economic, technological and long-term feasibility of geologic storage for hundreds of years to come.

Summary

GoldSim is a powerful and flexible Windows-based computer program for carrying out probabilistic simulations of complex systems to support management and decision-making in engineering, science and business. The program is highly graphical, highly extensible, able to directly represent uncertainty, and allows you to create compelling presentations of your model.

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The software is used by nearly 600 organizations in over 30 countries worldwide.

About the GoldSim Technology Group

The GoldSim Technology Group is a privately held software company dedicated to delivering software and services to help people understand complex systems and make better decisions. The combination of our diverse technical and business backgrounds, our extensive experience in modeling complex systems, and our ability to continuously enhance our state-of-the-art simulation tools allow us to efficiently solve difficult problems that cannot be readily addressed by others.

Our flagship GoldSim software package is based on technology developed over a period of over 20 years. GoldSim has been used by and/or for a diverse set of customers and clients, including government agencies in over 10 countries (such as the US Department of Energy, NASA, the Nuclear Regulatory Commission, and the California Department of Water Resources), research institutions (including Sandia National Laboratories, Los Alamos National Laboratory, the Paul Scherrer Institute, and MIT), and commercial organizations worldwide, including Amazon.com, Bechtel, BHP Billiton, Caterpillar, CH2M Hill, ConocoPhillips, Mitsubishi, Newmont Mining, Rio Tinto and Shell.

Our history is in the civil and environmental engineering arena, but GoldSim was designed from the ground up as a general-purpose, probabilistic simulation framework. As a result, the software is now being used in a wide variety of applications, ranging from long-term business planning for manufacturing companies to operational models of mines and power plants.

The GoldSim Technology Group focuses on building great simulation software and supporting the technical aspects of building effective GoldSim models. To provide other dimensions of complete solutions, we maintain close relationships with partners around the world, including consulting firms with specific expertise in the energy industry.

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